Integrating Efficient Grassland Farming and Biodiversity

Edited by

R. Lillak
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Proceedings of the 13th International Occasional Symposium of the European Grassland Federation
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Foreword

The developments in European Agricultural Policy have caused large changes in European farming and agricultural research systems, and new strategies and socio-economic factors need to be increasingly taken into account by farmers, scientists, advisors, environmentalists, and other stakeholders. Nevertheless, grassland will continue to play an indispensable role in obtaining high-quality products from ruminant farm animals.

In Estonia and several other countries roughly two groups of stakeholders, thinking and acting differently, have emerged: a) environmentalists who focus their research and activities on maintaining the diversity of nature (incl. grasslands) and wildlife, and regard agriculture as an environmentally hazardous factor, b) agricultural producers who have focused their operations on gaining profit in order to stay and be competitive on the market. The interests of both groups should not be ignored, and it is essential to find solutions to meet their goals.

This situation has led the organisers of the EGF 2005 Occasional Symposium to select ´Integrating Efficient Grassland Farming and Biodiversity´ as the general topic. The main goal of the Symposium was to find solutions how to integrate the biodiversity and efficient grassland management, including socio-economic aspects. The overlapping aspects of biodiversity and grassland farming and the question how to evaluate biodiversity in economical terms were underlined during the Sessions. Novel approaches to combine the benefits for the wildlife and producer were discussed.

It was underlined in the contributions that although nature conservation is very interested in species-rich grasslands, the grassland management for nature conservation purpose only is not sustainable in the long run. Profitable use of natural grasslands should be found by stakeholders with support from environmental agencies.

The present book covers some 145 scientific papers allocated to three Sessions. About 30 countries, each with different environmental and economic conditions, are represented by the authors. Thus, the book gives a broad overview of the current research work in this field in Europe. We have also a great pleasure to mention the large interest among European grassland family in the EGF 2005 Symposium in the year of the XX International Grassland Congress (in Ireland and UK, 2005)

During pre- and mid-conference tours, the participants were acquainted with the types of (semi) natural grasslands in Estonia – alvars, coastal meadows, flooded meadows, and wooded meadows. The present situation, perspective for the future and the overall value of the (semi)natural grasslands as a habitat for the endangered plant and animal species were covered. Advanced farms with different sown grassland management and research institutions were also visited.

We wish to thank numerous people for their help that made the organisation of the Symposium and the publishing of this book possible: the members of the Organising and Scientific Committees, the external reviewers and anglicisers, and the EGF secretary.

The invaluable help of Tiina Kivisäkk in correcting and formatting of the manuscripts is gratefully acknowledged. Thanks are also due to the sponsors and supporting organisations for their financial aid. This made it possible to keep conference fees on a moderate level.

We hope that those who attended the programs of the Symposium had pleasant and useful experiences from the 13th International Occasional Symposium of the European Grassland Federation, in Tartu, Estonia, 2005.

Are Selge	Rein Lillak
President of the Organising Committee	Chairman of the Scientific Committee

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Biodiversity in temperate European grasslands: origin and conservation

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Abstract

Northern Europe is in the forest zone, but wild megaherbivores have maintained grass-dominated vegetation here for the last 1.8 million years. Continuity of the grassland biome through glacial-interglacial cycles and connection to steppe vegetation has resulted in the evolution, immigration, and survival of a large number of grassland species. During the last millennia the effect of wild ungulates has been replaced by domestic grazers and hay making, and the persistence of grassland biodiversity depends on livestock farming. Local diversity is the outcome of colonisations and extinctions. Colonisations can be enhanced by maintaining networks of grasslands where species can migrate between sites, and by proper management that promotes establishment of new individuals. Extinction risk may be lowered in large grasslands, which may support large populations, and by proper management that promotes coexistence of species. Extinctions are accelerated by changes in environmental conditions favouring a few competitively superior plant species, especially increase in soil fertility. During the last century, natural grasslands in Europe have faced a dramatic loss of area and increased isolation of the remaining fragments, cessation of proper management, and increased load of nutrients. To achieve successful grassland biodiversity conservation there needs to be close cooperation between conservation managers and livestock farmers. For that, grassland management should take into account evolutionary and ecological rules behind the grassland biodiversity.

Keywords: biodiversity, conservation, evolution, species extinction, species richness

Introduction

Biodiversity conservation – preserving species and their genetic variability, ecological communities, and landscape variety is an urgent task for our society (Balmford *et al.*, 2005). Compared to other community types European grasslands have a rich flora and they may develop a very high small-scale species density (Pärtel *et al.*, 1996). For example, the highest vascular plant species numbers are found at the tiny scale of a few square centimetres to one square meter in temperate grasslands. In Laelatu wooded meadow in Estonia, 25 species of vascular plants have been described within 100 cm², and 42 species within 400 cm² (Kull and Zobel, 1991). In the same place 76 species of vascular plants have been described on 1 m² (Sammul *et al.*, 2003), which is the second highest record after 89 species in a shortgrass dry mountainous pasture in Central Argentina (Cantero *et al.*, 1999). High plant biodiversity is often reflected by high animal and fungal diversity, too (van der Heijden *et al.*, 1998; de Deyn *et al.*, 2003; Knops *et al.*, 1999). European grasslands are also rich in genetic variability within plant species (Prentice *et al.*, 1995; van Treuren *et al.*, 2005), contain many threatened species (Pärtel *et al.*, 2005) and they show a diverse landscape pattern (Jongman, 2002).
Grasslands in the temperate zone usually persist due to moderate disturbance: grazing, mowing, or fires. During the last millennia temperate European grasslands have been mostly managed by grazing of domestic animals or by haymaking. This is the reason why

this ecosystem has often been 'semi-natural' (van Dijk, 1991). This fact does not imply that European temperate grassland as an ecosystem is man-made. It means that large grazing mammals are an integral part of this ecosystem, be it wild game or domestic livestock. In this respect, temperate European grasslands are not different from grasslands in other parts of the world with temperate climate. In warmer and drier climates, grasslands are conventionally thought to be climatogenic, i.e. constituting the climax vegetation under the prevailing climate conditions. Both mammal grazing and fire, however, are aspects of their ecology that have been somewhat overlooked in the past. Successional development of prairies, savannas, and steppes into woodland might take place if not halted by wildfires (Bond *et al.*, 2005) and grazing (Craine and McLauchlan, 2004) while alpine grasslands are characterized by low temperatures and grazing (Körner, 1999). Thus, most grasslands are dependent on various kinds of physical disturbance disfavouring woody plants.

During the last hundred years drastic decline of grassland area and connectivity all across Europe has been detected (van Dijk, 1991). The main reason is that grassland farming is more efficient in cultivated stands than in natural permanent grasslands, but urbanization (Thompson and Jones, 1999) and air pollution (Stevens *et al.*, 2004) are also playing a role. Decline of European grasslands is threatening European biodiversity in all aspects, from genes to landscapes. For example in Finland at least 42 species of invertebrates, 4 species of vascular plants and 3 species of fungi which are primarily dependent on grasslands are already extinct and, respectively, 232, 60, and 38 species are threatened (Ikonen *et al.*, 2004). Combating this threat to biodiversity needs a new view of nature conservation (van Elsen, 2000). Traditional biodiversity conservation started with nature reserves from which all kinds of impacts by humans and their domestic livestock were excluded. In the case of European grasslands, strict exclusion of management by humans most often leads to a loss of grassland area due to succession into scrubland and forest. As most of the wild-living large herbivors are now extinct in Europe, grassland farming is important to biodiversity conservation (Sutherland, 2002). On the other hand, while abandoned grasslands that have undergone successional change into scrubland and forest can sometimes be reverted, grasslands that have been converted to arable fields undergo changes that are mostly irreversible.

There is still a long way to go to achieve successful cooperation between farming and biodiversity conservation (Kleijn and Sutherland, 2003). We are confident that the integration between effective grassland farming and biodiversity conservation is only possible if we follow the evolutionary and ecological rules of biodiversity dynamics in grasslands. There is, however, an optimistic outlook since agricultural research on grasslands is frequently concerned with biodiversity issues (Prins, 2004). In order to strengthen this contact we review (1) how the grassland biodiversity in temperate Europe has evolved, (2) what the main ecological rules are for maintaining high biodiversity, and (3) how this knowledge can be used for grassland biodiversity conservation and restoration.

Evolution of grassland biodiversity

The evolution and expansion of grasslands, with their uniquely coevolved grasses and grazers, took place during the Cenozoic (Retallack, 2001). The dominant plant group in grasslands, the grasses, originated at least 55 million years ago (Kellogg, 2001). Almost simultaneously, the first ungulates appeared (Janis, 1993). The shift of grasses to dominance in open habitats, i.e. the precursors of modern grasslands, however, took place much later. Likewise among ungulates, the grassland-dwelling bulk-grazer habit evolved later from an ancestral forest-dwelling browsing habit (Pérez-Barbería *et al.*, 2001; Janis *et al.*, 2002). True grasslands, and Serengeti-like communities of grazing animals, probably did not appear until the Late

Miocene in the New World and the Pliocene in the Old World (ca. 5 million years ago).

At least throughout the Pleistocene (the last 1.8 million years), but probably much longer, grassland vegetation has existed in Europe. During this epoch, long cold and dry periods (glaciations) alternated with short periods of warm and moist conditions (interglacials) with an approximate 100 000 year periodicity (Zagwijn, 1992). During glaciations, steppe-tundra on permafrozen soils dominated in Central and Northern Europe, while xerothermic grasslands dominated in the Mediterranean basin (Van Andel and Tzedakis, 1996).

Temperate forest species probably survived in small pockets at micro-environmentally favourable locations in Central and Southern Europe (Bennett *et al.*, 1991), while boreal forest species may have had a distribution as open taiga-like vegetation intermingled with steppe-tundra (Willis and Van Andel, 2004). In terms of flora, the steppe-tundra was an intermediate between modern temperate grassland and tundra, or a mosaic of analogs of these biomes, generally having much drier and more alkaline soils than modern tundra (Yurtsev, 2001; Zazula *et al.*, 2003). In each interglacial, the development of ecosystems followed a recurrent pattern of balance between open and closed vegetation, i.e. between grassland/tundra and forest (Iversen, 1958; Bradshaw and Mitchell, 1999; Birks and Birks, 2004). In the first part of each interglacial, grasslands on alkaline or neutral un-leached soils dominated. They were gradually replaced by forests. At the end of previous interglacials, in which human interference has been negligible, grasslands on infertile soils gradually increased again (Iversen, 1964; 1969; Willis *et al.*, 1997; Wardle *et al.*, 2004).

Thus, grasslands have existed continuously in temperate Europe for millions of years, albeit with highly variable extent. This history of extension and contraction has shaped the biota of temperate European grasslands through speciation, extinction, and exchange of species with other biomes, such as steppes, temperate forest, alpine grasslands, tundra, and Mediterranean communities. A rich fauna of large mammalian herbivores was an integrated part of this grassland biome. During the penultimate interglacial, the Eemian (ca. 120 000 years ago), 17 species of large herbivores were native to lowland north western Europe (Svenning, 2002). Probably similar numbers have been present in all Quaternary interglacials except our own, the Holocene (Bradshaw *et al.*, 2003). Among these species were now (regionally) extinct elephant, rhinoceros, hippopotamus, giant deer, and buffalo, extant red deer, fallow deer, and bison, and species now found as domesticated livestock only, i.e. aurochs (cattle) and horse.

During periods of maximum forest cover, grasslands and their associated biota survived in refugia, often in places where edaphic and climatic conditions have been suboptimal to trees (Ellenberg, 1988). Similarly to full glacial conditions, cold and dry places have prevented or retarded tree growth and regeneration and promoted grasslands. During interglacials, such conditions have mainly existed in alpine environments. In addition, warm and dry places, moderately unstable soils, and floods have promoted grassland resistance to woody plant invasion. These conditions have been found in a number of topographical and geomorphological situations, perhaps most prominently on shallow soils over solid rock or limestone preventing penetration of tree roots, and, in addition, steep slopes, sites exposed to strong winds, sandy infertile soils, and floodlands. To some extent, areas rich in such topographical features are at present-day relatively species-rich. Similarly, high-pH substrates tend to be more species-rich than low-pH substrates, due to the relative abundance of these substrate types in this biogeographical province during the evolution of the grassland floras (Pärtel, 2002).

Palaeoecological evidence of a grassland element in the landscape-scale vegetation comes from, among others, chalk hills in England (Bush and Flenley, 1987; Bush, 1993; Waller and Hamilton, 2000) and sandy infertile soils in Jutland, Denmark (Odgaard, 1994). One may hypothesize past synergistic effects of edaphic and topo-climatic conditions with disturbing agents such as fire and herbivores. Where wildfires created glades in the primeval forest, these would have been more resistant to forest regeneration under grazing by wild ungulates and under the described climatic and edaphic conditions.

Most plant species presently found in Central and Northern Europe are endemic to the temperate European grasslands and can only be protected here (Pärtel *et al.*, 2005). Traditionally, phytogeographers have been less interested in this general pattern than in exceptions to it. A number of plant species have characteristic distribution patterns, with main distribution ranges to the southeast or the southwest (Meusel, 1940; Meusel *et al.*, 1965). Plant species associated with contrasted edaphic conditions often exhibit widely differing distribution tendencies (Böcher, 1945). For example, plant species characteristic of grasslands on unstable infertile acid sandy soils are predominantly distributed in Western Europe, along the Atlantic coast. This pattern suggests that suitable habitat for these species has had a distribution more stable in time and space in this area than in Central and Eastern Europe. The genetic diversity of one species of this kind, *Carex arenaria*, increases southward to reach a maximum along the coast of the Bay of Biscay (Jonsson and Prentice, 2000), suggesting that this species survived the last full-glacial in refugia in this region or further to the south. Conversely, many plant species characteristic of grasslands on unstable infertile calcareous soils have distribution centres in Eastern Europe and scattered distributions in Central and Northern Europe. This pattern may indicate predominant survival of the last glaciation in steppe sites to the south-east, and subsequent (re)-immigration into Central and Northern Europe during late-glacial times and later (Pott, 1995). For the majority of species, which are endemic to the biome of temperate European grasslands, however, glacial survival in refugia far outside Central Europe is unlikely.

Pastoralism and arable farming, were introduced to Central Europe in simultaneous waves; ca. 5,000 BC (band-ceramic culture), ca. 1000 years later to Western Europe and ca. 2000–3000 years later to the Baltic area and Scandinavia (Champion, 1984). When selecting suitable areas for settlement, the first farmers probably sought out regions where, among other things, open pastures were easy to maintain, in other words, places where the edaphic and climatic conditions have been suboptimal to trees and natural grasslands were already present (Sammul *et al.*, 2000a). Arable fields created by slash-and-burn of forest, probably played a smaller role in rural economy, and took up considerably smaller areas, than pastures. As human populations grew, new areas were cleared of forest and turned into arable and pastureland (Pott, 1995; Bredenkamp *et al.*, 2002; Poschlod and Wallis de Vries, 2002). Plant and animal species from the natural grassland refugia in the primeval forest expanded appreciably in distribution, whereas distributions of forest organisms contracted. Some grassland species were probably redistributed, deliberately or not, considerable distances by humans and their livestock. In the Iron Age, hay meadows came into existence, providing a new and slightly different habitat for grassland biota. Despite some differences, in terms of qualitative impact on the vegetation, between hay making and ungulate grazing, the similarities are striking (Pykälä, 2000). Generally speaking, when agriculture was introduced, livestock grazing and haymaking replaced the grazing and browsing by wild megaherbivores. This is the solution to the apparent paradox that most conservation interests today are focused on apparently man-made habitats (Duffey *et al.*, 1974; Hillier *et al.*, 1990).

The agricultural practices of livestock grazing and haymaking, however, were not only beneficial to grassland biota. In many situations, arable farmers have exploited and exterminated grassland biota. For example, loess soils and deep rendzinas often support species-rich grassland communities, but are also profitable to arable farming. Thus, many grassland areas were turned into arable land or intensively managed rangelands (Bailey, 2000). The last wave of this development was seen in the Soviet agricultural expansion onto 'virgin' steppe lands, and similar expansions into vast natural grassland areas on other continents, but the exploitative position of arable farming with respect to grasslands has existed since the first farmers. Therefore, modern semi-natural grasslands, with their biota of native grassland species, are now found mainly in situations and locations unsuitable to agriculture, such as hilly terrain and shallow soils on rock outcrops and elsewhere.

Ecology of grassland biodiversity

Evolutionary processes have created a set of plant species that can sustain life in grasslands – the species pool (Zobel, 1992; Pärtel *et al.*, 1996; Zobel, 1997). Diversity at the smaller scale cannot exceed the limit set by the species pool, but, rarely reaches it (e.g. Collins *et al.*, 2002). Local diversity may be limited by lack of propagule dispersal, or by interactions in the local abiotic and biotic environment, e.g. competitive exclusion by superior species (Tilman, 1999), or lack of symbionts and presence of pathogens (de Deyn *et al.*, 2003).

The present climatic and land-use history has formed complex landscapes, where different vegetation types form a mosaic (Jongman, 2002). Grasslands have mostly occurred as fragments embedded in other types of vegetation. We can look at grasslands as 'islands' in the 'sea' of other type of vegetation: forests, wetlands, agricultural and urban areas. We shall use the term 'patch' for such grassland 'islands'. Consequently, we can use the 'equilibrium theory of island biogeography' to explain how the level of biodiversity is determined by the balance between local immigration (dispersal and establishment) and local extinctions (MacArthur and Wilson, 1967). Nowadays, 'metacommunity theory' (set of dispersal-connected local communities) has partly taken over the island diversity theory (Leibold *et al.*, 2004).

In concrdance with the theory, diversity is higher in grassland patches that are larger and better connected to other grassland patches, as shown in grassland fragments in Sweden and in Denmark (Köchy and Rydin, 1997; Bruun, 2000). Larger patches can support larger and genetically more diverse populations that have less dramatic population oscillations and a smaller probability to go extinct. Well-connected grasslands can get new species and genes which can build-up local diversity and replace these species and genes which have gone extinct. There are, however, other practical aspects too: larger and well-connected patches are probably more likely to be managed properly (grazing, hay-making). For grassland species, small fragments may not be large enough to support viable populations alone, but populations may still persist due to continuous inflow of propagules from surrounding populations. This phenomenon is called 'spatial mass effect' or 'rescue effect' (Shmida and Ellner, 1984; Kunin, 1998). Within a metacommunity small fragments are important components for the whole system and they may act as stepping-stones for dispersal.

Besides area and isolation, a grassland patch with different shape can have different potential for species gain and losses. Grassland margins are mostly less suitable for grassland species than the central areas (Luczaj and Sadowska, 1997; Morgan, 1998). This can be caused by shading from a neighbouring forest or by extra nutrient inflow (see below). Thus, grasslands round in shape have a higher potential for diversity due to higher area to perimeter ratio.

The surroundings of grassland patches are important for biodiversity, too. The 'sea' around a grassland patch may also support some grassland species (e.g. road verges, edges of ditches and fallow fields; Cousins and Eriksson, 2002), or they may be totally unsuitable for grassland species.

Species dispersal is a stochastic process. Ultimately dispersal is dependant on the distance to other patches (Coulson *et al.*, 2001) and on presence of dispersal vectors. Domestic animals can successfully act as seed dispersers (Fischer *et al.*, 1996; Kiviniemi and Eriksson, 1999; Couvreur *et al.*, 2004). In order to do this, however, they must be able to move from one site to another. Shepherding was once common in Europe, but has now almost dissapeared (Poschlod *et al.*, 1998; Bruun and Fritzbøger, 2002; Suárez and Malo, 2002; Znamenskiy *et al.*, 2005).

Successful species dispersal requires considerable time. If grassland continuity has been interrupted, for example if the grassland has become overgrown by scrub or has been cultivated, to restore it again, seed dispersal will have to start from the beginning. Seed banks do not generally persist long-term in grassland soil (Kalamees and Zobel, 1998; Bakker and Berendse, 1999; Mitlacher *et al.*, 2002). If we consider the arrival of a new species as a random process, then, given more time, a site can 'collect' more species. Thus, age of a grassland patch is an important factor for generation of high diversity (Ejrnæs and Bruun, 1995; Kukk and Kull, 1997; Pärtel and Zobel, 1999). Even if a species is present in a community, dispersal can result in the establishment of new genotypes. For example, in an old calcareous alvar grassland on Öland, there was a large number of different genotypes of grass *Festuca ovina* found under different micro-environmental condition (Prentice *et al.*, 2000).

There are, however, plenty of examples which do not support the equilibrium island theory and suggest that present-day diversity is mainly determined by factors other than current area or degree of isolation (Simberloff and Gotelli, 1984; Eriksson *et al.*, 1995; Pärtel and Zobel, 1999). In recent studies this controversy has been solved. Due to recent rapid disappearance of grasslands the current patch size and isolation is completely different from that which occurred during previous centuries when the diversity was formed. Using historical maps we can look at former grassland areas and their isolation. These two characteristics describe actually the present-day diversity (Helm, 2002; Lindborg and Eriksson, 2004). This means that the present-day high diversity may be a remnant from a previous habitat area and connectivity and may not be supported by the current system. The time lag between increase of isolation over a critical level and subsequent loss of species may be 100 years or more, thus largely hindering our ability to make appropriate conservation decisions. If we do not ensure good species dispersal between sites in the future, extinctions are very likely to occur. This phenomenon has been coined the term 'extinction debt' (Hanski and Ovaskainen, 2002).

While landscape-scale processes determine the potential for plant community species richness (community species pool), local processes within the community determine the actual diversity at the site. When a new species has successfully arrived in a grassland patch, first it must be able to establish a new population. Secondly, it should be able to persist in competition with other species. Local diversity is always a balance between the input of propagules of different species, their establishment, and persistence in competition with neighbours (Mitchley and Grubb, 1986; Watt and Gibson, 1987). The local processes are mainly determined by grassland management, but moderate natural disturbances can also promote species' establishment and prevent competitive exclusion.

Grassland management affects the structure of the vegetation and determines the abundance and distribution of gaps in which propagules can establish. For example, it has been demonstrated that the litter layer which appears after abandonment of grazing or mowing strongly limits the germination of seeds and establishment of seedlings and leading to decline in diversity (Milton *et al.*, 1997; Foster and Gross, 1997; Tilman, 1997).

High small-scale diversity is only possible if many different individual shoots (ramets) can be 'packed' into a limited soil surface area. The conditions on grasslands are such that they not only enable close 'packing' of ramets but also enable close proximity of individuals of different species. The latter is only possible when competition between individuals is not strong enough to eliminate one of the neighbours. The common feature of all European species-rich natural grasslands is that they have a relatively low vegetation and low (but not the lowest) productivity. The mechanisms whereby intermediate levels of disturbance and/or intermediate levels of productivity coincide with the highest species density in grasslands (Grime, 1973; Connell, 1978; Huston, 1979) are still poorly understood (Palmer, 1994). Competition is considered asymmetrical when access to the resource that is competed for is monopolised. It is well known that competition becomes harsh and eliminative for subordinate species when it is asymmetrical (Weiner and Thomas, 1986; Peet and Christensen, 1988) and not interrupted by disturbance (Grime, 1973; Grime, 1977). In very broad terms, one can say that competition for above-ground resources (e.g. light or space) is often asymmetrical whereas competition for below-ground resources (water, nutrients etc.) is mostly symmetrical (Peet and Christensen, 1988). Nevertheless, there are multiple ways of how above- and below-ground competition interact in different species (Cahill, 2002), and the productivity of the community strongly influences the dynamics of competitive exclusion.

The availability of light to a single ramet depends largely on comparative difference in size of neighbouring ramets. When productivity of the site is high, plants obviously grow faster and difference between relative growth rates of neighbouring ramets leads to differences in size of shoots. Further on, the difference in size accumulates and species with low stature may become outcompeted unless they have some specific adaptations that enable them to tolerate low level of light availability or escape from competition. Enhanced productivity can reduce diversity when fertilisers are applied to natural vegetation (Smith *et al.*, 2000; Sammul *et al.*, 2003) and also during restoration of natural grassland in a habitat that previously received fertilizer applications and, thus, has high level of residual fertility (Marrs, 1993; Janssens *et al.*, 1998).

Continuous low-intensity management by mowing or grazing has a disproportionately large effect on competitive dominants, and by reducing the asymmetry in size distribution of plants it reduces the probability of competitive exclusion (Lepš, 1999). The reduced asymmetry of interactions is further amplified by the fact that uniform mowing and grazing balance the differences between different species in other aspects of population dynamics, such as mortality, reproduction, and vegetative propagation which are commonly ramet size dependent and constitute one part of competition for space (Barkham, 1980; Pitelka *et al.*, 1985; Weiner, 1988). Thus, beside the direct effect on development and species composition of the grassland (Austrheim and Eriksson, 2001; Cousins and Eriksson, 2001), management regime also influences the dynamics of species interactions.

Conservation and restoration of grassland biodiversity

The design of grassland conservation measures should acknowledge the different processes described above. We are proposing a simple five-point scheme that should be followed fot decision-making at grassland biodiversity conservation.

1) Existing grassland habitats should be maintained for large scale stability. When conserving diversity of vegetation in natural grasslands, it is important to prevent large-scale destruction of habitat (e.g. ploughing, Smith *et al.*, 2000) and deterioration of habitat quality (e.g. fertilization). The establishment of diverse vegetation is an extremely long-term process, while all large disturbances destroy vegetation almost instantaneously. Moreover, even residual cultivation effects bias the flora to the favour of annuals and ruderal species (Donelan and Thompson, 1980; Graham and Hutchings, 1988). The most diverse and species-rich meadows having a prevalence of species with life-history

characteristics that show slow growth and low reproductive rates, i.e. characteristics of species of stable communities (e.g. Graham and Hutchings, 1988; Sammul *et al.*, 2003).

2) The genetic diversity should be kept since this is providing the material for evolution (Prentice *et al.*, 1995; van Treuren *et al.*, 2005). Genetic homogenisation is a threat when single seed sources are used in restoration. Grassland continuity and small-scale habitat heterogeneity also support high genetic diversity.
3) Species dispersal should be supported. This means that management should be planned at the landscape scale enabling spatial and temporal continuity of the grasslands. Thus, sound conservation management of grasslands should concentrate on enhancing immigration (i.e. improving connectivity between sites). This is particularly important in grassland systems that are facing with an extinction debt. So far, most conservation efforts have concentrated on preservation of valuable sites. While this is extremely important, one must consider, that in addition to valuable sites, also less valuable sites often need to be protected to create stepping stones, migration corridors and secure presence of metacommunity systems.
4) Recruitment of new individuals should be supported through preventing the formation of litter layer, promoting small-scale patchiness (e.g., scattered tiny gaps with mineral soil exposed), and allowing seed to ripen (e.g., late hay making).
5) Species coexistence should be supported. This means preventing competitive exclusion of small-size species by taller ones. This can be achieved by proper management which prevents large species (both large herbs or grasses and woody species) to dominate. On the other hand it is important to avoid activities that lead to increase in productivity of the site (e.g. fertilization, or supplementary feeding of livestock) as this would inevitably cause increase in the intensity of competition and thus also exclusion of subordinate species (Sammul *et al.*, 2000b).

Grassland destruction and fragmentation has in many regions already gone so far that long-term sustainability of biodiversity is questionable. Grassland restoration may reduce the extinction debt and alleviate the effect of fragmentation in the long-term. When considering restoring grasslands, it is important to set the goal of the action and qualitative criteria for evaluation of the success. Simply restoring the landscape is much cheaper than restoring the diversity of species and vegetation types.

The obvious limitation in restoration of grasslands is time. Natural species immigration is a long-term process. The estimated speed of natural species immigration in grasslands ranges several orders of magnitude (Gibson and Brown, 1991; Olff and Bakker, 1991). It has been suggested that restoration of grassland vegetation on arable fields could take up to 100 years if the seed supply is in close proximity (Gibson and Brown, 1992).

During the first phases of restoration it is important to focus on improvement of immigration.

In cases when connectivity between different sites is good, no addition of seeds or other propagules is necessary. During the first years grazing is better as the main management tool because animals transport propagules and thus increase the speed of formation of field layer. Later on grazing may be used in combination with or replaced by mowing.

When connectivity is not sufficient to support immigration, seed sowing may considerably increase the speed of development of grassland vegetation. While seed limitation obviously restricts the rate of colonisation (McDonald, 1993; Zobel *et al.*, 2000) and sowing of seeds speeds the dispersal process, it is important to keep in mind that the appropriate microsites for the species establishment are not always available (Jones and Hayes, 1999) and it might be difficult to find the appropriate mixture of species that would suit the particular microsite conditions. Moreover, sowing seeds actually creates a higher level of genetic and species composition homogeneity between neighbouring sites as two important factors that create differences between habitats – time of arrival of different species, and genetic differences between populations will be homogenised. Thus, in this way one would interfere with natural distribution of species (Akeroyd, 1994) and with microevolutionary processes (Ashley *et al.*, 2003). It is important to make a good compromise between speed of the restoration process and the natural state of the end product when making decisions about restoration. We suggest that the natural immigration process should be adhered to as often as possible.

While restoration of natural grasslands is a very powerful tool, it can never be used without first properly preserving the existing grasslands. Restoration efforts start to pay back in 20–50 years when species diversity of restored grassland starts to reach levels of persistent ones (Gibson and Brown, 1991; Olff and Bakker, 1991; Smith *et al.*, 2000). Without existing grasslands there would be no sources for natural species migration. Moreover, the preservation of grasslands is order of magnitude cheaper than restoration. For example, the analysis of management and restoration costs of Estonian meadows shows that restoration is 25 to 30 times more expensive in both dry boreo-nemoral and floodplain meadows whereas expenses of restoration increase by 50% with every 4 to 5 years after the abandonment in wooded meadows (Ehrlich, 2004). Although currently management of grasslands to maintain high biodiversity is often incompatible with management for maximum economic profit (Hodgson *et al.*, 2005) different subsidy systems can be developed to allocate conservation funds in a way that produces the best ecological effect (Wu and Bogess, 1999; Johst *et al.*, 2002).

Conclusions

While forest should be the most abundant 'natural vegetation' in temperate Europe, a large part of the European plant and animal species is associated with open habitats. This fact stresses the importance of conserving the biota associated with grasslands, even when they occur in apparently man-made ecosystems. As grasslands have developed over many centuries with permanent extensive use for agricultural purposes, and since this practice has often led to valuable and diverse sites, the farmers are at the heart of grassland conservation. Only extensive agriculture can preserve these areas. Grassland farming practice aimed at conserving or restoring biodiversity is not as economically profitable as conventional grassland farming. Our society has, however, set measures to compensate for the income difference, literally paying for biodiversity. Even if the support does not totally cover the loss of income, keeping the natural grasslands is a good investment for the future when awareness of biodiversity value will definitely increase. Since there is never a surplus of money in environmental support schemes, the most efficient local management techniques should be used. For that, proper well-replicated networks of grassland biodiversity management experiments are urgently needed at the national and European levels. Using the scientific knowledge on evolution and ecology of grassland biodiversity, effective grassland farming and biodiversity conservation can be integrated.

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Grassland for agriculture and nature conservation: production, quality and multi-functionality

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Abstract

European grasslands encompass a wide range of habitats that vary greatly in terms of their management, agricultural productivity, socio-economic value and nature conservation status, reflecting local differences in physical environment and economy, the effects of traditional practices and impacts of recent management. Widespread loss of biodiversity, as well as other environmental problems, have resulted from agricultural intensification or abandonment. Policies that have contributed to this have been progressively revised, initially by agri-environment schemes, and subsequently through changes in farm support payments and stricter regulatory frameworks, though many threats remain. We consider the agricultural implications of grassland biodiversity in terms of impacts on herbage production, feed intake and forage quality. Grassland biodiversity is both an externality of particular environments and farming systems and also contributes to objectives of multi-functional land-use systems. In addition to meeting species conservation and habitat protection, grassland biodiversity can contribute to enhanced value of agricultural products of regional, nutritional or gastronomic value, and to non-commodity outputs: agro-tourism, ecosystem functions linked to soil and water quality, and resilience to environmental perturbation. Needs and to conserve and improve the biodiversity potential of agricultural grasslands of typical moderate/high-input management, and for marginal, including communally managed large scale grazing systems, are considered using examples from contrasting areas of Europe. These include reindeer grazing in northern Fennoscandia, winter grazing in the Burren, Ireland, and cereal-fallow sheep grazing system of La Mancha, Spain.

Introduction

Intensification of management on both grassland and arable areas, and agricultural abandonment on many marginal grazing areas, have had profound impacts on the nature conservation value and landscape integrity throughout much of Europe. In regions where intensive livestock production is practised, biodiversity has been greatly reduced, not just in terms of the numbers of plant species within pastures or meadows, and the genetic diversity of those populations, but in terms of the loss of fauna in and beyond the farmed area. These consequent losses arise from eutrophication of the soil and sward, resulting in either reductions in the flora and fauna of associated habitats such as field margins, hedges, streams and ponds etc. affected by eutrophication or, in many instances, habitat loss. The effects of nutrient and other inputs such as inorganic fertilizers, purchased feed, slurry applications and pesticides, and of field operations including reseeding, herbicide applications, hedge and ditch removals, drainage work, silage in place of hay, and of greater livestock densities have all contributed to biodiversity loss and impacts on the wider rural environment (e.g. Soule and Piper, 1992; Haggar and Peel, 1993; Marrs, 1993; Nösberger *et al.*, 1994). Managing for improved biodiversity and conservation objectives on such land is particularly challenging and needs to be seriously addressed.

On low-intensity livestock farmland, however, natural and semi-natural grasslands remain and are highly variable, often supporting considerable botanical diversity at a local scale, providing habitats for invertebrate and other faunal groups and delivering a range of ecosystem and socio-economic functions. These areas cover roughly 15–25% of the European countryside (EEA, 2004). Their variability reflects not only the underlying environmental conditions (soil type, geology, latitudinal and altitudinal ranges, and the effects of the pronounced west-east oceanicity-continentality gradient), but also the anthropogenic effects of pastoral farming systems. The role of past farming in creating and maintaining particular landscapes and biotopes is often not fully appreciated, even by ecologists (Bignall and McCracken, 1996). Settled agriculture in Europe developed over a long period in which the natural vegetation was either modified by livestock, supplanted by crops, or survived as remnants on field boundaries or sites that were marginal or inaccessible. In low- and medium-intensity farming areas the present-day rural landscape is therefore viewed either as having fragmented areas of the former wilderness habitat surrounded by improved agricultural land or, more logically, as a farmland biotope requiring management for biodiversity consistent with agricultural production and other ecosystem functions.

In this paper we consider the impacts of recent agricultural change and policy developments and the management, farming practices and techniques required on grassland and other pastoral ecosystems that can be implemented to help deliver nature conservation objectives. The links between biodiverse grassland systems and food product quality, grassland biodiversity and ecosystem functions, and the potential for grassland biodiversity in the context of wider community benefits are explored. Systems that represent typical agriculturally improved grassland are considered. Large-scale, including communally managed large scale grazing systems, are described using examples of semi-open landscapes from contrasting areas of Europe, based on a current European research project LACOPE (www.lacope.net).

1. Biodiversity and agricultural management of enclosed and improved grassland: some general principles

Plant species diversity in grassland, the actual species that are present, their relative abundance and the vegetative structure of the sward are largely determined by, (1) soil nutrient status and its modification by addition of fertilizers, liming and organic manures, including dung and urine from grazing animals; and, (2) defoliation and other disturbances, primarily through the intensity and frequency of grazing, or the timing and frequency of mowing, and by other natural environmental stresses (flooding, drought, fire, burrowing) or farming activities (cultivation, oversowing, drainage work, harrowing, herbicide applications etc.). The 'humped-back' model of Grime (1979) summarizes these phenomena in terms of species density in relation to stress/disturbance and in relation to increased standing crop. This interpretation is consistent with observations that increased nutrient additions, particularly nitrogen (Charles and Haggar, 1979) and phosphorus (Janssens *et al*., 1998), lead to dominance by a small number of plant species (in temperate European lowland mesotrophic grassland these frequently include *Lolium perenne, Phleum pratense, Dactylis glomerata, Rumex obtusifolius;* on marginal and upland swards the shift may be towards *Agrostis capillaris* and *Holcus lanatus*). Although regular defoliation of swards is necessary to maintain biodiverse as well as species-poor grassland, frequent cutting and grazing arrest the flowering and seeding cycles of dicot species. Thus, agronomic practices that lead to agriculturally improved herbage production and/or forage composition are essentially incompatible with aims of management for sward biodiversity. Furthermore, losses of diversity resulting from soil nutrient inputs are largely irreversible because of high residual fertility of soils, thus limiting opportunities for enhancement of diversity by de-intensification of management. These aspects are discussed elsewhere in these proceedings (Isselstein *et al*., 2005).

Grassland biodiversity and agricultural land management: the policy context

Until the mid-20th century (more recently in some areas) agriculture was generally of low intensity and benign for nature, providing living space and habitat diversity alongside the utilization of land for food production. Agricultural intensification became accepted and justified by the compelling imperatives of increased food requirements and food security of the expanding urban populations in the post-World War 2 period, and of raising incomes and working conditions for (a declining number) of farm producers. International recognition of the negative impacts of modern farming on nature, water quality, human health and the wider environment increased incrementally from the 1960s (Carson, 1962) although the roots of these concerns and the needs to incorporate nature and non-material outputs with agriculture have earlier origins (Worster, 1994). The scientific understanding and public awareness of the scale and effects of agricultural chemical inputs and mechanized operations, the cost to taxpayers of supporting food surpluses in Europe in the late 1970s, and concerns over energy dependence all became major drivers of, what was to become, a slow policy change. Successive measures have been adopted, at least within the EU (with similar legislation also adopted in some non-EU countries), to incorporate nature and landscape conservation within agricultural land, (EC, 1985; 1992) and limitations set on emissions of nutrients and pesticides. EU Nature conservation policy is based on two main pieces of legislation: the Birds directive and the Habitats directive. Its priorities are to create the European ecological network (of special areas of conservation), called NATURA 2000 and, importantly, to integrate nature protection requirements into other EU policies such as agriculture and regional development (Europa, 2005). Discussion of this is beyond the scope of this paper (see Buller *et al.* (2000) for an account of its effects in different European countries), but an essential feature has been the implementation of measures that provide farmers with financial incentives to encourage management that protects biodiversity and landscapes combined with specific regulatory actions. For many countries, including the UK, protection of biodiversity within agricultural habitats also became a commitment under the terms of the Convention on Biological Diversity in 1992. The CAP is now increasingly aimed at delivering benefits to wider society including environmental protection and the conservation of nature and landscapes. This is not just seen as meeting environmental preferences, but as essential for developing the long-term potential of rural areas and sustaining livelihoods, encapsulated in the Killarney Declaration and the Malahide Commitments of 2004, and the 2010 targets of the European Biodiversity Strategy. The present structures imply a long-term commitment to maintaining biodiversity objectives within the farmed environment. For grassland scientists this poses a number of challenges in terms of how these objectives can be met within the context of profitable and sustainable farming, with quality food production and wider ecosystem and socio-economic benefits.

Grassland biodiversity and agricultural output and utilization

Herbage production and sward biodiversity

The potential for greater herbage production from grass mixtures compared with monocultures was claimed by Charles Darwin in the 19th century, and underpinned the advocacy of complex sown mixtures for grassland reseeding during the early twentieth century (Elliot, 1946). Advances in plant breeding and grassland agronomy, and the need for managing swards for specific objectives such as high quality silage, subsequently contributed to a progressive simplification of sown grassland and a reduction in grassland species diversity, particularly on intensively managed land (Frame *et al*., 1995; Casler, 2001). Management inputs have effectively been used to substitute for some of the attributes such as spatial and seasonal complementarity of different species and functional groups, and positive species interactions. It is paradoxical, though timely, that in the context of multifunctional land use and sustainable management, that there should be further consideration of the relationships between species diversity and production.

Several recent research projects in Europe and North America have shown that greater plant species diversity can lead to increased plant productivity, with associated nutrient retention and ecosystem stability (Hector *et al.*, 1999; Tilman *et al*., 2001). Based on multi-site European experiments, Hector *et al.* (1999) found that 29 of 71 common species had significant though small effects on productivity, with one species, *Trifolium pratense*, having the greatest effect. Thus, increased productivity with species richness is not a simple one of species numbers – since productivity can saturate at a relatively low number - but of functional groups, of which the presence of legumes, long recognized by grassland agronomists as essential components for production, was a key feature (Spehn *et al.*, 2002). These findings and concepts link evolutionary biology to ecosystem functioning and have both direct and indirect implications for agricultural grassland management. But since they are derived from measurements made on soils without fertilizers or other agricultural inputs, and are based on cut plots on prepared sites, we must consider further other situations typical of agricultural grassland.

In multi-site field experiments in the UK in the 1980s, grassland production from permanent swards was compared with that of newly sown *Lolium perenne* at a range of fertilizer N rates. First-year sown *Lolium* swards had greater herbage yields than identically managed permanent swards of more diverse composition; this applied across the fertilizer response range and at all sites. In subsequent years differences in productivity were, in most cases, higher on the permanent swards under nil-N inputs, and were similar on the two sward types under inputs of 150 kg fertilizer N ha^{-1} $year^{-1}$, but with some relative advantages of permanent grassland being apparent on sites that had the oldest and most botanically diverse swards. Production advantages to sown swards occurred when fertilizer inputs above 150 kg fertilizer N ha^{-1} $year^{-1}$ were applied (Hopkins *et al.*, 1990; 1992) from which we must conclude that the sward diversity/ productivity correlation applies mainly under low-input situations. In low-input situations, relatively high herbage production can, in some cases, be realized from species-diverse grasslands; but in the context of agricultural management it is relevant to examine further how this translates into animal nutrition, through effects of herbage on intake and nutritional quality.

Grassland biodiversity and herbage intake

Grazing animals on mono-specific swards have limited choices: to graze or not, or if the sward has some structural variation, to select between different fractions of leaf and stem within the canopy. In a two-species sward, such as a grass and a legume (e.g. *Lolium perenne* and *Trifolium repens*), the choice is greatly extended as the two species have different nutritional and structural characteristics; the responses to this choice vary over diurnal and seasonal timescales (Rutter *et al.*, 2004). From studies of grazing behaviour at this simple two-species level of sward biodiversity, sheep and cattle show a partial preference for *ca*. 70% clover in their diet (Nuthall *et al.*, 2000; Champion *et al.*, 2004). Relative intake of grass and clover has been shown to be considerably different than their proportions in the sward on offer (Champion *et al*., 2004; Rutter *et al*., 2004; 2005), implying selectivity and searching out of a preferred feed (in this case, white clover, particularly in daytime, and higher fibre grass in the evening). Furthermore, the animals' desired proportions of clover, and, at least for sheep, the total herbage intake, are affected by the spatial scale (patch size) of clover and grass within the sward.

In sown multi-species swards, or permanent swards of diverse botanical composition, livestock may be presented with an array of choices of species and plants at different growth stages, reflecting differences in content of carbohydrate, N, fibre, and possibly also of minerals, condensed tannins and other secondary metabolites. The implications for grazing preferences and intake rates on biodiverse grassland are therefore considerable, though at present poorly understood. In one example (using goats) selection from amongst a choice of different grass species tended to maximize intake rate, with only a small amount of residual variation explained by the individual preference for each grass species (Illius, 1999). Information of intake and feeding preference of non-legume dicot species in diverse swards is sparse, although a number of studies have shown that intake of fodder-based rations increases as the proportion of grasses declines relative to that of legumes and fine herbs (Jans, 1982; Lehmann and Schneeberger, 1988). The consequences of this effect show up in milk yield of dairy cows, with a reported 40% greater milk production potential from a green fodder diet with a grass: herbs+legume ratio of 40:60 compared with a ratio of 90:10. Similar evidence of higher intake from botanically rich green fodder, compared with maize silage, has been reported for fattening bulls (Lehmann and Schneeberger, 1988). There are, however, plant morphological characteristics and sward responses to environmental stress that can limit intake on some types of biodiverse pastures. Tallowin *et al*. (2002) reported on the agronomic constraints of using Cirsio-Molinietum fen meadow in the UK for summer cattle grazing. Low animal growth rates, low herbage energy value, and some mineral imbalances and deficiencies were identified and these increased from summer to autumn. Thus, we can identify situations where biodiverse pastures provide resources for high intake of nutritionally adequate forage and others where this is not the case. Intake of biodiverse forage will depend on the characteristics of the plants species present and their growth stage. Many grassland dicot species have evolved adaptations as potential defence strategies against herbivory, including anti-feedant secondary metabolites, structural reinforcement (e.g. spines or toughened leaves) and adaptive growth forms (e.g. basal rosettes and lignified stems) (Herms and Mattson, 1992). There is, therefore, an *a priori* inference that herbivory and thus intake of some dicot species will be lower than for grasses and forage legumes, especially under continuous as opposed to rotational or short-term grazing, or under environmental stress. The issue is further complicated by the consideration that some plant secondary metabolites may have evolved for other plant survival strategies (e.g. to attract pollinators) and thus not necessarily deter herbivory. Other metabolites contribute to the 'goals' of grazing animals for acquisition of nutrient requirements, including supplying fibre needed for rumen function.

Grassland biodiversity and herbage quality

The feeding value of herbage depends on intake, nutrient content and nutrient availability of the herbage once ingested. One of the strongest agronomic reasons for reseeding botanically diverse permanent swards is to create a grass crop, consisting of a few species (sometimes one species) and varieties with defined and predictable nutritional values at a given growth stage. This is particularly important for situations such as high-quality silage, where conserved grass forms the main ration of winter-housed livestock (Beever *et al*., 2000) and under some grazing situations also. Many of the plant characteristics that affect intake by livestock, such as stem: leaf ratio, differ between grass species and vary with growth stage, and are reflected in herbage nutrient content. Comparisons of herbage sampled from identically managed pure sown *L. perenne* swards and permanent swards of mixed species composition have shown that *L. perenne* usually has higher digestible organic matter content (digestibility value) at the same sampling dates (Hopkins *et al.*, 1990). The presence of some legumes, particularly

Trifolium repens, can maintain the overall sward digestibility over a longer period because its leaves and petioles are replaced as it matures. The presence of other leafy herbs in a diverse sward might be expected to confer similar advantages, particularly deep-rooting species that maintain active leaf growth in summer during periods of soil moisture deficit; conversely, other herbs that develop a high proportion of stem and high fibre content as they mature would result in a net reduction in digestibility.

The nutritional quality of herbage has wider dimensions than the simple token measure of digestibility, and species diversity in grassland is the basis for a wide variation in biochemical properties (Rychnovska *et al*., 1994). There are trade-offs between widely understood measures of herbage quality and other traits that affect agricultural utilization. One widely recognized instance of nutritional advantages for livestock linked to sward composition is through condensed tannins (proanthocyanidins) present in a number of pasture species including trefoils (*Lotus* spp.). These can improve protein digestion, reduce bloat, reduce the burden of intestinal parasites and possibly reduce methane emissions from livestock (Aerts *et al*., 1999; Waghorn *et al*., 2002). Horses in particular are often considered to benefit from having access to diverse pastures containing herbs (Allison, 1995). A number of the frequently occurring herb species of mesotrophic grassland contain higher concentrations of mineral elements (Ca, Na, K, Mg) than in the associated grass components (Hopkins, 2004), and this function may be important on sites low in particular soil nutrients. While the content of most vitamins in herbage is not considered to be a significant issue for ruminant nutrition that of vitamin E has livestock health implications and affects milk and meat quality (Beever *et al*., 2000). The content of vitamin E in relation to pasture type, species, and plant age, as with many other aspects of plant species and animal health, remains relatively poorly understood. Potential benefits linked to plant biochemical diversity are unavailable to livestock under more intensive production systems, although this must be balanced against the possible exposure to toxic or other injurious plants that can occur in botanically diverse swards.

Grassland biodiversity as both an output and an input of multi-functional land management

Biodiversity, where associated with agricultural production, has largely been regarded as a positive externality to the process of food production, and as a product (environmental good) of a particular (usually low input) farming system and environmental influences such as hydrology, pH and past ecological succession; in this context it may provide a range of benefits to wider society without necessarily conferring significant direct benefits to the producer. Furthermore, farm output under management required to maintain biodiversity may be inadequate to meet the income expectations of farmers in the 21st century. The basis of most environmental management agreements implemented since the 1980s is that society at large, through taxation, contributes to the cost of environmental goods and compensates the farmer for additional costs or income foregone. Development of long-term management strategies for integrated sustainable agriculture and conservation requires a better understanding of the potential values to farmers and wider society of farmland biodiversity. There is a need to identify and better understand situations where biodiversity is an input to, as opposed to simply an output of, agriculture and other land use functions; these can include food quality, agro-tourism, and ecosystem functions.

Food quality

There is increasing emphasis on the marketing of niche food products by geographical origin, method of production, gastronomic value and nutritional and health properties, and thereby improving financial returns for farmers and the wider rural economy. Production in which grassland biodiversity is an input to the livestock production food chain is embedded in some speciality systems, notably in mountain areas of Europe (Peeters and Frame, 2002). The diet of ruminant animals can affect not only taste but also the chemical composition of meat and dairy products produced, with consequences for human health; examples include the ratio of mono-and poly-unsaturated fats, cardio-protective omega-3 fatty acids, and content of minerals and anti-oxidants (O'Keefe and Cordain, 2004; Wood *et al*., 2004). Further understanding of particular sward types and plant species components of ruminant diets, including their utilization by local livestock breeds, in relation to the quality and value of meat and milk products may provide increased economic opportunities for producers. There are also marketing opportunities that target the 'green consumer' who is prepared to pay a premium for produce linked to a environmentally acceptable production system, in the same way as certificated organic produce. Floristically diverse grasslands also have the potential to provide nectar sources for honey bees and thus an additional high-value consumer product.

Agro-tourism

The growth of tourism and increased popularity of outdoor recreation also confers direct economic advantages to areas where conservation of biodiversity, wildlife and scenic landscapes have been achieved. The potential for landscape and wildlife interest to contribute to the rural economy is affected by agricultural management and grassland species composition, and these in turn affect habitat quality, e.g. for freshwater fish, bird life, etc. (Vickery *et al*., 2001). The value to local rural economies of green tourism can often exceed that directly attributable to farming (Pretty, 2002). While this income may not always benefit farm businesses directly, it can provide diversification opportunities for individual farmers, e.g. direct retailing of local produce, provision of accommodation, facilities for angling, game shooting etc. A number of web-based marketing initiatives have been adopted that link on-farm biodiversity with agro-tourism, and partnerships between conservation organizations and farms such as the Green Gateway scheme in south-west England (Devon Wildlife Trust, 2005) have been set up.

Ecosystem services

Biodiverse grasslands, and the management required to maintain them, may also deliver or contribute to other ecosystem services such as catchment management and carbon sequestration. Farmland vegetation has an important role in surface catchment hydrology, with potential effects on rates of run-off from slopes and subsequent discharge from rivers and streams, and the vegetation and its management can further affect water quality in terms of transport of sediments, micro-organisms and nutrients. Thus, we can consider differences in sward structure, and the presence of trees, shrubs and species that improve stem flow or affect soil structure and thus percolation, as well as wetland areas such as reed beds that act as filters (Worrall, 1997) as having important economic implications. In this context the role of scrub perhaps needs to be reconsidered as a component of managed grassland, including intensively farmed grassland, rather than simply an environmental problem associated with inappropriate management and under-utilization (FACT, 2003). The need for a better understanding of how different sward types and their associated vegetation affect surface hydrology and water quality is gaining importance in the context of climate change. Increased frequency of high intensity rainfall events leading to downstream flooding, and changes in the seasonal distribution of rainfall with more summer droughts are projected to occur with greater frequency under future climate change scenarios

(IPCC, 2001). Allied to these changes, botanically diverse swards may provide greater resilience to droughts or other environmental perturbations partly through a wider gene pool (Tilman and Downing, 1994; Dodd *et al.*, 2004). Carbon sequestration of soils is accountable under the Kyoto Protocol and there is significant potential to increase C sequestration by changes in grassland management (Jones and Donnelly, 2004; Sousanna *et al*., 2004). Options for achieving increased C sequestration include increasing the area of long-term grasslands by reducing short-term leys, maize and arable crops, as well as maintaining existing permanent grass, particularly peat grasslands as carbon sinks are important (Freibauer *et al*., 2004).

2. Biodiversity and multi-functionality of large-scale grazing systems: general principles

In Europe there still exists a variety of livestock systems which are based on migration. Transhumance (Bunce et al., 2004), and the year-round migration of cattle (e.g. in Mediterranean countries) and reindeer herds (Northern Fennoscandia) are organized on a communal or co-operative basis. There are also grazing systems which are privately or co-operatively managed, making use of marginal land, rough grazing land, stubble fields in agricultural landscapes and natural complexes. The succession cycles of vegetation communities with smooth gradients (ecotones) between fallowed and pastured land are an intrinsic part of large-scale grazing systems, with a gradient from young stages with open soil (disturbed patches) to a closed vegetation cover.

A common feature of many high biodiversity value grazed habitat complexes is their strong dependence on large-scale grazing systems. The size which can be considered as large depends on the regional nature and the regional traditions; the range is from <1 km² (e.g. commonages in Connemara, West Ireland) to several 1000 km² (e.g. reindeer grazing migration between the northern Swedish lichen tundra and the Norwegian mountain chain in the Dividalen region). Large-scale grazing causes high structural diversity (γ-diversity) at different scale levels which provides a broad range of habitat requirements for high α-and β-diversity (diversity of species and communities).

From an ecological point of view these pastoral systems have also contributed to the development of unique landscapes that have almost disappeared from the more intensively managed surrounding areas. They can provide and maintain habitats for species which depend on ecotones between, e.g., forest and grassland, and on specific landscape features and disturbance regimes. These systems have a socio-economic meaning for the region in which they operate, as they are closely linked to its provision of a unique landscape, which in turn affects the tourism potential of the locality. Landscapes develop as a complex, and grassland management corresponds with the changes in the landscape context and the socio-economic context. Much of the species richness and biodiversity of Europe was developed and has been maintained by pasturing. After the Ice Age, the natural re-invasion of species and the human impact by pasturing developed simultaneously. By the end of the Middle Ages the small areas with arable land were enclosed and the landscape used for pasturing, as documented by contemporary painters. Regional and social identity was influenced by pastured landscapes, and in many regions of Europe this identity is still bound on landscapes formed by pasturing systems, even where they have lost their original economic basis.

Grazing systems organized on a communal or co-operative basis, either permanently or seasonally, can utilize different vegetation types and landscapes, including forests, pastures and mires, and even some arable land, and generally use larger land areas than individual family farms. The emergence of co-operative structures enabled exploitation of additional grazing

resources, remote from the villages and/or with difficult access. Co-operative grazing systems enable grazing by big flocks or herds, with low costs, and their biodiversity effects vary with scale.
(1) At the landscape scale, large-scale grazing produces parkland or grove-land. The scattered northern Europe timberline and the alpine timberline are products of grazing, mixing forest patches together with tundra or sub-alpine meadows. Similar landscapes are documented in the lowlands on historic maps and occur as rare remainders of commonages in Upper Bavaria.
(2) At the medium or ecotone level, grazing produces spatial smooth gradients, e.g. the shrub belt and tall herb belt between forests and meadows, or gradients between raised bog hummocks and fen vegetation. Large-scale grazing also produces time gradients by effecting cycles of young and older succession stages in a space- time gradient. In most landscapes these time cycles are additionally maintained by management (burning, tree harvesting).
(3) At the micro or patch level, the trampling action of grazing animals produces micro habitats and bare soils which serve as secondary habitats for species of young and dynamic ecosystems. Many plants need bare soils to germinate. The size of the grazing units depends on the density of accessible grazing resources within the region.

Table 1. Hierarchical typology of large-scale grazing systems: LACOPE project

Group 1: Year-round grazing systems
Northern-most Fennoscandia: long distance migration between winter- and summer-grazing grounds along climatic gradients.
Upland sheep and cattle grazing in hyper-Atlantic regions of Ireland, UK and south-west Norway, with two variants: (i) year-round grazing, managed during summer as rough grazing on blanket bogs and heath lands in a hyper-Atlantic environment, combined with improved grazing grounds near farm-steads, and (ii) large-scale grazing period in winter (inverse transhumance) in regions with high yearly average temperatures (Bunce et al., 2004).
Mediterranean year-round grazing with sheep, cattle, pigs or goats, and movements driven by high temperature /drought effects on summer feed, with three variants: (i) Polygono cereal-fallow system of La Mancha; (ii) Mediterranean transhumance (Montados and Dehesas agro-silvo-pastoral systems) with short displacements or long distance migration between village-based winter grazing and summer grazing in the Mediterranean uplands; and (iii) short-distance mountain-foothill migration in Mediterranean areas.
Group 2: Seasonal grazing combined with an indoor period
This group is sub-divided into five regional types:
Middle-European transhumance systems with temporal indoor feeding (classic transhumance)
The indoor feeding period in central Europe caused by harsh winter weather. Livestock systems are farmstead-oriented and production of winter forage is optimized. Traditional access to grazing rights in remote areas. Examples include: sheep transhumance at the Swabian Jura, south-west Germany (Luick, 1997).
Allmende system with summer grazing on marginal sites or/and on rough grazing areas in the periphery of villages and farm-steads; stationary grazing on commonages, currently co-operatively or privately managed (Lederbogen *et al*. 2004). The Allmende pastures form a spatial continuum with the farm-steads or are located in the vicinity so that products are processed at the permanent farm-stead.
Short distance migration combined with temporal indoor feeding; ‘modern’ type of migrating cattle and sheep flocks.
Mediterranean short distance migration with seasonal indoor feeding

Regions where co-operative pastoral systems have survived in Europe do not generally have a good potential for agriculture, when considered in terms of productivity or profitability on a per hectare basis, due to their climate and topography. In Table 1 a hierarchical typology of large-scale grazing systems is presented. Today, the existence of these structures is threatened because of changes in agricultural land-use practices and inappropriate governmental policies, which have resulted in intensively used, even overexploited regions on the one hand, and abandonment of marginal ones on the other. Many of the species that depend on open or semi-open landscapes are now seriously endangered. Therefore, to maintain these systems, and the habitats and species that depend upon them, the challenge lies with the difficult adjustments in terms of modern economics, of the resource exploitation to the needs of the local population. The following examples, studied in the LACOPE project (www.lacope.net) illustrate, for contrasting areas of Europe, co-operative pastoral systems linked to particular habitats, and the management practices and techniques that are needed to maintain the production system and the nature conservation value of the area.

Examples of large-scale grazing systems and their biodiversity and agricultural / socio-economic implications

Reindeer herding in northern Fennoscandia

The characteristics of this system are long-distance migration between winter- and summer-grazing grounds and the utilization of feed resources exclusively from semi-natural landscapes. The migration follows continental climate gradients and is necessitated by the need to save forage resources and to protect the lichen cover from trampling in the continental winter areas.

Traditional Sámiland, Sapmi and the whole of Fennoscandia are very heterogeneous landscapes, and migration from a forested valley to unforested mountains is similar to movement from tundra to taiga. Since the Ice Age the reindeer (*Rangifer tarandus tarandus*) has been the dominant grazer in Fennoscandia in the Arctic and Sub-arctic zones. The area is characterized by a sharp gradient in climate and grazing conditions, created by the high mountains. Their western slopes and summits are strongly influenced by the wet Atlantic climate. Reindeer can graze the western habitats in summer, but in winter they have no access to the vegetation, due to the thick snow cover. On the winter grazing area different conditions prevail on the leeward slopes of the mountains and on the extensive Precambrian plateau east of the mountain chain. The climate is dry with precipitation primarily as rain in summer; winters are cold and snow cover is thin. Extensive lichen heaths, providing lots of winter food for reindeer if properly used, thus characterize the area. The thin, powdery snow typical of the area makes winter grazing easy. However, the lichens are extremely brittle during dry summer days. Thus, even low numbers of reindeer can destroy the lichen cover if they are present in the area under summer conditions.

During the period 1960–1990 reindeer management experienced major technological, economical and political changes. The production system changed from a subsistence pastoralism to a motorized and market-oriented industry, moving away from near-complete dependence on animal and human muscle power. In parallel, the Sámi society came under the 'protection' of the modern welfare state, giving access to extended schooling, housing, health care and social security. In short, a traditional livelihood encountered modernity, which became a serious challenge to Sámi communities and resource management. Moreover, internal regulations for the promotion of agricultural settlements further limited the extent of land-use for reindeer management. The encroachments of modern society have led to a fragmentation of reindeer management land and thus a marginalization of traditional livelihoods.

These changes have relevance for biodiversity. Some of the grazing is due to lemmings and voles, so grazing would not disappear if reindeer were removed, but a comparison of both sides along a reindeer fence suffices to show that habitats change when grazed or left ungrazed by reindeer. Intense grazing contributes to maintain what Zimov *et al.* (1995) call the 'steppe stage' of the tundra (more palatable graminoids, less mosses, less ericoids (in Fennoscandia) and/or unpalatable tussock graminoids (in Beringia) (Olafsson, 2001; Olafsson and Oksanen, 2002). The interaction between reindeer and rodent grazing is currently being investigated. Long-tailed jaegers are used as surrogates of the threatened arctic foxes as the latter are too rare for sufficient collection of field data. Both species need higher rodent densities for successful breeding. From the data obtained so far, neither positive nor negative grazing impacts on jaegers can be detected, but all the data so far are from Finnmarksvidda where grazing impacts on rodent habitats are modest. The plant target species are rare arctic-alpine plants which grow on calcareous soils. Their distribution (and rarity) is connected to the occurrence of these soils above the timberline. Grazing-induced erosion creates more habitat for rarities by spreading the lime and nutrient-rich material of the dolomite rocks to wider areas. Furthermore, these plants rely on local disturbances for successful reproduction. The wider habitat amplitude created by grazing influences metapopulation dynamics: more suitable habitat means lower risk of local extinction plus shorter dispersal distances and higher propagule production, increasing the recolonization rate of habitat patches, from where a local population has become extinct.

Contemporary Sámi reindeer herd management is a low-intensity, low-profit industry within a robust culture based on vulnerable resources. The present destabilizing factors include direct encroachments on pasture land, disturbances of pasturing and animals by other activities (forestry, tourism, mining etc.) leading to fragmentation and increased need of technical facilities (UNEP, 2001). This development also has wide implications in terms of property rights, and long-term effects of encroachments and disturbances are undermining existing property rights. A further destabilizing factor has been the replacement of animal and human muscle power by modern transport, and the integration of the herders into the surrounding society. Herder families could hardly resist being a part of the monetary based society, and the cost problem associated with new herding technology is to some extent also a treadmill effect (Riseth, 2000).

Overgrazing is the main internal problem. This danger is greatest for the lichen pastures of winter, than for the green pastures used most of the year. Serious overgrazing may require up to 20–30 years of recovery time. Green pastures can stand much heavier pasture utilization, changes in vegetation to more productive and pasture tolerant species, e.g. from heather species to grass species, can be promoted (Olofsson, 2001). Moreover, mat-forming lichens will have their highest production level at an intermediate grazing intensity of winter pasturing. Accordingly, some rotation in winter pasture use between years is a favourable strategy, which also is a natural strategy for the animals.

The Burren in Ireland

This area has a traditional management involving a period with large-scale grazing in winter – an 'inverse transhumance.' In terms of biodiversity the Burren is a particular hot spot of species richness on karstic limestone hills. Winter grazing is released to the uplands where the ground is warm enough for continuous vegetation growth during winter. Livestock, mainly suckler cows and sheep, are sent out for large-scale grazing in an non-herded management system. During summer the farm land in the valley is used and the vegetation in the uplands can recover.

Negative impacts on species diversity have been documented on those parts of the uplands that have no rest from grazing during summer time, and where additional feeding with silage during winter times has lead to nutrient accumulation and local trampling effects. The balance of livestock density between winter grazing and summer grazing has changed because of higher productivity of grassland management in the valley. For generations the grazing rights in the Burren have been partly rented by "rancher" farmers from the larger surroundings of the Burren. This causes a competitive situation with respect to feed resources between external and local farmers who are more interested in winter grazing. The optimized management for the Burren relies on a good co-operation between nature conservation interests (Wildlife Committee of the Heritage Council) and both groups of farmers (Burren representatives of the Irish Farmers' Association) (Dunford, 2002).

The Polygono system of La Mancha sheep grazing in Spain

The traditional cereal-fallow system with sheep as the dominant herbivores (one-year winter cereal, one-year fallow) is evolving towards either continuous cereal cropping, or towards a more intensive ploughing regime during the fallow year. Both trends, favoured by increasing mechanization of the agricultural farming practices, are reducing the availability of grazing resources by shortening the growing period of fallow-associated vegetation. The lack of specific subsidies is diminishing the crop fields managed through a rotation of crops between cereal and forage legumes (vetch), with or without a fallow year in-between. This kind of crop rotation is relevant for the economy of the grazing system as a potential source of local fodder (Caballero, 2003). The current trend towards a reduction of grazing determines results in an increasing area of 'eriales' which are no longer grazed, and in particular the more distant areas from the sheepfolds are being progressively abandoned, favouring shrub encroachment and probably a loss in herb species diversity (though increased shrub species diversity).

The territory of a village is divided into allotments connected with contractual grazing rights for sheep. The land (95% comprises arable fields) is owned by cereal producers and partly in public property. Short distance migration through mostly flat landscapes are typical for the region of La Mancha. A dry summer season frequently brings a bottle neck in feed supply. For this reason the sheep owners search for opportunities to fill the diet gap with additional forage from legume fields and other crops. Food resources are mainly based on agricultural residues (cereal or legume stubbles and fallow land), non-arable land such as natural grassland, shrub-steppe vegetation (*eriales*) and Mediterranean forest and shrubland. Parcels of olives, vineyards and irrigation are, by law, excluded from grazing use by pastoralists who rent the grazing allotments (*polígonos de pastos*).

In terms of biodiversity relevance one of the target species for protection in the context of large scale grazing systems in La Mancha is the Great Bustard (Otis tarda). The population of the Great Bustard in the Iberian Peninsula is linked to the cereal-farming regions with dominance (census 2001–2002) in Castile-Leon (10500 individuals), Extremadura (6000 individuals), Castile-La Mancha (4500 individuals), the Madrid region (1150 individuals distributed in 13 leks), and Portugal (some 1500 individuals). Approximately 60% of the world's population of Great Bustard is concentrated in the Iberian Peninsula (www.proyectoavutarda.org). Since hunting this bird has been prohibited in Spain since 1980, the population is recovering, although the future of this species is linked to farm practices and urban development in the Spanish cereal regions (Alonso et al., 2003).

There are a number of destabilization effects which are threatening this land-use system. Recent subsidy-driven tendencies in Spain's agriculture have induced a continuous disconnection of the two land uses which were formerly closely linked through traditions and dependency (organic fertilization). Irrigation leads to reduced periods of set aside. Subsidies for vineyards and olive production have caused an increase of enclosed land for grazing. Marginalization processes and scattered property structure in the arable fields makes it nearly impossible to turn towards a concerted strategy for stabilization of the La Mancha sheep grazing system. Forage deficits appear mainly in winter. Shepherds are landless and have no direct access to land for producing additional forage (Caballero *et al*., 2003).

Outlook and conclusions

The impacts of agricultural change on biodiversity and landscape during recent decades are well understood, and reforms of agri-environmental policies are now providing frameworks for incorporating biodiversity and other environmental objectives into agriculture. Many threats remain, in both the now-fragmented areas of agriculturally improved productive lowlands, and also in the marginal areas of Europe where traditional systems are disappearing or lands are abandoned. Challenges for researchers and policy makers include appraisal of the value of elements of biodiversity within the rural economy, including links with quality of farm products, the value of tourism in relation to farmland and rangeland management, impacts of biodiversity on livestock health and nutrition, and the role of biodiversity in whole ecosystem management, including soil and water conservation. The current food security provision that Europe now enjoys cannot necessarily be assured in future decades in the face of issues such as climate change, world population growth and uncertainties over supplies of fossil energy and water. Thus, many research challenges remain if we are to successfully manage agri-environmental ecosystems to deliver food and biodiversity benefits.

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Socio-economic conflicts between farming and nature conservation interests in grassland use

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Abstract

The paper will start with a brief summary of the development of present grassland functions. It tries to address the reasons why several new social demands for grassland use have emerged recently. Both expectations of production (i.e., farmers' society, the social minority) and nature preservation (representative of global society, the social majority) will be analysed and potential conflicts are outlined. Through detailed analysis, the differences in expectations of farming and nature conservation at different social levels (from the individual to society as a whole) are presented. However, social and economic conditions may differ among locations, regions, and countries and these differences may explain the different social responses to these interests. It is difficult to find any overall compromise between production and nature conservation interests, although there are various solutions which may successfully address the problems between farmers and environmentalists. A presentation of some of these solutions from different European countries will give practical aspects of the problems and will try to outline future trends for solving these kinds of problems in this respect in the European Union member states.

Key words: grassland functions, social demands, farming, nature conservation, socio-economic conflicts

Introduction

Recent developments in grassland use have resulted in a sophisticated grassland philosophy, which underlines the multifunctional role of grasslands in modern societies. Social demands for, and expected benefits from, grasslands are as follows:

- to provide livestock with good quality forage,
- to furnish habitats for wildlife, both flora and fauna,
- to contribute to the attractiveness of the landscape,
- to provide suitable vegetation cover for outdoor recreation and leisure.

European grasslands are able to meet these demands through their production and non-production functions. Social groups, however, may have conflicting interests in these functions. For example, farmers wish to make production from grasslands increasingly efficient, while an increasing proportion of the larger society, which has developed a keener eye for environmental awareness, primarily wants to see the environmental benefits of grasslands. As the agricultural value (productivity) and natural preservation (environmental) value of grasslands are antagonistic to some extent (Wilkins, Harvey, 1993), a compromise between these interests seems difficult to put into practice. While the preservation of the natural and scenic values of grasslands is unquestionably important, the farmers' interests should not be neglected either.

Materials and Methods

This paper has been compiled on the basis of personal experiences participating in international (European Grassland Federation Meetings and symposia, European study tours) and Hungarian (conferences, field visits) professional activities, as well as on literature reviews (EU and Hungarian agro-environmental policy, nature reservation regulations). A theoretical approach and practical examples are used to outline the key aspects of the topic.

The present rural situation and the farmers' society

Presently, the most important principles of socio-economic development in Europe are the sustainable and multifunctional use of resources. In this respect, the role of rural areas and farming society is increasing, as these care for natural resources, including the biodiversity of wildlife and the beauty of the landscape. The future of these resources depends on the situation of rural areas and farming society. The present developments in this respect, however, are not promising. Some warning indicators about the worsening rural situation are:

- weakening rural economy related to agriculture,
- continuous decrease in rural populations,
- lower incomes compared to national averages,
- depopulation threats in certain areas (e.g. hard economic conditions),
- ageing society as young people move to cities,
- agriculture as a whole can sustain an increasingly smaller proportion of society as a whole,
- farming as a career is losing its attractiveness among young people.

Under these conditions, rural society is less capable to respond to new challenges properly. One of the challenges facing farmers is the growing social awareness of environmental issues. This challenge is now a real pressure on farming communities, as the social majority is demanding environmentally-friendly practices from the rural minority. Several other factors also make it difficult for farming societies to take up the challenge in many European regions:

- The lower than national average qualification of farmers makes it difficult for them to understand the spirit of environmental awareness,
- In many rural situations, only agriculture can provide families with a living, so they have to make the best use (income) of their land.

Confronting the interests of farming and nature conservation

As farming and nature conservation interests are of a complex nature, it is difficult to find solutions to their conflicts. First of all, society has to understand the points-of-view of both sides. Any examination of these has to start at the individual level.

Arguments from the side of the farmers:

- as a property owner, the farmer wants to manage his land without any restriction, and insists on personal freedom in farming,
- farmers want to exercise their property rights,
- farmers want to attain the highest possible income for their families,
- farmers want to reduce production costs as much as possible,
- farmers, wherever possible, want to manage the farm in the traditional way, and would not like to modify their practices,
- farmers demand moral and financial appreciation from society for their produce,
- farmers expect *quid pro quo* when it comes to responding to societal pressure.

After reviewing these arguments, it is obvious that any prohibitions introduced by nature preservation measures are rejected by farmers. The rejection is more severe if there is pressure on farmers to make a living for their families on their land/farm.

On the other hand, growing environmental awareness has world-wide appeal. The key role of grassland ecosystems in environmental sustainability and nature conservationhas been recognised. For example, in Hungary, a study (Nagy, 2002) found that 45% of protected plant and animal species require grassy vegetation for survival. More than half of the protected plant species can be found in rocky mountain grasslands (Tardy, 1997). By now, nature reservation policies have outlined the main objectives regarding grassland use:

- to maintain, or possibly restore, the species diversity (both plants and wildlife) of grassy ecosystems,
- to preserve site specific historical natural landscapes of high scenic value.

These objectives are met by controlling farm practices and any other activities on nature reserve lands. Control is managed by site specific measures imposed by nature reserve regulations.

The nature of these nature reserve measures is prescriptive or prohibitive, imposing drawbacks for farming. These measures may refer to different elements of farming: e.g. inputs (fertilizers and other chemicals), methods and timing of farm works (e.g. grazing methods, cutting techniques, date of turning out to grazing, cutting time). The farming regulations of nature preservation restrain the freedom of farmers to perform day-to-day activities as they would wish, i.e. if they are interested in quick, cheap, productive, cost-saving, profitable and innovative techniques of farm activities. Thus, examples of drawbacks may be as follows: reduced freedom of farm activities, higher production costs, lower incomes from farming and, as a result, lower profit from farming, and extra labour input.

The nature of the conflicts between farmers and nature conservation activists can be summarised as being both mental and economic. The spirit of the conflicts between farming and nature conservation can be approached by the priority ranking of the two issues. The ranking of farmers' interests are: 1. production, 2. scenic landscape, and 3. biodiversity (species and ecosystems). The ranking of nature preservation is the reverse of this i.e.: 1. Biodiversity (species and ecosystems), 2. landscape, and 3. farming.

Technical content of nature conservation regulations – a Hungarian case study

The largest Central European National Park, the Hortobágy, was established in 1975. Since then, nature reserve regulations have evolved in response to the changing conditions in the National Park. Present regulations (Aradi, 2002) refer to:

Grazing – turnout time, grazing season, end of grazing, preferred grazing animals

Use of animal units on the reserve

- forage preserved for winter must be transported on dry roads in summer,
- permission is necessary for winter use of animal units,
- winter walking of animals is limited to approved areas,
- weedy patches must be mown before seed ripens,
- buildings cannot be used for purposes (e.g. storage) other than animal farming,
- wastes and manure have to be stored separately,
- wastes must be transported off site one week after the end of the grazing season at the latest,
- areas for haystacks and manure are marked out by nature reserve agents,
- manure must be transported off regularly,
- manure transport has to be agreed upon with nature reserve,
- nature reserve permission is necessary for e.g. the renovation, expansion of buildings.

Transport on steppe roads

- no night traffic, the use of reflectors is prohibited,
- a written agreement is necessary to access any usable roads,

- approved roadways cannot be used in rainy weather,
- machinery transport requires a case-by-case permit,
- animals can be transported by vans only on solid roads,
- on muddy roads, transport/traffic is prohibited,
- traffic on grassland along approved roadways is prohibited,
- transportable road conditions have to be kept up; road works must be done according to necessity. Times and methods for road works must be agreed upon with the nature reserve authorities,
- transport may be limited in favour of wildlife.

Grassland cultivation

- the use and storage of agrochemicals is prohibited,
- manuring (area, time, methods) requires a special permit,
- damage to the sod (e.g. harrowing, disking, rolling) is prohibited,
- only physical weed control (hoeing, mowing) is permitted on weedy patches,
- burning is possible between November 25 and December 24, according to special directives issued by the nature reserve,
- in cases of fire, chemicals cannot be used, fire fighting must be done by the farmers at once and the nature reserve has to be informed immediately,
- water control on the land can be done exclusively with special permission from the nature reserve,
- fences can be used only with special permission from the nature reserve,
- grazing pressure is determined by the nature reserve. Other limitations (species, breeds and seasons) can be introduced as well. Losses because of these limitations cannot be reclaimed from the nature reserve. Limitations are determined preferably before the grazing season starts, or sometimes on an *ad hoc* basis,
- goose grazing is prohibited in general,
- pigs can be grazed with special permission in closed areas,
- taking pets (cats, dogs) into the nature reserve area is prohibited except for animals from old-established Hungarian sheepdog lines,
- herbs and mushrooms can be collected with a case-by-case permit,
- repair of sweep-pole wells must be done annually, wells out of use must be covered, equipment to supply drinking water to animals must not destroy the landscape. Windmill pumps may be established with special permission,
- no entry, or entry is limited to some areas,
- any activities running contrary to the interests of the nature reserve is examined under contravention or criminal procedures.

Cutting harvests

- are preferably avoidable,
- need special permission which must be in the hands of the mowers and must be presented to the nature reserve agents on site who have the right to stop mowing and send machinery and people out of the area,
- mowing can be started after the 15^{th} of June; very special permission for an earlier start is possible,
- 200 m wide belts along both sides of roads cannot be mown, because of landscape values,
- areas excluded from cutting harvest are determined by the nature reserve,
- cutting operations works (e.g. mowing, baling) at night is prohibited,
- hay bales must be transported from grasslands as soon as possible,

- transport of hay bales can be done on dry soil,
- wastes cannot be left in the fields,
- mowing is supervised daily by nature reserve agents,
- any damage to ground or sod must be rectified by the farmers.

This long list of what can be done, what cannot be done, what is compulsory, what is prohibited, and what has to be permitted, shows the very complicated nature of nature reserve regulations. Activities specified in the regulations define the scope of work of nature reserve agencies. However, farmers, whose main job is agricultural production, may consider these regulations to be just one extra burden on an already difficult lifestyle. It is not only challenging to learn and follow the regulations, but this takes time, labour and energy, and has causes negative financial consequences on farm profits.

Managing the conflicts

Without a doubt, the interests of the actors seem to be antagonistic. The severity of the conflicts depends, however, on the conditions under which they exist. The key point in this respect is land ownership. If land ownership rights are practiced and farming is conducted by the nature reserve organisations, it is very easy to harmonise the interests and the conflicts do not exist. Efforts of nature reserve organisations in many countries (e.g. in Hungary; Tardy, 1997) to buy land can eliminate these conflicts. The problem, however, is that financial resources are not enough to buy all the land under or intended to be put under l protection.

An intermediate situation is that the nature reserve exercises the actual land ownership rights, but farming is under taken by tenant farmers. The conflicts between the partners' interests exist, but compromise is made by a land tenure contract describing the conditions of the reserve. The contract between the partners in this situation is voluntary; some incentives may encourage the farmer to accept the reserves conditions.

The worst situation is if the farmer has ownership of land on the reserve. In this situation, the farmer wants to maximally exercise the freedom to farm as he sees fit, and the nature reserve wants to see its regulations observed. The gap between their interests is obvious. The arguments between them may go to extremes. Tools to handle the situation may include criminal prosecution, forcing the observances of regulations by law, or conducting compensation schemes.

The prosecution of farmers is rarely successful. Only farmers with a high level of qualifications and in good financial situations can understand the modern 'legalese'. Legal measures may only be temporary, as changing conditions may change the farmers' attitudes towards nature conservation regulations. Prosecution is useless if farmers are less qualified or are under pressure to make a living from agriculture.

Forcing the observance of nature reserve regulations by law is considered by farmers as dishonest or an infringement of their rights. Farmers try to circumvent the regulations as soon as they are out of immediate contact with the inspectors, and the nature reserve staff may want to respond to such behaviour with awkard behaviour (e.g. too frequent visits). Such conflicts cannot be managed by forcing the observance of nature reserve regulations over the long term.

Fortunately, by now, we have workable methods to manage conflicts between farming and nature reserves by way of compensation schemes. Some of these have existed for a couple of decades (e.g. management agreements in Dutch agriculture, similar schemes in the UK – Frame, 1990), and recent EU policy can also support the meeting of farming and nature reserve objectives (1257/1999 Council Regulation). These compensation schemes work on a voluntary basis. Farmers can apply for payments from the reserves. However, these schemes cannot solve the conflicts in every case. Some problems of these compensation payments in Hungary – and probably in some other Central and Eastern European countries – are as follows:

- compensation payments were introduced much later than reserve regulations had come into force,
- the total reserve area is much greater than the area covered by compensation payments,
- financial resources are too restricted to increase the payment areas according to demand,
- some farmers (small landholders, the elderly and less educated ones) are not aware of the payment schemes,
- the compensation procedure is too bureaucratic and time consuming,
- the payments do not cover the real drawbacks to farmers (i.e. only partial compensation is offered),
- national payments and EU payments, in total, differ between member states (e.g. EU payments are calculated to cover the total costs and to contain financial incentives as well, but incentives are not included e.g. in Hungarian compensation).

The problems and disparities described above are great obstacles to a well-balanced agricultural and nature reservation policy. However, developments of late demand a solution. In order to achieve a real solution, it must be seen that environmental and nature conservation affairs are of international nature. Both national and international measures must contribute to the elimination of the antagonism between farming and nature conservation interests on the basis of equality of the partners.

Conclusions

Both farming and nature conservation are important requirements for modern societies.

Nature conservation is a new challenge for farming communities in many parts of Europe.

Interests of farming communities and nature reserve agencies seem to be antagonistic, but they have to co-exist with each other over the long term.

The best solution to eliminate the gap between the different interests is land ownership and farming within the same organization.

If the above solution cannot be arranged, correct compensation schemes can solve these problems.

The compensation schemes are fair if the total drawbacks to farmers are totally compensated for by society.

Environmental and nature conservation affairs have international implications and international bodies should take responsibility as well to cover the costs of nature conservation.

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An outcome-based payment scheme for the promotion of biodiversity in the cultural landscape

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Abstract

Internalising positive externalities of land use through agrarian politics is state of the art both politically and scientifically. Currently, farmers receive compensation payments for ecological goods and services in the framework of agri-environmental programs, which are predominantly action-orientated. For further development of these programs, however, the social acceptance and the efficiency of the programs have to be improved. This paper describes a decentralised outcome-based payment scheme which meets these requirements: Within this payment scheme, farmers will be rewarded for the outcomes of ecological services. These outcomes are ecological goods that represent plant biodiversity. The payment scheme takes into consideration fundamental criteria of market economy such as supply and demand. On a voluntary basis, farmers may offer ecological goods e. g., through a bidding procedure. The payment scheme is a regional program in the sense of the EU-principle of subsidiarity, and the preferences for ecological goods of the local population will be taken into account through a participatory approach.

Key words: payment scheme, biodiversity, agri-environmental programs

Introduction

Since the reform of the Common Agricultural Policy (CAP) in 1992 agri-environmental programs have played an important role in the second pillar of the CAP. The member states apply these programs throughout their territories according to the environmental needs while in Germany the federal states are responsible for this. So far, programs have been up to 75% co-financed by the EU agrarian household. The further development of the agri-environment programs is the central aim of our research project. Currently, most of these programs are action orientated. This means that farmers receive compensation payments for particular environmentally sound measures such as the reduction of stocking rates, the abandonment of fertilisers or herbicides, or mowing at a later time in the year. In these programs, premiums are usually uniform throughout a federal state. However, evaluations have indicated that programs lack both, economic efficiency and social acceptance, as well as the expected favourable impacts on biodiversity (Kleijn and Sutherland, 2003; Wilhelm, 1999; European Commission, 1998).

These results were the starting point for the development of a new reward scheme for ecological services of farmers. Four main points make this payment scheme different from actual programs: (i) It is an outcome based system. The farmers will be rewarded for ecological goods of plant biodiversity as transparent results of ecological services. (ii) The payment scheme is decentralised in the sense of the EU-principle of subsidiarity. (iii) It takes into consideration the fundamental features of markets such as supply and demand. A regional advisory board is responsible for decisions about the demand for ecological goods. (iv) The preferences of the local population about ecological goods will be taken into account.

We developed this reward system in our model region, the Northeim district in the southern parts of Lower Saxony (Germany). However, it could easily be assigned to other regions. This new reward scheme includes prospects for the introduction of ecological goods as a new line of agricultural production.

Regional ecological goods

To be suited for an outcome based and market-orientated payment scheme ecological goods have to meet special requirements. The production of the goods has to be voluntary, their appearance has to be related to a particular field, and the producer of the goods respectively. Secondly, the definition and the identification of goods have to be transparent for both farmers as suppliers of goods and society on the demand side. In addition, monitoring of the goods must be feasible. Bearing these aspects in mind, goods related to plant biodiversity seem to be most suitable as ecological goods.

Another basic requirement is that rewarding farmers for the production of these ecological goods must be in accordance to European legislation (Council Regulation (EC) No 1257/1999). This means that the goods have to exceed ecological outcomes of farming in terms of 'good farming practices'. Ecological goods thus have to be defined by criteria which are related to the intensity of cultivation. The occurrence of goods has to be proven in an easy and timely way and their verification has to be justiciable. As a consequence, the definition of the goods has to be precise and specific, and explicit methods for controlling are to be developed. Beyond the inherently positive effects of plant diversity the goods should also implicate positive external effects on animals and abiotic resources (Bertke, 2005; Gerowitt *et al*., 2003b). Ecological goods can roughly be classified into three groups: goods related to grassland, to arable land, and landscape structures such as hedges, balks, fallow lands, and stripes along watercourses. Overall, the locally adapted catalogue of ecological goods for the Northeim district includes 37 ecological goods: three goods related to grassland, four goods related to arable land, and thirty goods related to landscape structures. The goods are defined by means of different criteria such as the number of species per unit of area, the composition of plant species, vegetation structures, and square measures like the breadth of linear landscape structures or the minimal length of hedges or lines of trees (Bertke, 2005). With respect to transferability of the payment scheme to other regions this catalogue could be used as a basis for Lower Saxony for example. The catalogue may easily be adapted to the local peculiarities in other regions in co-operation with their regional advisory boards as explained below. In the following description, the process of defining an ecological good is outlined. As an example the definition of grassland-related goods is chosen. In the first place the aims to be achieved by the production of these ecological goods in the model-region, have to be determined. These aims are (i) the maintenance of grassland management particularly on marginal sites, (ii) the promotion of regional species-rich types of grassland, and (iii) the conservation of rare plant associations. According to these general aims two types of criteria for the ecological goods have been chosen. One criterion is the number of forb species and the other is a list with target species that indicate rare plant associations typical of the region. An analysis of grassland surveys confirmed a significant relationship between the number of forb species and various grassland management measures such as the nitrogen fertiliser use, the farming system (organic or conventional farming), and the frequency of cutting or grazing. A threshold value of the forb species number per 12.6m² (=circle with a radius of 2m) was developed that indicated to what extent the grassland management matches the guidelines of 'good farming practice'. The production of an ecological good can only be accomplished if management measures are required that are beyond these guidelines. Within these two types of criterions three quality levels of ecological goods have been defined. The lowest level is a number of 8 forbs per 12,6m². Apart from this minimum forb species number the higher quality levels require the occurrence of a particular number of target species from the species list (Bertke, 2005).

Supply and demand of ecological goods

The major idea of the payment scheme is the creation of a market for ecological goods. Consequently, the ecological goods have to be scarce and there must be a demand for these goods. An actual social demand is the justification for the transfer of public money into the production of ecological goods and the pre condition for the social acceptance of payment schemes. Several surveys of willingness-to-pay for environmental goods and services in the past have indicated an actual willingness-to-pay of the general public (Fischer, 2004; EORG, 2002). Ecological goods are public goods, that means there is an incentive to free-ride as people cannot be excluded from consuming these goods. Therefore, it is unlikely that a market with an individual demand for ecological goods of the regional society will spontaneously evolve. Consequently, the demand for these goods should be organised in a collective way. In this payment scheme ecological goods are considered merit goods: A regional advisory board acts as a representative of the local population, expresses the societies demand for ecological goods and allocates the funds to the respective goods (Hespelt, in press, Fischer, *et al*., 2003; Gerowitt, *et al*., 2003a). To justify this approach, economic valuation studies, focused on the preferences of the local population for ecological goods, are applied and have to be taken into consideration in the demand decision-making process (Fischer, 2004). Members of the regional advisory board are local stakeholders of the following groups: the local government, environmental and agricultural administration, local conservation NGO's, the farmers' union, and the land owners. The constitutional basis of the board guarantees that the locally relevant experts of environmental and agricultural issues can bring their knowledge about specific regional problems and needs into the decision processes of the board. Thus the ecological aims can be adapted to local conditions (Hespelt, 2005). Furthermore, groups with different interests in landscape, namely land use and nature conservation are represented in the board, and both interests have to be considered when making decisions about the regional ecological aims. The payment scheme offers farmers who are willing to enter the market an opportunity to produce the demanded goods on a voluntary basis. As long as farmers act according to the general rules, they may decide how to produce the goods as no guidelines are given, unlike in action-oriented programs. This is a new challenge for farmers, since they have to combine their classical production with the production of biodiversity. The payment scheme provides financial incentives for farmers to find innovative solutions for the improvement of biodiversity on their own.

The price of the ecological goods, established through supply and demand in the market system, is an indicator of scarcity. In our system there is only one actor on the demand side – the advisory board as the representative of the local population – while there are several farmers on the supply side. In this respect, this market for ecological goods is different from regular markets for private goods. To create competition among farmers in order to improve economic efficiency, additional features will have to be implemented. Supplier competition can be achieved using a tendering procedure (Latacz-Lohmann and Van der Hamsvoort, 1997). The bid prices for the ecological goods have to be calculated by the farmers based on their individual cost structures.

Outlook

The components of the payment scheme have been developed in an interdisciplinary research project which was started in 2001 at the Research Centre for Agriculture and the Environment of the Georg-August-University Göttingen in close collaboration with the regional advisory board in the Northeim district. In 2004 the payment scheme has been implemented into practice for the first time. The regional board decided on the demand for ecological goods related to grassland, and presently, for these goods a tendering procedure is conducted in the model region. Furthermore the transferability of the payment scheme onto another region differing in landscape, agricultural practice and socio-economic characteristics is investigated. The regionalisation and the analogy to market economy certainly provide an opportunity to make the design of agri-environmental programs more efficient. Furthermore through the participatory approach and the transparency of the reward scheme a higher public acceptance of transferring public money into agriculture can be expected.

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Effects of the Swiss agri-environment scheme on biodiversity

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Abstract

More than a decade after the introduction of the European agri-environment schemes there are a limited number of published studies evaluating these schemes. This study evaluates a Swiss agri-environment scheme designed to maintain and increase species richness in hay meadows. The aim was to test whether meadows under the agri-environment scheme (ECA hay meadows) had higher biodiversity than control meadows, whether biodiversity was higher in the centre than at the edge of meadows, and whether these effects differed between geographic regions. Using paired sampling, a total of 42 hay meadows were selected in three regions. The species richness of two taxonomic groups; vascular plants and wild bees was assessed. Species richness of both, vascular plants and wild bees was significantly higher on ECA hay meadows than on control meadows. The results for the plants and for the wild bees were consistent across the three study sites. It was concluded that the Swiss agri-environment scheme for hay meadows is a tool to preserve the diversity of biodiversity in agricultural landscapes.

Keywords: Agri-environment scheme, grassland, vascular plants, wild bees, species richness

Introduction

More than a decade after the introduction of agri-environment schemes in Europe and Switzerland, only a limited number of studies evaluating these schemes have been published (Kleijn and Sutherland, 2003). This study evaluates the ecological measurements of the Swiss agri-environment scheme, applied on hay meadows (ECA hay meadows). Two important management requirements on ECA hay meadows specify a late cutting date and no fertilizer applications. To date it has been taken for granted that there is higher biodiversity on ECA than on conventionally managed hay meadows. However it is important to ascertain whether there is actually a higher biodiversity on ECA hay meadows than on those managed conventionally. The study aimed to investigate possible edge effects on species diversity (Marshall and Moonen, 2002) and to assess if results on the effectiveness of the scheme can be extrapolated from one to several study sites.
The following hypotheses were tested:
1. Biodiversity is higher on ECA hay meadows than on conventionally managed hay meadows.
2. Biodiversity is higher in the edge compared to the centre of the meadows
3. Agri-environment schemes have similar effects in different regions.

A paired sample approach of ECA and control hay meadows was used to at least partially unlink spatial environmental variation and between-treatment variation. Biodiversity was assessed by investigating the species richness of vascular plants and wild bees. Both groups are potential indicators for grassland quality with regard to overall species diversity (Jacquemyn *et al*., 2003; Tscharntke *et al.,* 1998).

Materials and Methods

Study Design

Three study regions, two in the Canton of Lucerne (Ruswil and Flühli) and one in the Canton of Zurich (Bauma) were selected. Within each study region seven pairs of meadows were selected. The two meadows of one pair were close to each other, had similar abiotic conditions (e.g., soil type, water table, exposition, inclination, landscape structure), were surrounded by the same habitat type, but differed in terms of management. One meadow in each pair served as control and was conventionally managed according to common agricultural practices in Switzerland. The other meadow in a pair represented the treatment under the ECA management prescribed by the Swiss agri-environment scheme for hay meadows (ECA hay meadows) (Bundesbehörden der Schweiz. Eidg.).

Data collection

Within each transect (edge and centre of the meadow) we investigated occurrence of vascular plants and wild bees. This was done by direct observation and sampling in the period March–September 2003.

Vascular plant occurrence was of surveyed using 10 rectangles of 5 × 1 m on each transect. The distance between neighbouring rectangles was 5 m. In each rectangle all plant species were noted and their abundance was assessed by estimating the percentage of cover of each species within the rectangle.

Wild bees were investigated by transect and sweep net surveys. A transect survey consisted of catching all individuals that were observed on a transect during 15 minutes. Subsequent to the transect survey, a sample of sixty sweeps was taken on each transect. Between May and August, a total of three survey rounds were made for wild bees. Sampling was carried out between 10:00–16:00 and only on sunny days. The two meadows of a pair were sampled on the same day by the same person. Species of wild bees were then identified in the lab.

Statistical Analysis

Species richness was described by the number of species. We used a hierarchical ANOVA with the three fixed factors Region (the three study sites Bauma, Ruswil and Flühli), Manag (ECA versus conventionally managed hay meadows) and Pos (edge versus centre of meadows). In order to match the distributional assumption of ANOVA we transformed the data with the box-cox transformation if necessary (Sokal and Rohlf, 1997). All analyses were computed using the R software (R Development Core Team, 2004).

Results

Plants: A total of 246 species of vascular plants was recorded, with 159 species in Bauma, 173 species in Flühli, and 109 species in Ruswil. The average number of species per meadow varied significantly between regions (Table 1). Significantly more plant species occurred in ECA than in conventionally managed meadows and significantly more also at the edge rather than the centre of meadows (Table 1, Table 2). This was mainly due strongly positive edge effects in conventionally managed meadows, whereas the edge effects were significantly smaller in ECA hay meadows. The effectiveness of the ECA treatment did not differ between the three study sites (see interaction Region x Pos in Table 1, Table 2).

Wild bees: A total of 49 species of wild bees was recorded, with 28 species in Bauma, 31 species in Flühli and 26 species in Ruswil. The average numbers of species per meadow did not vary significantly between regions (Table 1). For this group also, there were significantly more species in ECA than in conventionally managed meadows and the number of species did not differ between meadow centre and edge (Table 1, Table 2).

Table 1. Mean and standard deviation of the number of species of vascular plants and wild bees per transect, for each of the three study sites, in ECA hay meadows (with agri-environment scheme) and conventionally managed hay meadows (without agri-environment scheme) and in the center or at the edge of meadows (n = 7 for each mean)

Vascular plants	ECA hay meadow		Conventionally managed hay meadow	
	centre	edge	centre	edge
Ruswil	29.71 ± 5.50	39.00 ± 8.85	18.29 ± 2.81	26.00 ± 5.45
Bauma	40.00 ±10.26	45.00 ± 13.55	31.14 ± 3.02	44.57 ± 9.57
Flühli	49.43 ± 10.63	47.00 ± 4.83	30.57 ± 8.81	40.57 ± 10.31
Wild bees				
Ruswil	3.43 ± 0.98	4.29 ± 1.80	3.71 ± 1.25	3.14 ± 1.57
Bauma	4.43 ± 2.44	4.71 ± 3.77	3.57 ± 1.40	3.71 ± 1.38
Flühli	4.43 ± 2.51	3.71 ± 1.50	3.29 ± 2.56	1.71 ± 1.38

Table 2. Analysis of variance (ANOVA) testing the effects of region (Reg), ECA treatment (Manag), and meadow edge (Pos) on the species richness of vascular plants and wild bees

	Df	Vascular plants			Wild bees		
		MS	F	*P*	MS	F	*P*
Reg	2	1.46	15.10	0.000*	0.06	1.07	0.363
Pair (n = 21)	18	0.10			0.05		
Manag	1	1.73	29.11	0.000*	0.17	4.78	0.042*
Reg x Manag	2	0.19	3.18	0.066.	0.05	1.31	0.294
Meadow (n = 42)	18	0.06			0.04		
Pos	1	0.93	35.29	0.000*	0.02	1.08	0.305
Reg x Pos	2	0.04	1.64	0.208	0.02	1.29	0.289
Manag x Pos	1	0.25	9.39	0.004*	0.03	1.45	0.237
Reg x Manag x Pos	2	0.02	0.69	0.506	0.01	0.65	0.530
Strip (n = 84)	36	0.03			0.02		

Discussion

The data confirm the first hypothesis, that species richness is generally increased on ECA hay meadows compared with conventionally managed meadows. For plants this results from lower fertilizer levels and later hay cutting under management rules for ECA hay meadows (Jacquemyn *et al*., 2003). The increase in species richness of wild bees can be interpreted as consequence of the increased species richness in plant food sources (Pfisterer *et al*., 2003; Gathmann *et al*., 1994). The second hypothesis, that species richness is higher in the edge compared to the centre of the meadows was only confirmed for vascular plants. These results suggest a more extensive management in the meadow edges and a high species exchange between adjacent habitats. Even though the scheme had in all three regions the same effect on the two indicator groups, the significant differences in plant species richness between regions might be influenced by regional factors.

Conclusions

It was concluded that the Swiss agri-environment scheme applied to hay meadows is a tool to preserve biodiversity in agricultural landscapes.

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Assessing biodiversity on silvopastoral systems across Europe

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Abstract

Silvopastoral landscapes across Europe host a high biodiversity. Several indicators have been screened for their suitability to assess such biodiversity and the changes therein in order to contribute to policy and decision making processes and raise awareness among the citizens. Several of these have been proposed as a potential contribution to the environmental indicators promoted by the European Environment Agency. This paper presents the indicator '*Types of silvopastoral systems: species composition*' that highlights the relevance of silvopastoral systems for flora species but also for livestock breeds and therefore the importance for contributing to the European and global objective of halting the loss of biodiversity by 2010.

Keywords: biodiversity, agroforestry, silvopastoralism, indicators, Europe

Introduction

Silvopastoralism is one of the oldest practices of agroforestry, a deliberate growing of trees and livestock on the same unit of land in interacting combinations for multiple products or benefits from the same management unit (Nair, 1993). Silvopastoralism enhances biodiversity due to the gradients of environments that are created within (vegetation structure, shading, moisture), but also because of the preservation and improvement of landscape diversity, maintaining traditional systems, increasing connectivity within landscape components in benefit of the mobility of animals, therefore reducing habitat fragmentation. These systems may also simulate structures and processes that were important when wild mega-herbivores dominated in European forests. Due to the important economic, ecological and social role that silvopastoral systems play, there is a need to study their current state in order to set up a basis for further monitoring, management and planning of the production and conservation of natural resources in Europe. The important role that the different types of silvopastoral systems may play for sustainable land management and the preservation of biodiversity rich landscapes across many regions in Europe, justifies the development of indicators to assess its state and trends regarding biodiversity features. The latest proposal of amendment of the Rural Development Policy (14/07/2004 COM(2004)490) pays special attention to the development of rural areas and animal welfare. It gives special relevance to the combined agriculture and forest sector for the first time in European policy. Among the priorities of rural development concerning land use planning it is to support farmers to establish agroforestry systems combining extensive forest and agricultural systems.

Materials and Methods

An estimation of the potential extent of silvopastoral systems in Europe is calculated based on the CORINE LandCover database LCL using the software ArcMap™ for ArcGIS 8.1. The indicator 'Types of silvopastoral systems: species composition' is developed following a standard Indicator Fact Sheet Model designed by the European Environment Agency (EEA) (http://themes.eea.eu.int/indicators/). Information requested within the fact sheets refers e.g. to an overview or summary key message, and its assessment concerning policy relevance and environmental context. Information used for the proposed indicators has been based on a literature review on technical aspects of silvopastoralism and implemented related policies in Europe.

Results and Discussion

Statistics on silvopastoral systems are not collected in a systematic and harmonized way across Europe. This situation complicates an accurate estimation of their extent or comparing statistics between regions. Silvopastoral systems in their different types may fall under several of the different classes and subclasses within the CLC: (1) olive groves, (2) pastures, (3) agro-forestry areas, (4) broad-leaved forests, (5) coniferous forest, (4) natural grasslands, (5) sclerophylous vegetation and (6) transitional woodland/shrub. Nevertheless such classes and subclasses may include some areas that are not silvopastoral landscape and it is not possible to separate such distinctions within. When considering this potential area where silvopastoral systems may be represented it accounts for 170 million hectares over the area of Europe covered within CLC (433 million ha), but it shows a larger area than the current silvopastoral landscapes in Europe. A monitoring activity would therefore be needed if a reliable indicator has to be developed.

Silvopastoral systems that can be found across Europe are mainly based on autochthonous species of each region as it is reflected in the list of Table 1. Out of the occurring species, only few alien species e.g. *Eucalyptus globulus, Pinus radiata, Pseudotsuga menziesii, Quercus rubra* and *Robinia pseudoacacia* host this type of forests. This is very relevant concerning the added value using traditionally autochthonous species and the implications for enhancement of biodiversity. Furthermore, cutting trees for collecting animal fodder (twigs and leaves) was widely practiced from Nordic to Mediterranean countries, being probably the oldest form of fodder harvesting. Therefore the current reduction in pollarding, coppicing or shredding, results in a considerable loss to the cultural-ecological heritage because pollarded or shredded trees disappear from the landscape, being prone to die once management is stopped (Ispikoudis and Sioliou, 2004).

Livestock species suitable for silvopastoral systems depend mainly on the availability of fodder in the understorey, but they also feed on acorns, chestnuts, carobs or beechnuts. One of the advantages of livestock production within the silvopastoral systems is the extended grazing season due to the tree cover that reduces the negative effects of droughts and cold as compared to livestock production on more conventional pastures. Shading can also reduce drastically pasture production, but this negative effect can be avoided if tree cover is maintained below 55%. Main productive herbaceous genera are *Agrostis, Bromus, Dactylis, Festuca, Lolium, Lotus, Medicago and Trifolium* that are spread practically all over Europe without risk of extinction. With relevance for preservation of biodiversity, some of other species occurring in the understorey are included in the habitats listed in Annex I of the Habitats Directive (92/42/EEC) (habitats that require special areas of conservation for their preservation) such as *Erica tetralix, E. ciliaris*, *E. vagans, Ulex maritimus, Rhododendron hirsutum, Genista purgans,* and habitats of Juniper formations, matorral with *Laurus nobilis*, different phrygana formations (*Astragalus*), species-rich *Nardus* grasslands, sclerophyllous grazed forest (dehesas) with *Quecus suber* and/or *Q. ilex* and Fennonscandian wooded meadows, among others. Other species such as *Helianthemum alypoides, H. caput-felis, Festuca brigantine, F. duriotagana, F. elegans, F. henriquesii, F. summilusitana, Poa riphaea, Pseudarrhenatherum pallens, Thymus camphorates, T. carnosus, T. lotocephalus, Astragalus* *algarbiensis, A. aquilanus, A. centralpinus, A. macrocarpus, A. maritimus, A. tremolsianus, A. verrucosus, Cytisus aeolicus, Genista dorycnifolia, G. holopetala, Melilotus segetalis, Trifolium saxatile* (II), *Rosmarinus tomentosus, Thymus capitellatus, T. villosus* (IV), *Ulex densus* and *Rubus genevieri* (V), are considered of community interest under the Annexes II (species that need special area of conservation for their preservation), IV (species that require strict protection) or V (species of interest that are eligible for management) of the Directive. Such species and habitats may be preserved through a socio-economically and ecologically sustainable management in the silvopastoral systems avoiding static conservation.

Table 1. Main occurring species or genera in silvopastoral systems across Europe

Tree species
Autochthonous or sub-spontaneous
Abies alba, Acer monpessulanum, Acer opalus, Acer platanoides, Acer pseudoplatanus, Alnus glutinosa, Alnus incana, Betula alba, Betula pendula, Castanea sativa, Celtis australis, Ceratonia siliqua, Corylus avellana, Cupressus orientalis,Cupressus sempervirens, Fagus sylvatica, Fraxinus angustifolia, Fraxinus excelsior, Fraxinus ornus, Juniperus oxycedrus, Juniperus thurifera, Ilex aquifolium, Larix decidua, Picea abies, Pinus brutia, P. halepensis, P. nigra, P. pinaster, P. pinea, P. sylvestris, P. uncinata, Populus sp., *Prunus avium, Quercus aegylops, Q. canariensis, Q. cerris, Q. faginea, Q. ilex, Q. petraea, Q. pubescens, Q. pyrenaica, Q. robur, Q. suber, Salix* sp., *Sorbus aucuparia, Sorbus hybrida, Taxus baccata, Ulmus minor*
Exotic
Eucalyptus globulus, Pinus radiata, Pseudotsuga menziesii, Quercus rubra, Robinia pseudoacacia, Eucalyptus camaldulensis
Understorey taxa
Main herbaceous genera
Agropyron, Agrostis, Anthoxanthum, Anthyllis, Arrhenatherum, Astragalus, Avena, Avenula, Brachypodium, Bromus, Cynodon, Cynosurus, Dactylis, Deschampsia, Festuca, Hippocrepis, Holcus, Lolium, Lotus, Lupinus, Medicago, Melilothus, Molinia, Nardus, Ornithopus, Phleum, Poa, Pseudoarrhenatherum, Pteridium aquilinum, Scorpiurus, Stipa, Trifolium
Main shrubs genera
Adenocarpus, Arbutus, Arctostaphylos, Bupleurum, Buxus, Calicotome, Calluna, Chamaerops, Cistus, Colutea, Coronilla, Cornus, Cytisus, Echisnopartum, Erica, Erinacea, Euonymus, Halimium, Hedera, Helianthemum, Helichrysum, Genista, Juniperus, Laurus, Ligustrum, Medicago, Myrtus, Olea, Ononis, Origanum, Pistacia, Ptilotrichum, Pterospartum, Prunus, Quercus (coccifera, lusitanica), Rhammus, Rhododendron, Rosa, Rosmarinus, Rubus, Santolina, Satureja, Sideritis, Spartium, Stauracanthus, Thymus, Ulex, Vaccinium
Livestock
Sheep, horses, goats, pigs, cows and wild ungulates

Europe hosts the highest animal domestic breed diversity in the world. Despite this fact, almost half of the European breeds are categorised as being at risk of extinction and trends are critical. However, Europe is the region where the highest proportion of breeds is under active conservation programmes (EEA, 2003). Table 2 shows the total number of European breeds for species of interest for silvopastoral systems. Europe accounts for 974 breeds out of risk, 660 threatened of extinction and 383 already extinct. Proportionally to each species the highest number of extinct breeds corresponds to pigs and cattle and the lowest to goats. Nearly half of the donkey and horse breeds are endangered. Sheep breeds are the least endangered. Extensive agricultural systems, like silvopastoralism, may favor locally adapted breeds that help preserving the typical habitats and provide a source of income from high quality food produce at the same time. Financial support per livestock unit when using local endangered breeds is foreseen under the new proposal of Council Regulation for Rural Development by the European Agricultural Fund for Rural Development (EAFRD). Thus, indirectly this could also favor the continuation of culturally important land-use systems and the typical landscape and biological diversity that comes with it.

Table 2. Number of European autochthonous livestock breeds: Total, End (endangered), Ext (extinct). Source: FAO Database (URL: http://dad.fao.org/es/home.htm)

	Total	End	Ext
Donkeys	21	12	3
Cattle	524	163	123
Goats	169	59	10
Horses	359	164	64
Pigs	298	110	89
Sheep	646	152	94
ALL SPECIES	2017	660	383

As example for these extensive systems, dehesas are considered to be one of the most important habitats for biodiversity in Europe containing many species from the Habitats Directive, especially birds and mammals (Bunce et al., 2004). Birds are an important bio-indicator of biodiversity. It is of high relevance to preserve ecosystems like dehesas and other extensive systems where the pasture and livestock production is combined with bird conservation (e.g. of imperial eagle *Aquila adalberti,* black vulture *Aegypius monachus,* common cranes *Grus grus* and other passerines and raptors).

Conclusions

There is a clear need for long-term monitoring to obtain harmonized figures between countries on the status and trends of silvopastoral systems. Such systems traditionally imply the use of autochthonous herbaceous and woody species (including trees) of which several are listed in the Habitats Directive with relevance for biodiversity conservation. Only few tree exotic species are used. Furthermore the loss of autochthonous animal breeds is currently at alarming level. Some of the domestic animal species may be introduced within silvopastoral areas due to their adaptation to each location for a successful implementation and their sustainable use over time. Traditional practices such as silvopastoralism will contribute to preserve valuable landscapes and species diversity. They will contribute to achieve the Objective of halting the loss of biodiversity by the year 2010.

Acknowledgements

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Soil chemical properties as indicators of plant species richness in grassland communities

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Abstract

The influence of soil chemical properties and various management regimes on plant species richness in grassland communities was investigated. Selected soil chemical properties were tested to define indicators for sustainable grassland management. For plant species richness in agriculturally-used permanent grassland communities, the lactate-soluble P content in topsoil is an important environmental factor. Species-rich grassland communities are restricted to soils with less than 25 mg P per kg fine earth fraction in topsoil.

Keywords: α-diversity, soil indicators, lactate-soluble phosphorus, threshold values, intensity of grassland management

Introduction

Soil indicators are important for nature conservation, as they allow the evaluation of the state of the environment and changes in it, and the establishment of the limits of intensification for grassland management. The primary aim of this study was to identify soil indicators for the intensity of grassland management, soil fertility and plant species richness in order to maintain and to utilize species-rich grassland ecosystems in a sustainable way. Further objectives were (1) to identify threshold values at which α-diversity changes clearly appear and (2) to provide information on the influence of various management regimes on plant species richness in agriculturally-used permanent grassland communities in a mountainous region, in Austria.

Materials and Methods

This investigation was conducted in the Styrian Enns valley and in the Styrian Salzkammergut (Styria, Austria). In the study area, ranging from 640 to 1275 m in altitude, mesozoic limestones, paleozoic phyllites, mica schists and gneisses predominate. Soils are mainly Cambisols, Leptosols, Gleysols, Gleyic Fluvisols and Eutric Histosols. The suboceanic climate is relatively cool and humid, with a mean annual air temperature of 5–7 °C and annual precipitation of 1000–1600 mm, of which 50–60% falls during the growing season (April–September). The mean monthly temperature is –3 °C to –5°C in January and 14 °C to 17 °C in July. The growing season is relatively short due to a long duration of snow cover. The climate favours grassland management: thus arable farming has no economically importance.

The studies were conducted exclusively on farms under practical conditions. The study area is suitable for this investigation, because (1) it represents a typical grassland region in Austria, (2) many soil types and grassland communities could be found within a small area and (3) a wide range of management intensities are present as a result of the small-sized farm structure and high site heterogeneity in the mountainous area. Only regularly managed permanent grassland communities with at least 10 relevès and soil analyses per association were selected for study.

The relevès were carried out according to the Braun-Blanquet approach (Braun-Blanquet, 1964). To determine plant species richness (α-diversity), the total number of vascular plant species within a homogenous investigation area of 50 m² was recorded. This area represents the minimal area of species-rich grassland communities. Soil samples from the topsoil (0–10 cm depth) were collected in autumn. Soil and water analyses have been conducted according to the ÖNORM methods (Austrian Standards Institute). Yield and mineral element content in the above-ground plant biomass were determined by using standard methods. For each plant community, the arithmetic mean and coefficient of variability were calculated. Relationships were determined by regression analysis.

Results and Discussion

Table 1 shows the plant species richness of managed grassland communities in ascending order. α-diversity varies greatly between the associations investigated. There was a clear relationship with the intensity of grassland management; plant species richness was generally lower under intensive management. The relative intensively-used pastures (*Alchemillo monticolae-Cynosuretum cristati* community) and mowing pastures (*Trifolium repens-Poa trivialis*-community) are characterized by a comparatively low plant species richness.

Table 1. Intensity of grassland management, plant species richness (vascular plants) and selected soil chemical properties (0–10 cm of soil depth) of important grassland communities

				mg kg^{-1}			
				CAL/DL		H_2O	
Plant community	n	igm	a-d	P	K	P	C_{org}:N_{tot}
Alchemillo monticolae-Cynosuretum cristati	24	4-5	36	57*	161*	8*	9.0
Trifolium repens-Poa trivialis-community	52	4-5	40	44*	139*	5*	9.3
Cardaminopsido halleri-Trisetetum flavescentis	30	2-3	41	38*	97*	10*	10.1
Alchemillo monticolae-Arrhenatheretum elatioris	45	3-4	42	36*	91*	7*	9.5
Cirsium oleraceum-Persicaria bistorta-community	19	2	44	28*	88*	5*	10.6
Festuca rubra-Agrostis capillaris-community	45	1-2	45	30*	108	6*	12.0
Geranio sylvatici-Trisetetum flavescentis	46	2-3	46	40*	103*	8*	9.8
Iridetum sibiricae	28	1	50	15	115*	2*	11.8
Festuco commutatae-Cynosuretum cristati	13	egr	54	23*	73*	2*	9.4
Mesobrometum erecti	22	1-2, egr	68	14	104*	2*	10.5
Narcissus radiiflorus-community	41	1-2, egr	70	16*	99*	3*	11.2

n = number of relevés and soil analyses; igm = intensity of grassland management (number of cuts/grazings; egr = extensive grazing); a-d = average number of species (vascular plants) per grassland community (α-diversity); P and K CAL/DL = lactate-soluble phosphorus and potassium content; P H_2O = water-soluble phosphorus content; * = coefficient of variability > 30 %

At the community scale, there was a relatively strong relationship between lactate-soluble (Figure 1) or water-soluble (not shown) P content in topsoil and plant species richness. Other soil chemical properties demonstrate no (pH, eC, C_{org}, N_{tot}, lactate-soluble K) or only a weak relationship (C:N ratio) with α-diversity. Obviously, a high plant species richness in grassland communities is associated primarily with a low P content in topsoil (Janssens *et al.*, 1998; Critchley *et al.*, 2002). The clear relationship between lactate-soluble P content in topsoil and plant species richness does exist only when comparing different grassland communities. However, within each vegetation type studied, there was no comparable relationship. This result demonstrates the scale-dependence of such investigations.

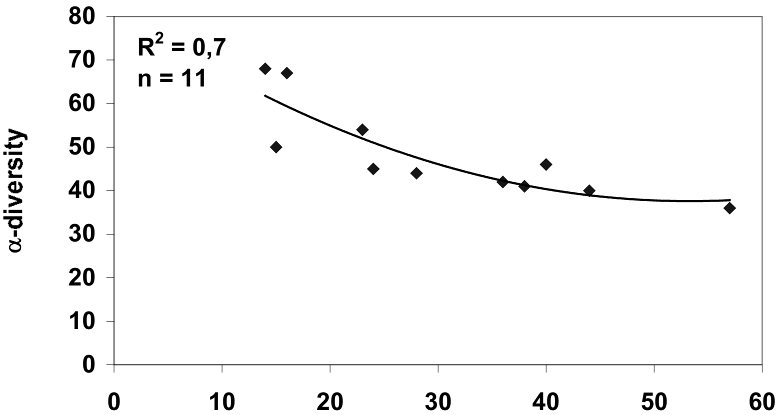

Figure 1. Relationship between plant species richness (vascular plants) and lactate-soluble phosphorus content in topsoil (0–10 cm)

The threshold value between grassland communities with high and medium plant species richness is a lactate-soluble P content of about 25 mg P per kg fine earth fraction. Nevertheless, a low lactate-soluble P content in topsoil is no guarantee of a high plant species richness. Only the combination of nutrient-poor soil, minimal environmental stress, moderate levels of disturbance (site regularly mowed or grazed) and a high regional species pool ensures a maximum of plant species richness.

Table 2. Nutrient leaching losses under permanent grassland at the location HBLFA Raumberg-Gumpenstein (Cambisol, monolithic lysimeter)

	mm	$kg\ ha^{-1}$					
year	sw	N_{anorg}	P	K	Ca	Mg	Na
2002	613	3.5	0.06	4.4	216.8	31.1	8.8
2003	266	1.4	0.03	1.0	85.0	14.3	3.8

sw = seepage water; $N_{anorg} = NH_4\text{-}N + NO_3\text{-}N + NO_2\text{-}N$

A high lactate-soluble P content in topsoil is a good indicator of a long-term application of fertilizers and intensive grassland management at present and/or in the past. Phosphorus accumulates in topsoil in the case of adequate fertilizer application more easily than nitrogen or potassium, because leaching losses of phosphorus (Table 2) and its removal due to harvesting the above-ground plant biomass (Table 3) are comparatively lower. Fertilizer is the main source for phosphorus enrichment in topsoil, as phosphorus input from wet deposition is insignificant (Table 4) and phosphorus from (rock) weathering is released in small amounts. Therefore, naturally-occurring lactate-soluble P content in topsoil is generally very low. Unfertilized alpine and grassland soils, for example, have a lactate-soluble P content in topsoil of about 4 to 25 mg P per kg fine earth fraction.

Table 3. Dry matter yield and amounts of nutrients in the above-ground plant biomass of selected grassland communities (1st growth respectively 1st cut)

Plant community	n	dt ha^{-1} DM yield	kg ha^{-1} N	P	K	Ca	Mg	Na
Alchemillo monticolae-Cynosuretum cristati	11	36	88	13	94	30	8	0.7
Trifolium repens-Poa trivialis-community	13	35	86	12	98	41	13	0.7
Alchemillo monticolae-Arrhenatheretum elatioris	25	37	86	11	93	30	10	0.7
Geranio sylvatici-Trisetetum flavescentis	18	33	75	10	66	32	10	0.7
Cardaminopsido halleri-Trisetetum flavescentis	23	36	74	10	68	28	10	0.7
Festuca rubra-Agrostis capillaris-community	10	16	35	4	24	9	4	0.1
Mesobrometum erecti	7	17	33	3	27	15	3	0.1

n = number of forage samples

The relatively strong relationship between lactate-soluble P content and potentially mineralizable N in topsoil indicates, that lactate-soluble P content is also an indirect measure of the N mineralization potential of agriculturally-used grassland soils (Bohner, 2005).

Table 4. Nutrient input from wet deposition at the location HBLFA Raumberg-Gumpenstein

year	mm pr	kg ha^{-1} N_{anorg}	P	K	Ca	Mg	Na
2002	1371	10	0.4	2	37	6	2
2003	871	7	0.2	2	25	4	2

pr = precipitation; N_{anorg} = NH_4-N + NO_3-N

Conclusions

In grassland communities, the lactate-soluble P content in topsoil is at the community scale a good indicator of the intensity of grassland management and soil fertility as well as a measure of sustainable grassland management. Species-rich grassland communities are restricted to soils low in lactate-soluble P content in topsoil; the threshold value for a high plant species richness was found to be 25 mg P per kg fine earth fraction. Indeed, higher naturally-occurring lactate-soluble K contents are obviously compatible with a high plant species richness.

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The National Hay-meadow Ecosystem Observatory: a tool to monitor and understand the ongoing changes in France

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Abstract

Hay meadows are habitats with specific fauna and flora that, ever-increasingly, are threatened by agricultural modernization. In 2001, in partnership with National and Regional Parks, a National Observatory was set up by ONCFS to monitor the changes in this ecosystem that, in France, stretches from the alluvial flood plains to subalpine meadows. The objective is to get simple standard information: the quantitative indices of ornithological richness and the hay-cutting dates (every year), a description of the flora and vegetation structure (once every 5 years), and the results of a survey (once every 5 years) of the agricultural management practices applied. These data were collected in 12-ha. standard units, in which hay meadows must, at least, represent 40% of the total surface area. In 2004, the national database collected material in 837 sampling plots, situated in 92 different regions (valleys, plains, plateaux,…) distributed all over France. In this paper, we present: i) the main indicators that allow us to describe the state of the ecosystem and its management regime at a national scale, ii) the trends observed between 2001 and 2004, iii) the modelling results (logistic regression) obtained with the help of variables that enabled us to derive the best quantitative indices of meadow-bird richness in France.

Keywords: hay meadow, breeding birds, monitoring, population trend

Introduction

In North America (Mc Coy *et al.*, 1999), as well as in Europe (Tucker and Heath, 1994), grassland birds are extremely vulnerable to the ongoing changes in farming practices. Most of these species are declining as a result of habitat loss or the intensification of pasture management (Broyer, 2001). For some years, to encourage grassland birds, government policies are being implemented that promote certain adaptations of current farming practices. But, at the same time, the mechanization process is still improving which encourages haymaking at an ever earlier date. Because of these opposite trends, large-scale monitoring of the meadow bird populations is needed, while the birds' degree of tolerance to the modernisation of farming practices must objectively be defined. Therefore, in 2001, in partnership with National Parks, Regional Parks, Natural Reserves as well as any other organisation interested in the topic, ONCFS launched a National Observatory to monitor these ecosystems and obtain a thorough knowledge of the long-term changes in hay-meadow ecosystems in France. The objective is to get standard data on the various meadow systems, from the alluvial flood plains to the subalpine meadows.

The observatory's objectives

The task of the National Hay-meadow Ecosystem Observatory is to gather, synthesize and issue annual data recorded in the *départements* (major French administrative geographical subdivisions) where nesting populations of grassland birds still remain. In every *département* involved in the program, a designated agent is responsible for:

- selecting coherent land units ('study regions') where, within the local farming system, hay-meadows have an important function;

- establishing 'sampling plots' in these study regions. A sampling plot is an area of 200-m radius (with a surface of roughly 12 hectares) that is stable from year to year, where hay meadows cover at least 40% of the total area, and in which standard data are collected on bird abundance and diversity as well as on vegetation characteristics and farm management;
- implementing the protocol and, every year, transfer the results to a national coordinating body.

In every sampling plot two categories of data must be collected: annual data (form A), and complementary data that are only needed every 5 years (forms B and C).

For form A, bird census results are recorded. This census is made by a static observer for two periods of 15 minutes in the centre of the sampling plot (in the first and the second half of the breeding season, before the hay is cut). On the basis of the data obtained by these counts, two indices are defined: the Meadow Passerine Index (MPI) and the index of Specific Diversity (SD). MPI relates to the number of individual passerine birds; SD is the number of grassland bird species. In the same A form, one may also find an estimation of the total area of hay-meadows within the sampling plot, as well as the proportion of grasslands already mown at 4 different dates: June 20, July 1 and 15, August 1.

Form B provides a description of the floristic composition and structure of the vegetation (height, density). Among these indicators, an index of floristic diversity gives the number of plant species in a 10 m × 2 m strip of hay meadow. Form C, which is based on a questionnaire submitted to the farmers, gives additional information on grassland management and, especially, on fertilizer applications.

Main results (2001–2004)

The number of study regions included in the monitoring programme is steadily increasing from year to year: 50 in 2001 (671 sampling plots), 75 in 2002 (782 sampling plots), 83 in 2003 (826 sampling plots), 94 in 2004 (921 sampling plots). When the protocol is not fully applied, certain sampling plots can be excluded from the analysis. A global report of the first 5-year period will be achieved in 2006.

Figure 1 shows the mean MPI values recorded in 2004, in sampling plots laid out in 92 study regions. These MPI values are listed by 3 different categories: I (MPI < 5), II (5 ≤ MPI < 10), and III (MPI ≥ 10). The highest MPI values are most frequently found in the flooded alluvial plains situated at low altitudes, except in the south of the Massif Central.

Figure 2 shows the MPI annual changes in the study regions between 2002 and 2003, and between 2003 and 2004: a decrease in passerine numbers (from category III to II or I, from category II to I), an increase (from category I to II or III, from category II to III), or stability within the same category. In the extremely dry spring of 2003, the cases indicating a decrease in numbers (2003 *vs.* 2002) were obviously more numerous than those denoting an increase. In the following year (2004 *vs*. 2003) the passerine numbers in most of the study regions were stable, since the cases of increase and decrease cancelled each other out and the data collected allowed us to monitor the local and overall grassland-bird population trends. Moreover, the variables that allowed us to describe habitat and farming management, could also be used to understand what conditions are required to preserve the bird's population balance, and explain the observed population trends.

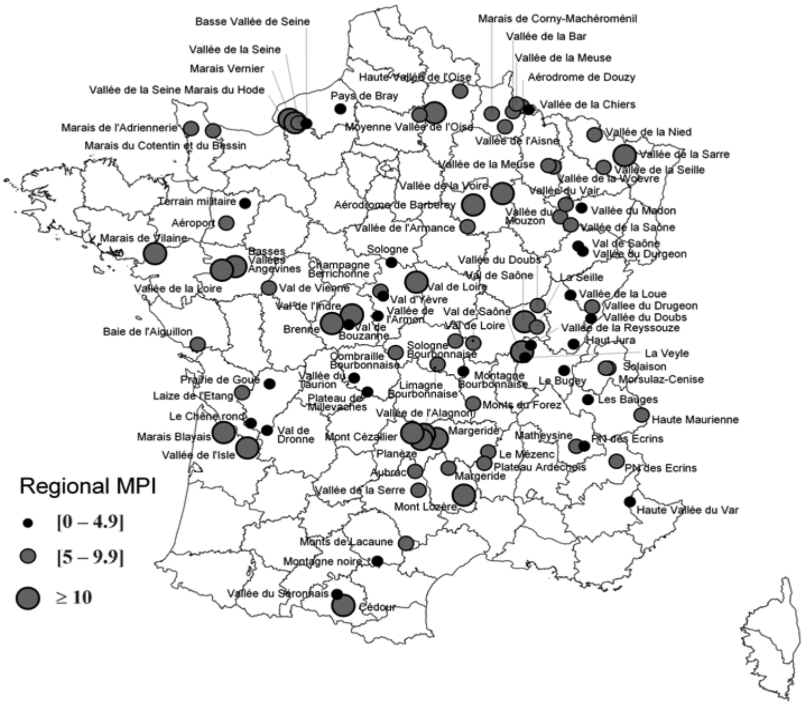

Figure 1. Means of Meadow Passerine Indices (regional MPI) in the study regions, in 2004 (n = 837 sampling plots where hay meadows are covering at least 40% of the total area)

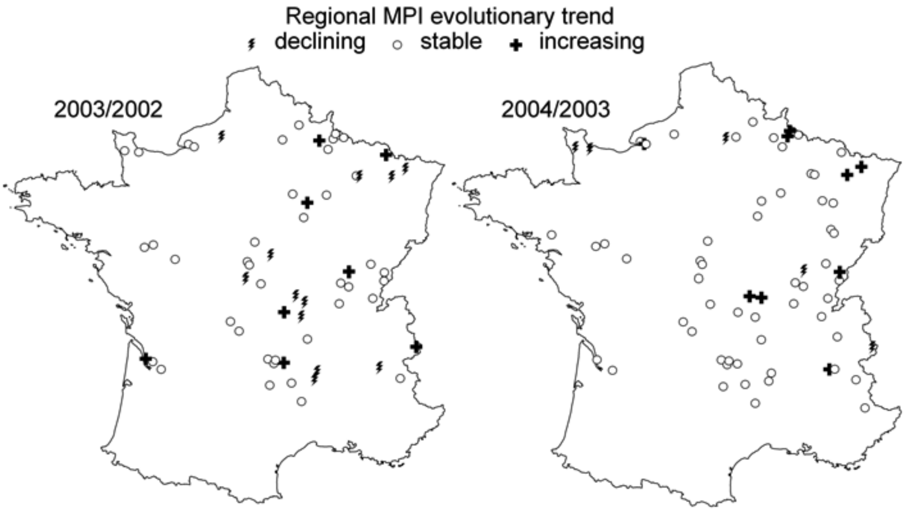

Figure 2. Trends in regional MPIs, between 2002 and 2003, and between 2003 and 2004 (passage to a higher or lower category, or stability)

Then, with the help of the set of variables measured by the National Observatory, the objective is to define a model relevant to cases of greatest passerine richness observed in France (MPI ≥ 10). In this paper, only a preliminary analysis is given to identify the most significant factors by means of a step-wise logistic regression with a descending option. For that purpose, we used the data of 529 A and B forms completed in 2001, 2002 and 2003. Then we made a first selection among all available explanatory variables and found proof that, when taken one by one, the abundance of *Apiaceae*, *Asteraceae*, and *Ranunculus*, the percentage of grasslands already cut on July 1, the height of dense grass covers, their altitude and floristic diversity as well as the mean MPI in the study regions, were correlated with the highest values of MPI (≥ 10). The final multivariate modelling (LR statistic = 337.68 with p value < 0,001) involved a combination of the following variables: mean MPI in study regions ($p < 0.001$), height of dense grass cover ($p = 0.013$), percentage of grass already cut on July 1 ($p = 0.067$), percentage of grass already cut on July 1 x altitude ($p = 0.033$).
The local abundance of meadow birds therefore depends on the vegetation structure (height and density) and late haymaking. However, bird density in 12-ha sampling plots can be mainly explained by their mean densities in the regions in which these are laid out.

Conclusion

Four years after its creation, the National Hay-meadow Ecosystem Observatory now has the capacity to provide annual standard information based on data from all over the country. This information will enable us to monitor the meadow-bird population trends, the changes in available habitat surface areas and timing of haymaking. Every 5 years, supplementary data will be collected to get a better understanding of the observed changes. Regarding the population balance, in a preliminary analysis, the importance of two variables has been identified: grass height and density, and the percentage of grasslands that are cut after July 1. However, whatever the management regime, it is highly probable that the meadows situated in regions with important grassland-bird populations will receive high densities of birds, which is a possible illustration of the source-sink process in bird habitats (Pulliam, 1988).

Observatory membership

The following institutes are members of the National Hay-meadow Ecosystem Observatory: Office national de la chasse et de la faune sauvage (national coordination), Parc national de la Vanoise, Parc national des Ecrins, Parc naturel régional des Boucles de la Seine Normande, Parc naturel régional des Bauges, Parc naturel régional du Queyras, Réserve naturelle de l'Estuaire de la Seine, Réserve naturelle de la Baie de l'Aiguillon, Groupe ornithologique normand, Centre ornithologique Rhône-Alpes, Chambre d'agriculture de la Savoie.

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Phytosociological and economic peculiarities of some flood-meadows

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Abstract

Flood-meadows, which represent 12% (approximately 100,000 ha in total) of natural and semi-natural grasslands, have an important economic value for Lithuanian agriculture as one of requirements for successful sustainable development. The flood-meadows are important territories of great and specific biological diversity. This paper deals with the syntaxonomic status of communities, the species diversity of some flood-meadows of Lower Nemunas in summers of 2002–2004 and estimating the productivity of these grasslands as well as demonstrating the optimal way for their management.

Keywords: plant communities, flood meadows, economic value

Introduction

Meadows are important producers of organic matter, and, have an important role in preventing erosion and act as migration buffers against the spread of adventitious species. Grasslands occupy near 42% (892,500 ha in total) of agricultural area in Lithuania and have an economic importance for the successful development of sustainable husbandry.

Flood meadows are an unique complex of landscape and various organisms, also of great importance in the protection of rare plant species. The areas of these meadows are rapidly decreasing due to the cessation of cutting and grazing (Katutis, 2003). These grasslands rapidly become overgrown with shrubs and the composition of plant species and communities gradually change. These unique natural and largest flood meadows lay on the Lower Nemunas and occupy 6,000 ha (Klimas, Gipiškis, 2002).

The aim of the research was to determine the productivity and biodiversity of different Lower Nemunas flood meadows, to clarify the syntaxonomic status of these communities and determine the best management.

Materials and Methods

The flood meadows of lower Nemunas were studied in summers of 2002–2004. The investigated flood meadows extend into different topographics types and ecological conditions of lower Nemunas. The soil characteristics have been described according to the A-L method as described by international classification (World Reference Base, 1998). The soil characteristics of the studied habitats are presented in Table 1.The flora was inventoried and economic productivity of selected meadows determined according to the classical method of representative fields (1m^2) (Braun-Blanquet, 1964). The investigations were carried out on grasses in the flowering stage each year (in the 3rd week of June). The swards of 6 representative fields were sampled, the species determined and grouped into 4 types (grasses, legumes, forbs and sedges), weighed and their contribution to the community determined: average values for each botanic-economic group was calculated. The hay yield was determined after air-drying.

Plant species were identified by Lithuanian and European flora keys. Plant communities were analysed and identified by the communities code (Balevičienė *et al.,* 2000). The feed values were estimated from plant chemical composition.

Table 1. Soil characteristics of investigated ecotopes, 2002–2004

Locality	Soil type and texture	pH_{KCl}	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Plant community
Merguva	*Hapli-Calcaric Fluvisoil;* light / medium loam on loamy sand	8.47	155	141	*Arrhenatheretum elatioris* Br.-Bl. Ex Scherrer 1925
Krakoniškės	*Hapli -Calcaric Fluvisoil*; light loam on loamy sand	7.4	154	141	*Arrhenatheretum elatioris v. Calamagrostis epigeios*
Plaušvariai, Plaškiai	*Hypogleyi-Calcaric Fluvisoil*; loamy sand / loam on sand	7.0	144	139	*Phalaridetum arundinacea* (Koch 26) Libbert 1931, *Alopecuretum pratensis* Regel 1925, *Alopecuretum pratensis* v. *Bromus inermis*
Šilininkai	*Hypergleyi-Calcaric Fluvisoil*; loam / loamy sand or turf	6.5–7.0	159	141	*Deschampsietum caespitosae* Horvatić 1930

Results and Discussion

Different fluvisoils with different physical structure and chemical composition are present in flood meadows of lower Nemunas. Their fertility and saturation by water determine the various growing conditions and the wide plant diversity. Alluvic soils are fertile and the productivity of the meadows investigated was high. The greatest phytodiversity was formed in the Merguva meadows which lay further from lower Nemunas. Greater species diversity is determined by deeper ground water levels as well as by fertile soils. The inundation water retain small alluvic fraction in the central part of Nemunas flood plain were Krakoniškės meadows are located. Further from Nemunas River the ground water is deeper at 0.6–1.0 m and the humic horizon is deep. In these fertile soils the *Arrhenatheretum elatioris* Br.-Bl. Ex Scherrer 1925 community belonging to *Arrhenatheretalia elatioris* Pawłowski 1928 alliance predominates. This association belongs to *Molinio-Arrhenatheretea elatioris* R.Tx. class. The characteristic species of this association is *Arrhenatherum elatioris* which has a distribution which is wider than that of the association. This species can often comprise a nearly pure sward, but often grows in sparse clumps between which there are suitable conditions for other species (*Dactylis glomerata*, *Galium mollugo*, *Helictotrichon pubescens*, *Rumex thyrsiflorus*) in abundance. *Tragopogon pratensis* was determined as the constant species. Mesophytes such as *Festuca pratensis*, *Heracleum sibiricum*, *Lathyrus pratense*, *Vicia cracca* spread constantly and are often abundant in *Arrhenatheretum elatioris*. *Achillea milifolium*, *Briza media*, *Equisetum arvense*, *Taraxacum oficinale*, *Veronica chamaedrys* and other dry habitat species are frequent as accompanying species. The diversity of species of these grasslands was demonstrated further by the identification of 28–30 species of

Magnoliophyta. The projection cover exceeded 80% with predominating species from the *Poaceae* family in *Arrhenatheretum elatioris* communities. These communities are one of the most productive and highest feed value (6.9 score) meadows, which grow up on the higher localities of central part of backwater (Table 2). *Arrhenatherum elatioris* sward is suitable for forage production because of good chemical composition of the crop and good haymaking conditions. By using additional fertilisers and more intensive growth of good feed grasses, the disappearance of less useful plants such as *Calamagrostis epigeios* can be expected as well as the increased sward productivity.

Table 2. Productivity and botanical composition of meadows

Locality	Community	Botanical composition				Hay yield t ha^{-1}	Feed value score
Merguva	*Arrhenatheretum elatioris*	Grasses	Legumes	Forbs	Sedges		
Krakoniškės	*Arrhenatheretum elatioris* v. *Calamagrostis epigeios*	90	4.6	5.0	1.4	3.43	6.9
Plaušvariai, Plaškiai	*Phalaridetum arundinacea* (Koch 26)	89	4.0	5.4	1.6	2.41	5.1
	Libbert 1931 *Alopecuretum pratensis* Regel	91	3.8	2.6	3.1	3.17	6.4
	1925 *Alopecuretum pratensis* v. *Bromus inermis*	90	4.0	4.8	2.2	4.21	8.7
Šilininkai	*Deschampsietum caespitosae*	73	2.1	2.9	2.2	2.15	2.8
$LSD_{0.05}$		1.04	0.16	0.19	0.20	0.11	0.09

Arrhenatheretum elatioris v. *Calamagrostis epigeios*, the characteristic community of forest and steppe zones are established in the central part of the flood plain where sandy deposits and average soil moisture conditions. The characteristic species of *Arrhenatheretum elatioris* v. *Calamagrostis epigeios* are xeromesophytes. This is not a constant community, in which other species can invade afterwards: not tolerating the turf *Calamagrostis epigeios* is outcompeted and remains only as a mixture in newly established communities. The cover in the *Arrhenatheretum elatioris* v. *Calamagrostis epigeios* community reaches 90 %, in which the largest area is occupied by grasses and legumes. The tallest species of community (*Calamagrostis epigejos, Dactylis glomerata, Helictotrichon pubescens, Alopecurus pratensis*) reach 1.1–1.3 m. Also present in these meadows *Lathyrus pratensis*, *Medicago falcata*, *Vicia cracca, Galium spp*. and other mesophytes. *Arrhenatheretum elatioris* v. *Calamagrostis epigeios* communities are not productive (5.1 score) and the abundance of *Calamagrostis epigeios* reduce their feed value. In accordance with *Arrhenatheretum elatioris* v. *Calamagrostis epigeios* community's lability and the need to improve feed value and productivity, increasing the fertility of these meadows and cultivation of more valuable species such as *Dactylis glomerata* or *Alopecurus pratensis* would be useful.

The characteristic species of Ass. *Phalaridetum arundinacea* are *Phalaroidis arundinacea* and *Lysimachia nummularia*. This community are frequent in the lowest part of floodplain, rather than in central area and where the ground water is 50–60 cm deep. The sward reaches up to 110–130 cm, is dense and the ground cover is 80–90%. *Caltha palustris*, *Carex gracilis*, *Poa palustris*, *Ranunculus repens*, *Agrostis stolonifera*, *Cardamine pratensis*, *Lychnis flos-cuculi*, *Potentilla anserina*, *Galium palustre* grow as constant species in *Phalaroidis arundinacea* communities. The chemical composition of such sward is not good (5.1 score) due to poorly digestible cellulose of *Phalaroidis arundinacea* and sedges. Areas of *Phalaroidis arundinacea* are not good for haymaking because they are often flooded. However, the data of the complex examinations in Lithuania indicate, that *Phalaroidis arundinacea*, *Bromus inermis* and their mixtures can be used as possible alternative fuel – bio-fuel (Kryzeviciene et al., 2004).

Alopecuretum pratensis v. *Bromus inermis* community grows in the similar habitats as *Phalaroidis arundinacea*. Both communities occupy large areas and develop in flooded areas with fluctuating soil water conditions. Higromesophytes and mesohigrophytes are abundant in these communities forming grass swards. Such plant communities are widespread in West and Middle Europe, and along river valleys reach to the north and east as far as Krasnoyarsk land. *Alopecurus pratensis* is the characteristic species of *Alopecuretum pratensis* v. *Bromus inermis* community. Prevalence of this species is determined more by edaphic conditions than the climate and therefore the amplitude of its habitat is rather narrow. In these communities the diagnostic species were: *Bromopsis inermis*, *Calamagrostis epigejos*, *and Carex praecox*. As well as diagnostic species of communities *Persicaria amphibia*, *Symphytum officinale*, *Veronica longifolia* were found. *Festuca pratensis and Poa triviali*s which are good feed species as well as *Ranunculus acris*, *Vicia cracca*, *Rumex acetosa* grow abundantly. Rhizome forming herbs spread in these communities. *Alopecuretum pratensis* v. *Bromus inermis* communities produce early growth and are productive; their hay quality (8.7 score) is protein and mineral rich and digestible. However, farming conditions in these habitats because of waterlogging are not good.

Deschampsietum caespitosae is present in the lower localities of Nemunas delta. *Deschampsia cespitosa* and *Carex disticha* predominate and form high tussocks among which other hygrophilous species occur. The projected cover demonstrated the lowest cover (70%) of the meadows studied. These communities grow in areas which are periodically flooded and are on light, acidic, boggy soils, with a thin humic layer, low lime content, a high ground water level and poor aeration. Therefore the characteristic species (*Festuca pratensis*, *Phleum pratensis*, *Poa trivialis*, *Ranunculus acris*, *Rumex acetosa*, *Trifolium pratense*) do not grow abundantly there. Accompanying species *Agrostis stolonifera*, *Carex nigra*, *Carex panicea*,*Ranunculus repens*, *Trifolium repens* also occur. *Filipendula ulmaria*, *Geum rivale*, *Lychnis flos-cuculi* spread frequently among the herb species. *Deschampsietum caespitosae* communities are not productive, with a poor feed value (2.8 score). They provide a good habitat for wild animals and birds, but not for farming because big investments for their improvement would be required to make them productive i.e. by fertilising, sowing of good grasses and regulation of water-level.

Conclusions

The investigated vegetation of flood meadows belongs to two Molinio-Arrenatheretea elatioris R. Tx. 1937 class orders: *Molinetalia caerulea* W. Koch 1926 and *Arrenenatheretalia elatioris* Pawlowski 1928. Ass. Alopecuretum pratensis v. Bromus inermis communities were the most productive (4.21 t ha^{-1} of hay) and with good feed value and grew on fertile alluvial soils. The utilisation of these meadows is often difficult because of wet soils. The conditions for haymaking are better in drier meadows, where the production of 3.41 t ha^{-1} of hay and with good feed value of *Arrhenatheretum elatioris* communities is obtained. The *Phalaridetum arundinacea* communities are productive, but their hay is of poor quality and utilization is often restricted because of flooding. The productivity of *Deschampsietum caespitosae* communities was the lowest with 2.15 t ha^{-1} of hay. Because of poor hay quality and their undulating nature these meadows are best used for grazing.

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Spread and control of *Calamagrostis villosa* above the upper tree limit in the Giant Mts., Czech Republic

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Abstract

The response of expanding *Calamagrostis villosa* sward to cutting and nitrogen availability was studied in a manipulative experiment in the Giant Mts (Krkonose, Karkonosze). The aim of the study was to answer the following questions: Is it possible to restrict the spread of *C. villosa* by regular cutting? Is the spread of *C. villosa* determined by high nitrogen availability or cessation of regular defoliation management of subalpine grasslands? Cutting once per year caused significant changes in sward structure and explained the more than 20 % variability of the vegetation data (RDA analysis). On the other hand the nitrogen fertilization (30 kg N ha^{-1}) explained the 1.3 % variability only and its effect was not significant. Coverage, sward height and biomass production of *C. villosa* significantly decreased in cut treatments, however the biomass production of other dominant grasses (*Anthoxanthum alpinum*, *Avenella flexuosa*, and *Nardus stricta)* was not affected by cutting. We can conclude that (1) It is possible to restrict the expansion of *C. villosa* by regular cutting, (2) spread of *C. villosa* is determined not only by the high amount of nitrogen deposition in recent decades but even more by cessation of regular management.

Keywords: expansion, defoliation sensitivity, cut, nitrogen fertilization, deposition

Introduction

In the last few decades, the spread of *Calamagrostis villosa* and *Molinia caerulea* into *Nardus stricta* dominated subalpine grassland (*Nardo-Caricion rigidae* alliance) was recorded in the Giant Mts. (Lokvenc, 1996; Fabiszewski, Wojtuń, 2001, Hejcman *et al*., 2003). The *Nardo-Caricion rigidae* alliance represents a significant relict type of grassy tundra vegetation, with the centre of natural distribution in Scandinavia, Scotland and Island (Krahulec, 1985). High nitrogen deposition is the generally accepted cause for the increase of grasses with higher nutrient demand without regard to agricultural activities being performed before the World War II. According to Lokvenc (1996), these long-term defoliation activities resulted in elimination of tall plants and favoured *Nardus stricta*. Hejcman *et al*. (2003) with respect to high defoliation sensitivity of *Calamagrostis villosa* considered expansion of this species as partly natural long-term succession after cessation of management. In our experiment, we want to answer the following question: Is it possible to restrict the spread of *C. villosa* by regular cutting? Is the spread of *C. villosa* determined by higher nitrogen availability or cessation of regular defoliation management of subalpine grasslands?

Materials and Methods

The study site lies above the upper tree line at the altitude of 1370 m in the western part of the Giant Mountains (Harrachov meadow, 50°45'32" N, 15°32'28" W, Czech Republic). The soil types are podzols developed on medium grain porphyric granite or granodiorite. The mean annual temperature is 2 °C and the mean annual precipitation is 1380 mm. Vegetation belongs to the *Nardo-Caricion rigidae* alliance. The dominant species were *Calamagrostis villosa* (37.2%), *Deschampsia flexuosa* (21.1%), and *Nardus stricta* (16.1%), followed by *Galium saxatile* (6.5%), *Anthoxanthum alpinum* (4.8%), *Carex bigelowi* (4.6%), and other species. The site was used for haymaking and cattle grazing since the 17th century until World War II. In spring 2000, we established a randomized complete block experiment with four replications in 5m × 5 m plots. To eliminate the edge effect, the central 1m × 1m plots using a continuous grid of nine square subplots were used for data collection. There were two factors with two levels. These resulted in four treatments: unmanaged control (Co), fertilized (F), cut (C), and cut fertilized (CF) plots. As a fertilizer we used NH_4NO_3 in the dose of 30 kg N ha^{-1} per year. Table 1 shows a detailed description of applied treatments.

Table 1. Description of investigated treatments

Abbreviation	Treatment	Cut	Fertilization
Co	Control	not cut	not fertilized
C	Cutting	cut once a year at the end of July	not fertilized
F	Fertilization	not cut	fertilized once a year at the end of July
CF	Cutting and fertilization	cut once a year at the end of July	fertilized once a year at the end of July

The percentage cover of all vascular species, the number of *C. villosa* tillers, and the height of sward before cutting were estimated separately in all subplots of each 1 m^2 plot. Baseline data were collected in 2000 for each plot before the first experimental manipulation. Sward height before cutting was taken as the mean of ten randomly chosen tillers of *C. villosa.* The biomass samples were collected after the vegetation sampling and samples were sorted into species, oven dried for 48 hours at 85°C and then weighed.
A redundancy analysis (RDA) in the CANOCO program (ter Braak & Šmilauer, 2002) was used to evaluate the plant species' composition data. ANCOVA was used to analyze the aboveground biomass data, and the repeated ANOVA measurement to analyze *C. villosa* sward height, coverage, and number of tillers.

Results

Coverage data. We revealed significant changes in sward structure caused by year to year variability. The year to year effect explained 3.4% variability in sward structure whereas the effect of fertilization explained a negligible percentage of cover data variability (only 1.3%). However the highest share of sward structure variability was explained by cutting (20.2%) and in contrast to fertilization, coverage of sward components was significantly affected by cutting. *Calamagrostis villosa* responded highly negatively to cutting and only moderately positively to fertilization (Fig. 1). Coverage of *C. villosa* decreased from 45% and 42% in C and CF treatments in 2000 to 14% and 12% in 2004, respectively. From Figure 1 it is obvious that coverage in both these treatments was parallel without changes in differences over the course of time, thus the effect of nitrogen addition was small. Comparison of both uncut

treatments indicates the same result because no increase in cover differences was detected.
Number of tillers. We recorded a high year to year variability in number of *C. villosa* tillers. An increase of tillers was detected in all treatments in 2001, whereas there was a decrease in following seasons, with the exception of only the control in 2002. Effect of treatment and interaction treatment and year was significant. The number of tillers was 688, 1336, 757, and 623 in C, F, Co, and CF treatments in 2004, respectively.

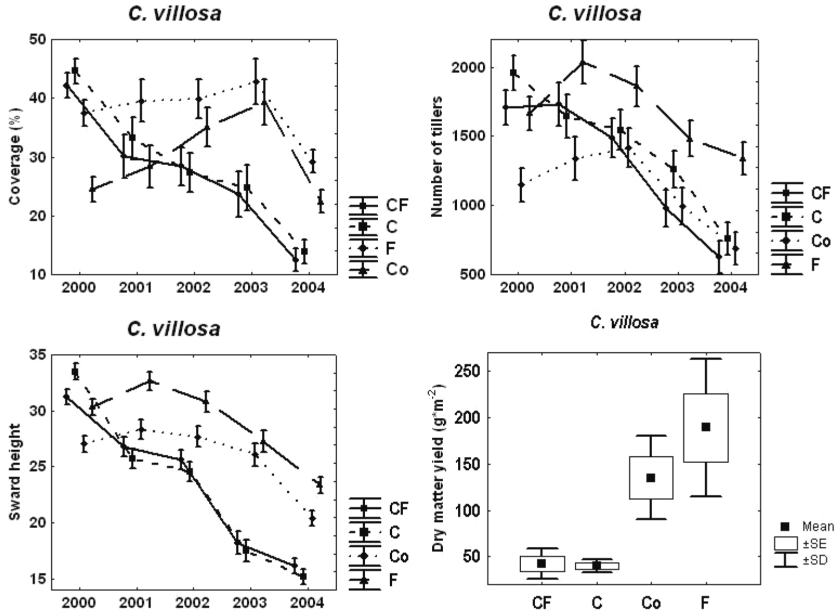

Figure 1. Coverage, number of tillers, sward height, and aboveground biomass production (in 2004) of *C. villosa* as a function of investigated treatments. Treatment abbreviations are in compliance with Table 1

Sward height. The height of *C. villosa* is represented at the same time as the height of the entire sward before cutting because this grass species was the highest plant in all treatments. Sward height was different for each year of study and had decreasing tendency in all treatments with exception of year 2001 only (Fig. 1). We recorded an increase in Co and F treatments. We recorded the lowest sward height in both cut treatments at the end of the experiment in 2004. Sward height was significantly affected by year, treatment and by interaction of treatment and year.
Aboveground biomass production. The total biomass production, as did the biomass production of *C. villosa,* differed substantially between treatments predominately due to cutting in 2004 (Figure 1). Significant differences were detected between cut and uncut treatments without substantial effect of nitrogen addition. Five years of cutting decreased biomass production of *C. villosa* approximately to 1/3. Effect of cut and fertilization on biomass production of other sward components, *Anthoxanthum alpinum*, *Avenella flexuosa*, *Galium saxatile*, and *Nardus stricta,* was nonsignificant. *Anthoxanthum alpinum* moderately increased biomass production and number of inflorescences in fertilized plots. All of the above mentioned plants are short grasses or prostrate herbs.

Discussion

Restoration of cutting management affected sward structure much more than did the increase of nitrogen availability. We recorded decrease in coverage, biomass production, number of tillers, and in sward height in 2004 even in control plots. This was probably caused by extremely cold weather conditions during this growing season. Although high nitrogen deposition is often showed as the main reason for spread of tall species in the landscape, termination of regular defoliation can be obviously more decisive factor because of the reduction of species that are sensitive to defoliation. In our experiment, reduction of the tallest plant *C. villosa* and no effect of cutting on other short species are in accordance with the concept of defoliation sensitivity (Briske, 1996). According to this concept, tall species are more sensitive to defoliation due to the removal of a higher proportion of photosyntetically active organs. Cutting is therefore a highly selective treatment limiting often tall species and on the contrary, unlimiting or supporting short or prostrate plants. The non-limiting effect of cutting on short or prostrate species was demonstrated by *Anthoxanthum alpinum*, *Avenella flexuosa*, *Galium saxatile*, and *Nardus stricta* in our experiment.

The effect of nitrogen fertilizazion was minor in contrast to the effect of cutting. Biomass production of *C. villosa* did not differ under C and CF treatments thus the regeneration of this species after defoliation was not promoted by adding nitrogen. Indirect proof for sensitivity of *C. villosa* to defoliation is its absence in regularly cut and fertilized meadows and its expansion after termination of management there (Krahulec *et al.,* 1996). We concluded that *C. villosa* is probably highly sensitive to cutting but this sensitivity is not reduced by addition of nitrogen. With respect to this fact, we consider the recent expansion of *C. villosa* into subalpine *Nardus stricta* grassland to be related to cessation of defoliation activities, as well as the high nitrogen deposition in late decades.

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Assessment of biodiversity functions with agro-ecological indicators in agricultural areas

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Abstract

Agricultural areas include a unique biological diversity which is the basis of human activities. Conservation of this biodiversity is therefore fundamental and requires an operational approach. Biodiversity can be related to three main functions: i) patrimonial functions that concern the conservation of landscape aesthetic and threatened species, ii) agronomic functions that are related to the resistance to biotic and abiotic stress, and production in cultivated ecosystems, and iii) ecological functions that are implied in ecosystem functioning with specific habitats and species. Agro-ecological indicators have been built to help decision-making and evaluate the impact of farm practices on biodiversity functions in grasslands, crops and unproductive areas, from the field to the landscape scale. These indicators are designed with data on farm practices which are easily accessible for the non specialist. Indicator validation is carried out with relevant site data which are related to biodiversity (biotic indicators, species richness)

Keywords: biodiversity, assessment, agricultural area, agro-ecological indicators, sustainable agriculture

Introduction

Biodiversity protection can be motivated by ethical reasons (Brundtland, 1987; CBD, 1992; Cairns, 1997) or pragmatic reasons, like the maintenance of a potential reserve of interesting genes for plant breeding and services for agriculture ((Paoletti *et al.*, 1992; Peeters and Janssens, 1995; Altieri, 1999; Duelli and Obrist, 2003).

For better biodiversity, conservation at a large scale of territories, knowledge and creation of conservation tools are necessary not only in protected and semi-natural areas but also in agricultural areas. However, biodiversity is very complex with the interaction of different scales (species, community, ecosystem, landscape) in relationship with a socio-political component (Gaston, 1996).

In order to promote sustainable agriculture, conservation of biodiversity needs operational definitions of biodiversity and relevant tools: i) the vision of the biodiversity as a function modified by farming practices, ii) using agro-environmental indicators which give synthetic information for decision-making.

Biodiversity as a multi-function modified by farming practices

Authors have given different ways to define biodiversity as a sum of several functions. Biodiversity may be seen as an entity which has only ecological functions (Noss, 1990), agronomic functions (Paoletti *et al.*, 1992; Paoletti, 1995; Gurr *et al.*, 2003; Peeters *et al.*, 2004) or a set of identified functions (Duelli and Obrist, 2003). The latter have reviewed the different aspects of biodiversity with complementary approaches into three functions which motivate preservation and studies on biodiversity: conservation, biological control and resilience. We propose an extension of this definition in three main functions: patrimonial, agronomical and ecological functions (Figure 1). All elements of biodiversity which represent a heritage constitute the patrimonial function. It is the case of landscape aesthetic, patrimonial habitats and species like wetlands and threatened species. Biodiversity is also the basis of agriculture and gives several services. Resistance of biotic (pests and diseases) and abiotic (microclimate, soil structure) stress, and economic value are agronomic functions. Ecological functions of biodiversity are its implication in the food web and thus in nutrient cycling, and in water quality.

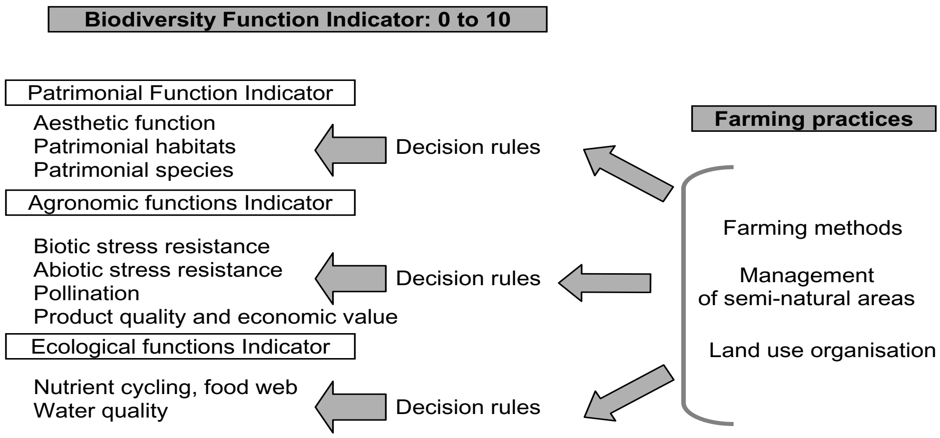

Figure 1. The different indicators of the biodiversity functions modified by farm practices

Each biodiversity function is represented by a particular indicator based on decision rules. These decision rules are built from farming practices which have a strong influence on the studied function. Farming practices are divided in three groups: farming methods (eg tilling, rotation, management of semi-natural areas (eg hedges, herbaceous strips, wetlands,…) and organisation of land use (eg grasslands, crops, forests).

Building Agro-ecological indicators: example of the aesthetic function

Agro-ecological indicators are based on a interaction matrix (Leopold *et al.,* 1971) in order to evaluate the effects of farming practices on different components of the agroecosystem (Girardin *et al*., 2000; Pervanchon *et al*., 2002). These indicators use easily accessible data that can be collected by non-specialists. However, the building of indicators is dependent on scientific knowledge (Girardin *et al*., 1999).

At the landscape level, biodiversity has an aesthetic function which creates an identity feeling for residents, and a recreation object for tourists.

The indicator of aesthetic function is based on three main landscape parameters: diversity, naturalness and openness (Figure 2). The choice and the weight of each landscape parameter are the decision rules of the indicator 'aesthetic function'. Landscape elements are divided in different types: spatial forms (crops, grasslands), linear forms (hedge, road) and punctual forms (isolated tree, stone). The diversity parameter is the quantity of these landscape elements. Diversity is the first parameter related to habitant feeling (Weinstoerffer and Girardin, 2000; Schüpbach, 2003; Arriaza *et al.*, 2004; Palmer, 2004). Presence of preserved areas and wild areas are strongly linked to aesthetic quality of the landscape. Thus, each landscape element has a natural value which contributes to naturalness (Kuiper, 2000; Schüpbach, 2003; Arriaza *et al.*, 2004). Openness is a limiting parameter which defines the range view of the observer

(Weinstoerffer and Girardin, 2000). Each landscape element has an openness value related to it height.

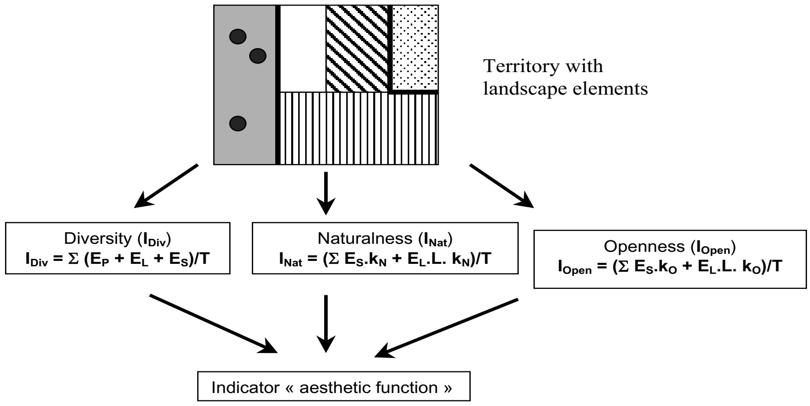

Figure 2. Calculation of the indicator 'aesthetic function' with $\mathbf{E_P}$: punctual element, $\mathbf{E_L}$: linear element and $\mathbf{E_S}$ spatial element of the landscape, $\mathbf{k_N}$: naturalness value of the landscape element **E**, $\mathbf{k_O}$: openness value of **E**, **L**: length of $\mathbf{E_L}$, and **T**: transect

For easy access to data for the indicator calculation, landscape elements are sampled on two orthogonal transects applied to the region (Keichinger, 2001). The first transect is in the North-South direction and the second is in the West-East direction. The sum of the different types of landscape elements gives the diversity parameter. Then, the weighted sum of landscape elements by their respective naturalness and openness value gives the mark of two other parameters. Results of each parameter are converted in a mark between 0 and 10. According to Girardin *et al*. (1999), when the mark is between 7 and 10, management is sustainable. The three parameters are aggregated and give the final mark. For the indicator "aesthetic function", the minimal mark is chosen as final mark. Indicators will be calculated and validated on the region of Vittel, North-Eastern part of France (50 km²) characterized by its high rate of organic farming practice.

Conclusions

Amongst many tools which assess biodiversity, agro-ecological indicators give synthetic information which may help decision-makers for the management of a region. Their building and validation procedure can be applied for all biodiversity functions in order to give a global value of biodiversity functions at the landscape level.

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Central Lithuania's natural grasslands and their state

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Abstract

In Central Lithuania natural grasslands account for as little as 1% of the total grassland area. The larger part of natural grasslands has survived in the valleys of rivers and streams. Continental grasslands account for as little as 3% of the total natural grassland area. All these grasslands are of paramount importance for the conservation of biodiversity and landscape. From the 19 plant communities identified while inventorying natural grasslands all over Lithuania, there were 14 distinguished in the central part of Lithuania. The three plant communities that were found to be dominating were: (1) All. Caltion palustris R. Tx. 1937 em Lebrun et al., 1949; (2) All. Arrhenatherion elatioaris (Br.-Bl. 1925) W. Koch 1926; (3) All Magnocaricion elatae. These occupy 60% of the total natural grassland area. Some plant communities (All. Caricion nigrae; All. Caricion davallianae; All. Plantagini – Festucion ovinae; Vilion caninae Schwicherath 1944) occupy only 2% of the total natural grasslands.
In all the investigated grasslands of Central Lithuania, 21 plant species were found which were included in the Lithuanian Red Book, and 7 habitats of protected, rare or endangered wildlife of European importance.
Three major groups of natural grasslands have been identified according to their practical use:
(1) Grasslands that were currently not used, still with abundant biodiversity but already degrading; (2) Extensively used grasslands with a vast biological diversity; and (3) Intensively used grasslands with an impoverished biological diversity but still maintaining the characteristics of natural grasslands.

Keywords: natural grasslands and their communities, biodiversity

Introduction

Central Lithuania is a region of intensive agriculture, where the largest part of agricultural land is ameliorated and cultivated. Very few natural grasslands and pastures have survived and concern has recently been shown for the conservation of natural grasslands. Some municipalities have launched research into biological diversity in order to conserve the natural values present in their territories. An inventory of natural grasslands in Central Lithuania was started only in 1994, and in that year the main focus was placed on natural grasslands in river and stream valleys. The second stage of the inventory was started in 2003 and encompassed all natural grasslands and other biotypes overgrown with herbaceous vegetation that are still being used or were used for agricultural purposes. This stage of the inventory was financially supported by the Dutch Government.
Statistical data suggest that until then natural grasslands had not been distinguished from cultivated grasslands and pastures. Only fragmentary phytocenological tests were conducted. Earlier efforts of botanists were centred in the valleys of major rivers of Lithuania (Natkevičaitė – Ivanauskienė, 1955, 1957).

Material and Methods

The inventory of 2003–2004 was carried out following the methodology elaborated by the Institute of Botany, which lists 19 plant community alliances to be inventoried and mapped. Each grassland vegetation area larger than 0.5ha (50m x 100m) was mapped, while areas smaller than 0.5 ha were mapped provided that they were isolated, relevant from the national and regional viewpoint, and stable. Grassland inventory was conducted simultaneously with other research into grassland biological diversity: grassland types were identified to the associations level, and all species of higher plants were registered. On the basis of research findings, rare and protected species were discriminated, and habitats of European importance and their distribution were identified. In addition, all species of butterflies were recorded. The information on natural grasslands management was collected by questioning owners of the grasslands and by examining the current state of grasslands.

Results and discussion

During the research period 2003 and 2004, out of 19 plant community alliances distinguished while inventorying Lithuania's grasslands, 14 were identified in Central Lithuania (Rašomavičius, 1998). The three plant community alliances were found to be predominant: (1) All. *Caltion palustris* R. Tx. 1937 em Lebrun et al. 1949; (2) All. *Arrhenatherion elatioaris* (Br.-Bl. 1925) W. Koch 1926; and (3) All. *Magnocaricion elatae*. They account for 60% of the total area of natural grasslands. The following grasslands community associations were found to be extremely scarce: All. *Caricion nigrae*, All. *Caricion davallianae*, All. *Plantagini – Festucion ovinae* and All. *Violion caninae* Schwicherath 1944. They account for as little as 2% of all natural grasslands. The occurrence of other plant community associations is moderate: All. *Bromion erecti* Br.-Bl. 1938, All. *Geranion sangvinei* R.Tx. in Th. Müller 1961, All. *Trifolion medii* Th. Müller 1961, All. *Cynosorion cristati* R. Tx. 1947, All. *Alecorion pratinsis* Passarge 1964, All. *Molinion caeruleae* W.Koch 1926 and All. *Senecion fluviatilis*. The larger part of these grasslands communities are found in the valleys of rivers and streams, and continental grasslands account for approximately 3%.

In Central Lithuania 432 species of higher plants (except for moss) were found. Vestigial natural grasslands in Central Lithuania were found to contain 21 plant species included in the Lithuanian Red Book (Balevičius, 1992). Most of these species occur only in natural grasslands communities, while the others occur in other biotopes (forests, swamps, etc).

The inventory revealed dramatic differences in the abundance of the protected species. Some of the species are not yet very rare and currently they are not in danger of extinction: *Dactylorhiza incarnata, D. longifilia, Gentiana cruciata, Gladiolus imbricatus.* Other species are much scarcer, since they occur in several places only: *Orchis militaris, O. mascula, Lithospermum officinale, Mentha longifolia, Campanula bononiensis, Gymnadenia conopsea, Pinguicula vulgaris, Iris sibirica, Hypericum hirsutum, Conioselinum tataricum*. In Central Lithuania very rare species were identified only in one or two habitats, they include*: Gentianella amarella, Dactylorhiza cruenta, Orchis morio, Primula farinosa, Ophrys muscifera, Carex buxbaumii, Taraxacum suecicum*. Most of the protected species were found only in the extensively used grasslands.

The Directive (92/43/EES) on natural habitats and wildlife envisages protection of nearly 200 rare and rapidly becoming extinct habitats and their inclusion in the EU protected territories' network NATURA 2000. In Lithuania there are 52 habitats of European importance that have to be protected, and in Central Lithuania's grasslands we identified 7 such species: (1) 6430. Hydrophilous tall herb fringe communities of plains and of the montane levels; (2) 6510. Lowland hay meadows (*Alopecurus pratensis, Sanguisorba offininalis*) (3) 6450. Northern boreal alluvial meadows; (4) 6530. *Fennoscandian wooded meadows; (5) 6410. *Molinia* meadows on calcareous, peaty or clayey-silt-laden soil (*Molinion caeruleae)*; (6) 6230. *Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe); and (7) 6210. Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (**important orchid sites*) (Rašomavičius, 2001).

The most widespread are old natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (**important orchid sites).* Hydrophilous tall herb fringe communities of plains and of the montane levels, Northern boreal alluvial meadows, Lowland hay meadows (*Alopecurus pratensis, Sanguisorba offininalis*). To protect these habitats one should set up protected territories and regulate their management. The above-mentioned habitats of the European importance account for approximately 90% of the total area of protected habitats. Much smaller are the areas of *Molinia* meadows on calcareous, peaty or clayey-silt-laden soil (*Molinion caeruleae*). Very small, in one or two meadows, *species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas, in Continental Europe) Fennoscandian wooded meadows. Lithuania has not set up any of the reserves for the protection of these habitats in the territories that are still unprotected. Separate municipalities have set up reserves of only local significance where management activities are not regulated.

The quality and conservation of natural grasslands directly depend on their management, since intensive use of grasslands and rich biological diversity are not always compatible. This fact is confirmed by our research carried out in Central Lithuania.

Natural grasslands are rarely used intensively. Only the grassland and meadows present in the vicinity of farm homesteads are used intensively (applied with mineral fertilisers, cut twice a year, and the aftermath is grazed). A separate group of intensively used grasslands includes the grasslands that have been used exceptionally for grazing. On such grasslands livestock is grazed in paddocks from spring to late autumn. In practice, fertilizers are not applied to such pastures, and due to intensive grazing, very specific plant communities develop. Furthermore, they become infested with plant species that cattle do not eat. For example, the Nevėžis valley is heavily infested with *Cardus acanthoides* L.

Our research evidence indicates that most natural grasslands present in Central Lithuania are used extensively. They are cut by tractor or horse-drawn mowers, or scythes, only once a year. Grazing is not intensive or not used at all if the grassland is further away from the living place. There are also extensively used pastures, where cattle are only grazed, but the herbage is not cut. A slightly different vegetation forms here, compared with that of cut grasslands.

A special group comprises grasslands in places with difficult access. Such grasslands are either used sporadically or not used at all. Generally these are meadows overgrown with shrubs and scattered trees and are situated on river slopes or wet lands. Currently these grasslands are being encroached by woody vegetation. This process occurs at a different rate in different types of grasslands. Over the ten-year period dramatic changes have occurred in terms of grassland overgrown with trees and shrubs in Central Lithuania; however, it would be premature to draw valid conclusions since the research evidence is lacking.

Currently management of grasslands is largely dependent on the adopted laws. It is difficult to maintain large numbers of livestock on natural grasslands that cover small areas, while for the farmers with low numbers of livestock it is hardly possible to meet the EU requirements. Most Lithuanian smallholders keeping several cows are about to refuse or have already refused extensive farming and are turning part of the grasslands into other agricultural land or they simply abandon them. As a result, over the last ten years Central Lithuania has witnessed a further decline in the area of natural grasslands. This trend is likely to persist in the future, since with Lithuania's accession to the EU small farms have reduced prospects. The adopted early retirement scheme will further diminish the number of people keeping livestock. There are very few farmers involved in ecological crop production on the fertile soils of Central Lithuania.

Conclusions

Inventory of grasslands conducted in Central Lithuania suggests that natural grasslands account for less than 1% of the total grassland area. Continental grasslands in Central Lithuania account for as little as 3% of the total natural grasslands area. In Central Lithuania's grasslands 14 plant community alliances containing 21 species of protected plants were discriminated. Seven types of habitats of European importance were identified. A further trend in the reduction in the area of natural grasslands was found to persist, and the recently adopted laws generally contribute to the decline of natural grasslands in the central part. Lithuania and in the country as a whole.

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A policy to efficiently integrate biodiversity into grassland farming

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Abstract

In Switzerland, there has been a marked decline of extensively managed grasslands and of the associated high diversity of flora and fauna. Since 1993, the federal government has attempted to reverse this trend by offering financial incentives for low-input meadows and pastures. By their integration into grassland management, farmers can achieve a mosaic of low-, medium- and high-input plots. The best quality fodder from high-input meadows minimizes the use of concentrates in lactating cattle, and fibrous hay from low-input plots is used to feed heifers, dry cattle or horses. To improve the positive effects on biodiversity, extra bonus payments – based on criteria for biodiversity and connectivity of low-input grasslands – were introduced in 2001. Especially in hilly and mountainous regions, these new incentives have rapidly led to networks of species-rich grasslands, which should help to slow down the loss of biodiversity. Thus, natural diversity is becoming a farm product. Extensive and low-input species-rich grasslands make sense in terms of economics, ecology and herbivore physiology. This 'win-win-win' situation represents a major step forward towards a modern, multifunctional and sustainable agriculture.

Keywords: incentives, low-input grassland, grassland biodiversity, grassland management, multifunctional agriculture

Introduction

For topographical and climatic reasons, Switzerland is a country of grasslands. Extensive and low-input meadows and pastures contribute substantially to the country's biodiversity, with regard to both flora and fauna. As a result of the intensification of agriculture over the last 50 years, the area of species-rich grasslands and the associated diversity of flora and fauna have declined. Biodiversity, which has been reduced by increased fertilizer application and utilization frequency is further threatened by the isolation of the remaining species-rich habitats, as genetic diversity declines markedly in small, isolated populations (Baur *et al.,* 2004). In 1996, to counteract environmental impacts and biodiversity losses in the agricultural sector, the Swiss electorate approved a new constitutional article promoting multifunctional and sustainable agriculture. Thus, all farms that are entitled to receive direct subsidy payments must now comply with clearly defined minimum requirements of good agricultural practice. These include that at least 7% of the total area of each farm must be managed as Ecological Compensation Areas (ECAs). Apart from other semi-natural habitats such as hedgerows or extensive pastures, ECAs mainly consist of extensive or low-intensive meadows. The regulations essentially include a ban on the use of fertilizers (with the exception of a small amount of dung for low-intensive meadows) and a delayed first cut (15 June in lowlands, 1 or 15 July in mountainous areas) in order to favour the seeding of grasses and herbs, and to enable ground-nesting birds to rear their young. The financial incentives for ECAs depend on compliance with the regulations; i.e. they are action-oriented. They were set at a level designed to compensate for loss of profitability and for any additional efforts required. Accordingly, payments are higher for lowlands than for mountainous areas.

Inefficient promotion of biodiversity

The proportion of ECAs across Switzerland as a whole has increased during the last decade, primarily because 7% is *de facto* a legal requirement, rather than because of the financial incentives. In the intensively managed lowlands, however, the proportion has reached only 8%, thus missing the government's target of at least 10% by 2005 (Swiss Federal Office for Agriculture/BLW 2004). Shortly after ECAs were first introduced, environmental organizations pointed out that the positive effects on the diversity of flora and fauna were negligible. In previously intensively managed, species-poor meadows which had to be extensified, nutrient depletion often proved to be a lengthy process or even impossible. The late cut that was required meant that grass was often mown when it was over-ripe with negatives effects for the farmers (bad fodder) as well as for the biodiversity (eutrophication). In addition, the amount and diversity of seeds in the soil were often insufficient to permit the re-emergence of species-rich meadows. Ecological compensation was therefore perceived by many farmers as a pointless imposition. Because farmers optimized their ECAs according to management considerations, their locations were frequently suboptimal from an ecological viewpoint, e.g. on north-facing forest margins, and they were often isolated from each other. Finally, as soon as the permitted cutting date of 15 June was reached, grassland wildlife was deprived of structural features over a wide area within a short time, which had adverse effects on insects in particular.

New approach: outcome-oriented promotion of biodiversity and connectivity of ecological compensation areas

In 1995, the Federal Administration established the National Forum for Ecological Compensation, which had the task of developing solutions for the above-mentioned problems. This expert body included representatives of all parties with an interest in ecological compensation – agricultural and environmental administrations, the farming sector, agricultural consultants, researchers and nature conservation NGOs. A dynamic and creative process of development gave rise to the Ecological Quality Ordinance (EQO), which was enacted in 2001 (Official Compilation of Federal Law). In contrast to the previous principle of action-oriented financial incentives, it introduced the new principle of performance-based financial incentives both for botanical quality and for optimal ECA connectivity (Table 1).

Table 1. Direct payments for Ecological Compensation Areas (ECAs) by the example of an extensive meadow in the lowlands (in Swiss Francs per ha)

Basic payment[1]	1200
ECA-payment[2]	1500
Surplus payment for quality according to EQO[3]	500
Surplus payment for connectivity according to EQO[3]	500

[1] to receive any direct payments the farmer must comply with defined minimum requirements of Good Agricultural Practice; [2] basic conditions: no fertilizers, first cut not before June 15th; [3] the surplus payments for quality and interconnection can be cumulated

According to the quality criterion specified, a meadow has to contain at least 6 species from a list of some 30 readily identifiable species that indicate a high level of biodiversity (e.g. *Salvia pratensis*, *Knautia* spp., *Lathyrus pratensis)* (Pearson, 2005).
By interlinking the individual ECAs, a habitat network can be achieved, permitting renewed genetic interchanges among previously isolated subpopulations of plants and animals, and the

re-establishment of species in abandoned habitats (Jenny et al., 2002). The interconnection and management of ECAs is consistently guided by the specific requirements of (plant and animal) target species of local conservation interest (Jessel, 2002). The main EQO-criteria for ECA-interconnection are listed in Table 2.

Table 2. Main criteria for connectivity projects of Ecological Compensation Areas (ECAs) according to the Ecological Quality Ordinance (Official Compilation of Federal Law)

Define a minimal project area (e.g. at least 50 ha)
A map shows all ECAs and other natural elements (forest, rivers) of the project area[1]
Define target species (plants and/or wild animals such as birds or butterflies etc.)[1]
Plan measures to interconnect ECAs and natural elements according to the specific needs of the target species[1]
Define the target status of the ECAs and other natural elements and show them on the map “final situation” [1]
Set up a schedule for all measures to be taken
Submit the project to the cantonal administration for approval

[1] requires a qualified biologist

For example, *Aricia agestis*, a butterfly species that is threatened in Switzerland, depends on south-facing semi-dry grasslands (*Bromus erectus* meadows) with a high proportion of *Helianthemum nummularium* and *Geranium* species. These suitable habitats must be interconnected with linear structures (riparian or forest-edge fringes). During the flight periods in June and August, abundant supplies of blossoms should be available. From July onwards, eggs are laid preferentially in mown meadows. It is therefore important to stagger mowing times. At each cut, an unmown strip should be left comprising 5–10% of the plot area, to ensure that minimum supplies of nectar are permanently maintained (Rey and Wiedemeier, 2004). To optimize mowing times, the cantonal authorities can negotiate individual agreements with farmers concerning land use of specific plots.

Integration of species-rich meadows into forage crop production

ECAs can be essential components of modern grassland farming according to the Swiss concept of the graded management intensity in grassland (Jeangros and Thomet, 2004). Extensive, low-, medium- and high-intensive meadows make it possible for forage production to be adapted both to the natural potential of individual plots and to the livestock requirement. The best quality forage from intensively farmed meadows makes it possible to minimize the use of feed concentrates in lactating cattle, while the fibrous hay produced in extensively managed meadows can be profitably used particularly to feed beef cattle, dry cattle and horses.

Results and Consequences

In 2003, the EQO quality criteria were met by meadows covering a total area of 24,000 ha, i.e. about a quarter (26%) of all ecological compensation meadows (Table 3) and 9,604 ha (11%) were part of a connectivity project (BLW 2004).
In 2004, this area had already doubled, and the upward trend appears to be continuing. It is therefore to be expected that in a few years a substantial proportion of Switzerland’s ECAs will be interconnected. This makes it reasonable to hope that the dramatic loss of botanical and wildlife diversity can be slowed down, and that threatened plant and animal populations will be able to recover.

Table 3. Ecological Compensation Areas (ECAs) in the permanent grassland area of Switzerland 2003 (Swiss Federal Office for Agriculture/BLW 2004)

Categories	Area covered (1,000 ha)
Agricultural area (a)	1,067
Permanent grassland (b)	627 (59% of a)
ECAs in grassland[2] (c)	91 (14% of b)
ECAs in grassland with quality according to EQO[3]	24 (26% of c)
ECAs in grassland with connectivity according to EQO[3]	10 (11% of c)

[1] without alpine pastures; [2] Ecological Compensation Areas (ECAs) in grassland include litter meadows, extensive meadows and pastures (ban of fertilizers) and low intensive meadows (small amounts of dung allowed); [3] EQO = Ecological Quality Ordinance (Official Compilation of Federal Law)

However, it is still too early to assess how biodiversity will be affected by these measures. No less important, however, are the psychological effects of the EQO, which has strongly improved farmers' acceptance of ecological compensation and nature conservation. As food producers, farmers are used to ensuring that their products comply with strict quality criteria. The introduction of the EQO quality criteria placed ecological compensation on the same level as conventional agricultural products. There is now a demand from the Government for the agricultural product "biodiversity". The outcome is important, not the compliance with regulations that may seem pointless. The EQO has opened the eyes of many farmers to the beauties of nature. This emotional element probably explains why an unexpectedly large number of connectivity projects have emerged in a short time, even though the financial incentives are relatively modest and a great deal of planning is required.

Conclusions

The following conditions proved to be necessary to ensure optimal promotion of plant and wildlife diversity in grassland areas:

The measures need to be both economically attractive for farmers and adapted to agricultural production. Therefore, in addition to adequate financial incentives, there is also a need for farm structures that permit the integration of extensively managed grasslands. If these conditions are met, species-rich meadows make sense for farmers in terms of economics, animal physiology and ecology. The modern farmer can thus be motivated to produce not only milk and meat but also natural and landscape diversity. The integration of ecology, economics and ethology gives rise to a "win-win-win" situation. Confronted with globalization pressures (WTO, EU), multi-functionality is the only possible survival strategy for Switzerland's agricultural sector.

From a biological perspective, it is assumed that at least 10–30% of grasslands should be covered by appropriately interlinked low-input meadows and pastures with high floristic diversity[1]. The decisive factor for wildlife is then the permanent availability of structural features and flowers, which can be achieved by adopting a staggered mowing regime and leaving un-mown strips of grass temporarily in place.

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[1] on dairy farms extensive and low intensive grassland should not cover more than 10 to 20% of the grassland area, otherwise excessive amounts of concentrates would be necessary for the cow's feeding (Jeangros and Thomet, 2004).

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Managed grassland habitats in relation to woodlouse biodiversity in Western France

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Abstract

Woodlice are among soil invertebrates that may show a decrease in both abundance and species diversity in the context of intensive land-use. They could thus be a potential guide to ecosystem activity in cultivated grasslands. Diversity of woodlice was studied in artificial, temporary and permanent grasslands at a site practising mixed farming in Western France, using hand searching sampling methods during three periods: spring, summer and autumn. Results were different between the studied habitats, and between the three sampling periods both for woodlouse species diversity and relative abundance. Six species were found. Associations were dominated by *Armadillidium vulgare*, *Armadillidium nasatum* and *Philoscia muscorum*. With respect to habitat, more species and more individuals were found in permanent grasslands whatever the type. Depending on the species, the diversity and abundance will be different according to the season.

Keywords: woodlice, species diversity, alfalfa, grassland, soil arthropod

Introduction

The specific diversity and abundance of woodlice decrease within intensive agricultural systems, with particularly marked differences between organically managed and more conventional plots; herbicide application leads both to increased mortality and lowered fecundity (Paoletti and Hassall, 1999). Agricultural practices in these perennial habitats will affect these arthropods. Actions such as cutting or grazing lead to reductions in vegetation height and biomass and a partial or total destruction of litter, affecting the entire community (Curry, 1994). Cutting is a non-selective method of grassland management compared with grazing. Removal of forage will reduce available litter for soil decomposers. Trampling by herbivores causes not only disturbance of arthropods (Morris, 1978) but also a reduction in soil coverage by plants (Curry, 1994). As the climax vegetation in most Atlantic habitats is woodland, natural grasslands are relatively few. In recent years, the nature of managed grasslands has changed with a tendency towards reseeding and intensification on the better soils, and reduction of grazing or abandonment in more marginal habitats.

This preliminary study based at a site situated in Western France (Poitou - Charentes) sought to extend investigations of decomposition to semi-natural and managed grasslands, as an important land-use category in these regions. It aimed to look at the abundance and diversity of woodlice as a potential guide to ecosystem activity of natural and improved grasslands, and to relate this to their importance and conservation value. This involved first determining the species and their abundance in different grassland habitats in spring, summer and autumn.

Materials and Methods

Observations were made in the Fors sector (Deux Sèvres) in the Poitou-Charentes Region in Western France. This area has been mapped using GIS and has been the subject of major studies since 1994 involving crop rotations, entomological and ornithological observations (Clere and Bretagnolle, 2001). Fors is in a zone of mixed farming, with a recent history of intensification. Different types of grasslands were studied (Figure 1): artificial (clover, alfafa), temporary and permanent. 'Artificial grasslands' are those established for less than 5 years and sown exclusively with leguminous fodder crops. Temporary grasslands are similarly less than 5 years old sown with fodder grasses, pure or mixed with leguminous plants. Permanent grasslands comprise both plots sown for a long time (6-10 years) and natural grasslands, not reseeded. Between 3 and 5 individuals searched each plot and its connections (plot boundaries), collecting as many woodlice as possible by hand over a total cumulative period of one hour (30 minutes for sampling the plot at 10 searching stations at least, 30 minutes for sampling its different categories of connections: hedges, road verges, lanes and interfaces with other cultivation). All woodlice were collected for laboratory identification. When collecting, the type of soil (sandy, clayey), the quantity of stones, the air temperature, the rain (woodlice needing humidity; Miller and Cameron, 1987) and the plant species present were noted (their distribution also depending on plant assemblages; Slavecz, 1995). The proportion of bare soil and height of vegetation were observed, as were any human activities (cutting, silage, fertilisation etc.). Each plot with its connections was sampled at three periods: spring (8^{th} April to 21^{st} April), summer (18^{th} June to 1^{st} July) and autumn (27^{th} September to 4^{th} October). Whole results per plot (plot + connections) are presented.

Results

Six woodlouse species were encountered in grasslands. Clear differences were seen between the different types of grasslands and between seasons both for species diversity and abundance (Table 1, Figure 1).

Table 1. Relative abundance of species in grassland plots, mean and standard error of the number of woodlice per type of field at three seasons (P1 = spring, P2 = summer, P3 = autumn)

Type	Clover			Alfafa			Temporary grassland			Permanent grassland		
	P1	P2	P3	P1	P2	P3	P1	P2	P3	P1	P2	P3
A. vulgare	0	0	0	0.08	0.65	0.31	0.1	0.22	0.08	0.03	0.36	0.03
A. nasatum	0.06	0	0.2	0.07	0.29	0.04	0.52	0.60	0.46	0.63	0.36	0.37
O. asellus	0	0	0	0	0	0	0	0	0	0	0.02	0
P. muscorum	0.94	1	0.8	0.63	0.05	0.64	0.18	0.18	0.46	0.33	0.2	0.66
P. cingendus	0	0	0	0.13	0	0	0	0	0	0.01	0	0
P. scaber	0	0	0	0.09	0.01	0.01	0	0	0	0	0.07	0
Number of plots	1	1	1	6	6	6	4	4	4	4	4	4
Mean	119	16	266	36.8	21.3	30.2	180.2	56.5	166.7	206.0	85.2	188.2
Standard error	–	–	–	9.6	12.1	4.8	51.0	52.2	48.7	59.9	34.4	40.6

Philoscia muscorum was common to each habitat to a greater or lesser degree. In clover, *Philoscia muscorum* was dominant. *A. vulgare* and *A. nasatum* were common to three habitat types but absent (*A. vulgare*) or very infrequent (*A. nasatum*) in clover (Table 1). *A. nasatum* was the dominant species in temporary grasslands. In permanent grasslands, *A. nasatum* was the most frequently encountered species followed by *P. muscorum* and lastly by *A. vulgare*.

Oniscus asellus was found only in older grassland and in summer. *Porcellionides cingendus* was present in spring in alfalfa; *Porcellio scaber* was infrequent only occurring in summer in permanent grassland and in alfalfa (Table 1). Genus *Armadillidium* was dominant in summer, while *P. muscorum* was less numerous in this season than during spring and autumn, although similar in temporary grassland and higher in summer clover (Table 1).

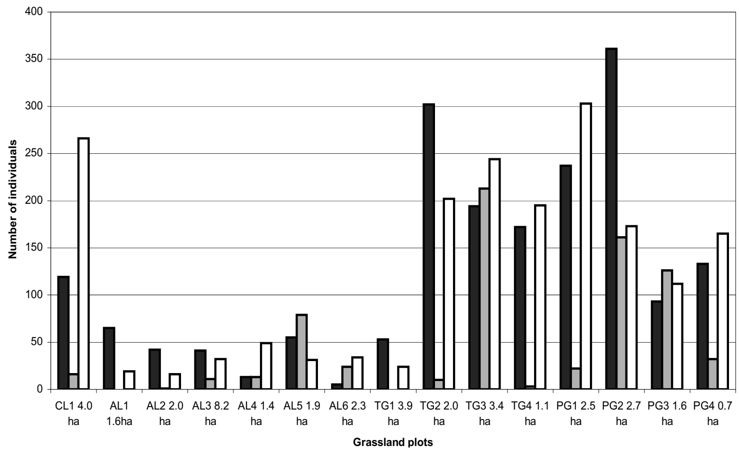

Figure 1. Number of woodlice sampled in each plot (plot + connections) in spring (black columns), summer (grey) and autumn (white) in clover (CL), alfalfa (AL), temporary grasslands (TG) and permanent grasslands (PG)

Although the hand-search method was not completely standardised, it reflects woodlouse abundance. More woodlice were captured in temporary and permanent grasslands than in alfalfa grasslands (Fig 1). The number of woodlice in the clover field was high (but only one plot studied). Abundance variability was low in alfalfa plots while it was very high in temporary and permanent grasslands whatever the season (Fig 1). Woodlouse densities were higher in spring and autumn, than in summer whatever the grassland type (Figure 1).

Discussion

Improved pasture and meadows of different ages and different seed origins, from grass to clover and alfalfa, were sampled during three periods at Fors. Woodlouse species diversity and abundance were different between grassland habitats and seasons. Such results are not surprising because woodlice are said to be very influenced by variations in habitat structure (Davis, 1984), while the presence of some species is linked with the degree of openness of the land, whereas other species are most usual in closed habitats (David *et al*., 1999).

Fors is in a zone of mixed cultivation and stock rearing, although with some intensification in certain areas. The differences between plots of the same type for temporary and permanent grasslands may be explained by differences in management type (grazing, cutting). For example, cutting for silage is mentioned to be a major disturbance for all soil arthropods (Curry, 1994). Woodlouse abundance was very low in alfalfa grasslands compared to other habitats. The number of cuts, and herbicide and insecticide applications on alfalfa could explain such low woodlouse abundance. Further, woodlice, being crustaceans, need a relatively damp environment. The alfalfa plots at Fors had more than 10% bare soil. Exposed rocks would heat up in the sun, which would tend to exclude woodlice.

Floristic composition is very important for arthropods, and particularly for woodlice. In our study plots, woodlice were more numerous in grasslands at least five years old than in younger grasslands. Any cultivation which took place in the preceding year is also important for woodlouse populations. The nature and structure of the soil are also very important factors. For example, inputs of fertiliser will change the pH (Paoletti, 1999) to a degree dependent on the nature of the soil. Woodlice have been shown to react to variations in pH. *A. vulgare* is more sensitive than *P. muscorum* or *P. scaber* to acid pHs and may be used as an indicator of acidification (Sastrodihardjo and Van Straalen, 1993). This species is equally influenced by levels of soil calcium, but is fairly tolerant to dessication.

Other, more general factors also affect woodlouse communities. Climatic conditions (temperature, humidity) affect the number of individuals and their reproduction. Also, the dominant species may change at different times of year: in permanent grasslands, populations of *P. muscorum* are highest in autumn, *A. vulgare* in summer and *A. nasatum* in spring.

On the other hand, the sampling method could be biased towards species capture during summer: *P. muscorum* could reach soil cracks where temperature and humidity are more suitable, and thus could not be captured while genus *Armadillidium* remain above the ground.

Conclusions

Certain woodlice species may be characteristic of various Atlantic grasslands, attributable to their different habitat factor preferences (pH, humidity etc.). These species may have value as easily identified bioindicators of undisturbed, semi-natural conditions. Work is in progress to treat the data according to the relationship between connections and plots, irrespective of the site, as hedges are the source of woodlice for grasslands.

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Biodiversity and grass production in grasslands liable to flooding: an attempt to simulate production

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Abstract

The alluvial Saône Valley (France) is designed as a special area of nature conservation. Permanent grasslands in this area are special ecosystems as far as their use is concerned: conservation of biodiversity, protection of water resources, flooding management, forage supplies. The prediction of grass production in these grasslands is studied in order to evaluate the impacts on grass production of a measure considered for the conservation of habitats (cutting delay)
The botanical composition observed in 15 patche s from 2001 to 2004 showed high number of species, according to grassland management and topographical localisation. The dates of flowering spread out from mid-May for the earliest to mid-July for the latest. Moreover, the botanical composition can vary between years as a function of the climate and especially the duration of flooding. It is an ability of these natural grasslands to adapt to climatic conditions.
We attempt to estimate the production of these grasslands with the crop model STICS adapted for grass production. The simulations have to be improved by taking into account the variation of botanical composition during the first growth, the particular conditions of mineralization of organic matter in the soil and a better characterisation of flooding duration.

Keywords: Natura 2000, flooded grassland, botanical diversity, grass production, crop model for grass

Introduction

The European and national environmental legislations (Community water policy, Directive of the conservation of natural habitats and of wild fauna and flora) define new aims for the permanent flooded grassland in the region of Saône valley (France, Saône et Loire department), related to protection of dwelling houses against floods and protection of animal and plants of Community interest. It implies for the farmers in the Saône Valley more and more constraints on the management of flooded grasslands.
The development agency of Saône et Loire department (Council of Agriculture), in association with research organization (INRA) tries to combine the different points of view of the ecologists, agronomists, governors and farmers. Research has been developed in order to help farmers to keep their permanent grassland despite the constraints and to adapt their management (date of cutting, fertilisation….) because the grasslands of the flooded area can represent in many farms a forage resource essential for the farm economic sustainability.
In this area, for birds and habitat conservation, delaying cutting is proposed to farmers. Some research focuses on the ability to predict the impacts of cutting delay on yield and feeding value of grass. The prediction of yield, taking into account different management regimes and variability of climate between years, is possible by the use of a crop model adapted for grassland. It aims at the prediction of variability between years of grass yields and further the prediction of production losses during the second growth when the grassland is cut after the

period of best production (quantity and quality) in accordance with the regulation for birds and habitat protection. The present paper presents the first results about the diversity of the flora in the flooded grasslands of the Saône valley area and the abilities for the model STICS to simulate grass production.

Materials and Methods

We chose the model STICS on account of its ability to take into account patch managements (cutting date, nitrogen fertilisation) and soil conditions. This allows the restriction of grass production due to the lack of oxygen during the flooding period to be taken into account.
STICS is a daily time-step crop model with input variables relating to climate, soil and the crop system. Its output variables relate to yield, both in quantity and quality, and to the environment (drainage and nitrate leaching). Crop growth is driven by the plant carbon accumulation (de Wit, 1978): solar radiation intercepted by the foliage and then transformed into aboveground biomass that is directed to the harvested organs during the final phase of the crop cycle. The crop nitrogen content depends on the carbon accumulation and on the nitrogen availability in the soil.
Main input data concern plant parameters, climate, soil, agricultural practices and initial data. Plant parameters used in this work were fixed to represent mean cultivated grass, while the others, featuring crop growth conditions, were measured or fitted for each patch. However, some parameters were not involved in other uses of the model like water logging sensitivity. Climate characteristics are temperature, rain, global radiation, potential evapotranspiration. These come from the nearest meteorological station (20 km), but as patches are in the Saône valley and meteorological stations only near the valley, rainfall regime is probably not properly estimated. Dates of flooding were estimated from the level of the river given by the 'Navigation', an official society watching the streams and rivers. Soil characteristics consist mainly of values allowing the calculation of water reserve in the soil (depth, humidity at field capacity and wilting point, soil density) and features allowing the soil mineralization: organic nitrogen, clay and chalk rates. Some parameters used in this work cannot easily be measured, like infiltration rate and run off. Dates of cutting or grazing and fertilization were recorded by farmers. Standard initial conditions (leaf area index, dry matter, plant nitrogen content) at the beginning of growth were used on account of unavailability of observations.
The present practices on flooded grasslands were identified in 2000 through a survey on farms. The soils in the flooded area were also described. Both, soil conditions and farmer's practices, allowed choosing a sample of grasslands representing the diversity of situations existing in the studied area. Regarding the hydromorphy level in the soil which mainly depends on their topographical localisation from the river, fifteen plots were selected : five were located on high position and corresponded to Fluviosol – the vegetation belongs to the Arrhenattherum elatius association-; five in middle position on Redoxisol – Senecio-Oenantetum media, Festuca pratensis association – and five on low position on Reductisol – Gratiolo-Oenanthetum fistulosea association. The soil names are given according to the French "Référentiel Pédologique" (INRA, 1992). Some grasslands received no mineral nitrogen fertilisation; for the others, nitrogen fertilisation reached 15 to 110 kg per hectare. No organic fertilisation was provided on these grasslands because of the constraint of flood. During four years (2001–2004), the flora of the patches was studied. Four times during the spring growth period, from the 15th of May to the 15th of July, all species were identified and counted using the de Vries method (de Vries and de Boer, 1959) The date of flowering of the main legumes (Trifolium pratense, T. repens, T. fragiferum, Lotus corniculatus) and grasses (Alopecurus pratensis, Lolium perenne, Poa pratensis and trivialis, Festuca pratensis, Phleum

pratense) was recorded. An area of 3 m^2 was cut in each grassland to estimate the yield. The comparison between measured and calculated values will be only made on the data of the first year (2001).

Results

The grasslands in the region of Saône valley show a high species richness, with about two hundred species, which could be explained by management, topographical localisation and climate of the year (flooding duration, temperature and summer drought). Mixed management – cutting and grazing – provides more extensive botanical composition (up to 45 species) than specialized management, i.e. only cutting or grazing. The grasslands on low topographical localisations have a higher number of species than the others and they often host plant species which are particularly threatened. Besides floristic diversity, a wide range of dates of flowering occurs in these grasslands. For grasses, the earliest is Alopecurus pratensis which flowers in the first two weeks of May. In the last two weeks of May, Lolium perenne, Poa pratensis and trivialis then Festuca pratensis flower. Phleum pratense flowers the latest, at the beginning of July. Among legumes, Trifolium pratense flowers early and briefly during May. The flowering of Trifolium repens and Lotus corniculatus is spread over a long period not depending on rainfall conditions. Trifolium fragiferum flowers very late from the end of June to mid-July.
Regarding the grass production, the observed values show that the growth patterns of final grass production are highly variable between patches: there are patterns without maximum (plateau), with one maximum or two. Moreover, the first value of measured grass production (mid-May) varies between patches (from 0.6 to 4.5 t/ha). According to the height related to the bank of the river (high, middle, low), the grass production is greater in the highest positions. The main aim of these simulations was to explore the abilities of the model to represent several patterns of growth, the effect of fertilization and the effect of flooding.

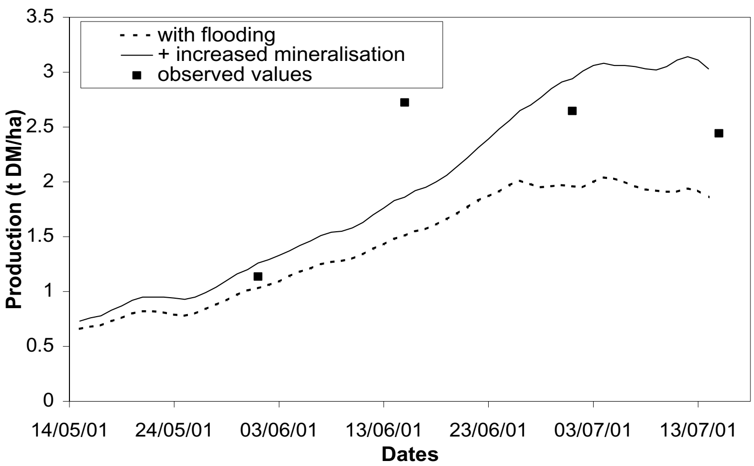

Figure 1. Effect of shortening the leaf life span on the production estimation (patch B3 (low position) in 2001, taking into account flooding, but suppressing nitrogen stress)

Even if the productions are never accurately estimated, the estimations are better in middle positions, than in the low and especially in the high positions (far from the river). In all cases, taking into account flooding delays the grass growth, and improves the model estimations (Figures 1 and 2), although the infiltration parameters used to empty patches are not easy to inform. Shortening leaf life span improves the estimations (Figure 1). When the nitrogen stress is active, the production was often underestimated (Figure 2), especially in clay soils (near 50 % clay). The actual level of production can be simulated by reducing or suppressing the nitrogen stress (Figure 1). Increasing the mineralization rate in clay soils (by changing the original mineralization parameters) improves adequacy between measured and simulated grass productions (Figure 2).

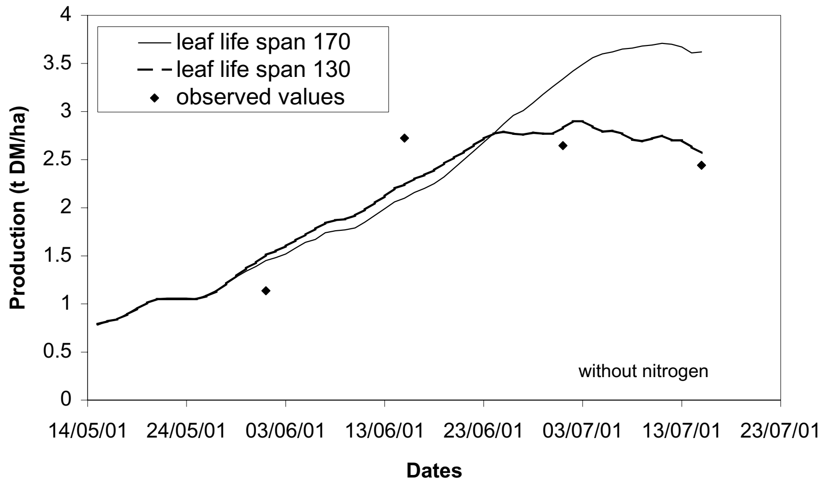

Figure 2. Effect of mineralization parameters on production estimation (patch B3 (low position) in 2001, with nitrogen stress, but decreasing mineralization inhibition by clay)

Discussion

The lack of accuracy between measured and simulated grass productions was due to a number of unknown variables. The input data were not well known as far as it concerns the dates of flooding, the possible amounts of nitrogen provided by the flooding water and the rainfall amounts. However, the adequacy was improved when we reduced the nitrogen stress value: the model overestimates nitrogen stress in spite of the high organic matter content. The production in low fertilised conditions essentially depends on nitrogen supply from the soil and it could explain why the simulated grass production does not reach the observed values. The nitrogen balance in soil is poorly simulated, perhaps because of the interaction of soil humidity and clay content on mineralization. Moreover, the nitrogen provided through fixation of endemic legumes was not taken into account in the configuration used. The predicting values were also improved when we modified plant parameter (leaf life span). The current plant parameters represent highly productive grass, whereas grasslands were made up from many species less producing than cultivated grasses. The use of more detailed plant features, allowed from characterisation of groups of plants with functional traits (Ansquer *et al.*, 2004) and knowledge of the changes of species during year can improve the estimations.

Conclusions

Even if we can estimate the grass production in some patches using STICS, we have to test it in more conditions (grasslands and years). Improvements in simulations of grass production could be gained by taking into account a better characterisation of flooding period. As the grassland are often nil or low fertilised, the nitrogen supply from the soil (mineralization) is more important than in other crops. The input data and the parameters influencing mineralization must be better known than usually. The species richness in flooded grasslands is high but differs between grasslands and during the time of growth. At the present time, these aspects are not taken into account by the model. The functional traits seem to be an interesting way to characterize plants and to introduce species richness in the crop model.

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Cultivation of different ecotypes of *Bromus erectus* Hudson of mountain permanent grasslands in lowlands adopting different sowing methods

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Abstract

A long-term cultivation of different ecotypes of *Bromus erectus* was performed to define their agronomic characteristics and to test different sowing methods to identify the most suitable for large-scale cultivation to produce seeds for restoration of disturbed sites in origin areas. The seeds were collected by hand in 8 grasslands of the Italian Central Apennines, differing in ecological and edaphic conditions and located between 775 and 1,525 m a.s.l. Broadcast and drill sowing was performed in lowland (50 m a.s.l.) according to a completely randomised design with 3 replicates on 2 m^2 plots. A sowing density of 5 g m^{-2} (corresponding to about 1,028 seeds) was used for both the sowing methods. At monthly intervals, from middle January and at fortnightly intervals from middle June, vegetation cover index and phenological evolution of the plants were assessed. Despite low initial emergence indexes recorded and regardless of the sowing method adopted, all the ecotypes reached a complete vegetation cover in one year time due to the high tillering ability of the species. All ecotypes did not reach fructification phase probably due to not completed vernalization.

Key words: seed propagation, ecotypes, *Bromus erectus*, permanent grasslands.

Introduction

Bromus erectus Huds. (*Poaceae*) is a hemicryptophytic herbaceous perennial species widespread in the Paleotemperate areale. It is distributed in the Italian peninsula except Sicily, from 0 to 1,600 m a.s.l. on perennial xerophytic and mesophytic grasslands of *Festuco-Brometea* class. Based on its wide ecological amplitude and consolidation attitude observed in the study area it could be favourably used for restoration of disturbed sites in protected areas instead of commercial species or varieties.

Taking into account both the advantages (need for small quantity of seeds, increased seed germination, faster development, earlier sexual maturity, easier seed harvesting and lower seed price) and the problems (first of all related to potential loss of intraspecific variability) connected with the propagation of the species outside their natural area (Peratoner, 2003) a cultivation of different ecotypes of *Bromus erectus* collected in mountain grasslands was established in lowlands. It was used to define their agronomic characteristics and to test different sowing methods for large-scale cultivation, especially considering the great difficulty of using selective herbicides with frequent invasion of other grasses (Krautzer *et al.*, 2004).

Materials and Methods

In several areas of the Italian Central Apennines (Monte Catria, Dorsale di Cingoli, Monti Sibillini, Monti della Laga) located on carbonatic and siliceous rocks seeds collections of different ecotypes of *Bromus erectus* were carried out in summer 2003.

Ripe seeds of *Bromus erectus* were harvested by hand from eight spontaneous grasslands with different ecological and edaphic conditions.

The cultivation trial was established at the experimental farm of the Faculty of Agricultural Science of the Università Politecnica delle Marche located in Agugliano (Ancona province, 13°22´E latitude and 43°32´N longitude), at about 50 m a.s.l. and on soil with clay loam texture, pH 7.9 (in H_20), 11.4 g g^{-1} of organic matter, 5 mg g^{-1} of assimilable phosphorus (P_2O_5), 142 mg g^{-1} of available potassium (K_2O), 220 and 121 mg g^{-1} of total and active carbonate ($CaCO_3$) respectively.
Mean annual temperature (T_{ma}) and precipitation (P_{ma}) were 14.5°C and 651.4 mm from November 2003 to October 2004. In comparison with the last thirty years, the mean values of temperature and precipitation of 2004 were higher (long-term average of 13.6 °C) and lower (long-term average of 702.6 mm) respectively. Dry periods were observed during the summer of 2004 when precipitations were low in July (13 mm) and August (18 mm).
After tillage the trial was established in 2 m^2 plots (1 x 2 m) that were arranged in a two-factorial completely randomised design (factor 1 = ecotype; factor 2 = sowing method) with three replicates, on a surface of 72 m^2.
In particular, sowing by drilling (5 rows per plot with 20 cm row width) was used for all ecotypes; broadcast sowing was tested only for four ecotypes (1.Settecerri, 2.Rigo, 3.Colle Pisciano, 4.Monte Acuto). The sowing was performed by hand on 25th November 2003 and a seed rate of 5 g m^{-2} was used (corresponding to about 1,028 seeds).
Starting from January 2004, seedling emergency, vegetation cover and phenology of the cultivated ecotypes of *Bromus erectus* were assessed. In particular, in the middle of January seedling emergence (% of the sown seeds) by positioning a 0.2 m quadrat at 3 pre-fixed points along the plot diagonal in the broadcast sowing plots and on 5 pre-fixed lines on the relative rows in the drill sowing plots. At monthly intervals, from the middle of January and at fortnightly intervals from the middle of June, vegetation cover index and phenological evolution of the plants were assessed. Vegetation cover was assessed in each plot according to Braun-Blanquet (1964) measuring the cover degree as the vertical projection of all aerial parts of plants as a percentage of the total plot area. Phenological evolution was assessed adopting the sampling method used for seedling emergence. According to Jouglet *et al.* (1982), a determined phenological phase was assigned when at least 66% of the individuals reached that phase. The analysis of the phenology evolution was performed on the basis of meteorological data recorded in Agugliano and, particularly, on the temperature sum (°C d) determined as described by Giardini (1982) starting from the sowing date and considering 0°C as base temperature.
The data were subjected to ANOVA analysis by means of SAS software (1985) and according to Gomez and Gomez (1984). In particular, vegetation cover and emergence data analyses were performed on arcsine-transformed data. Student-Newman-Keuls (SNK) test was used to compare the ecotypes within a same sowing method; Least Significant Difference (LSD) test was used to compare the ecotypes broadcast and drill sown.

Results and Discussion

The first seedling emergency occurred one month after the sowing and, in general, after about two months *Bromus erectus* highlighted a mean emergence index of 26%. The comparison between the ecotypes within the sowing methods highlighted significant differences both in broadcast and in drill sowing (Table 1). With the broadcast method, ecotype 4. Monte Acuto showed the highest emergence (62%). With the drill method, ecotypes 1. Settecerri, 4. Monte Acuto, 5.Montemonaco and 7. Prati di Ragnolo showed the highest emergences and ecotype 6. Pretare the lowest (about 8%). The significant differences between broadcast (43%) and drill (21%) methods could be probably due to the too great sowing depth (3–4 cm) adopted in the drill sowing. In fact, *Bromus erectus* needs a maximum sowing depth of 1.5–2 cm (Krautzer *et al*., 2004). The higher emergence observed for ecotype 4. Monte Acuto by both the sowing methods could be related to the xerophilous microbioclimate conditions of the harvesting site compared to the other mesophilous ones.

Table 1. Emergence % of the different ecotypes and sowing methods

Ecotype	Sowing			
	Broadcast	Drill		Mean
1. Settecerri	35.4^{b}	23.3^{ab}	A	29.4 B
2. Rigo	37.8^{b}	16.9^{b}	AB	27.3 B
3. Colle Pisciano	38.1^{b}	18.3^{b}	AB	28.2 B
4. Monte Acuto	61.9^{a}	26.2^{a}	A	44.0 A
Mean	43.3 A	21.2 B		32.2
5. Montemonaco	–	22.5	A	–
6. Pretare	–	8.0	C	–
7. Prati di Ragnolo	–	19.9	AB	–
8. Fonte Spicchi	–	12.3	BC	–
Mean	–	15.7		–

The dryness of this pasture is also confirmed by the characteristics of *Asperulo purpureae-Brometum erecti* association (Biondi *et al*., 1995) found in Dorsale di Cingoli in preceding studies (Taffetani *et al*., 2004). The mentioned conditions could have been provided to those individuals a greater dry resistance and emergence ability.

In rows and columns, means with no common letters differ significantly at 0.05 (small letters) and at 0.01 (capital letters) level. Superscript letters compare ecotyopes within each sowing method (SNK test). No superscript letters compare ecotypes with both the sowing methods (LDS test).

Concerning the vegetation cover of all ecotypes (Figure 1), on average between January and May a 5.5%-monthly increase was observed; from June to October a 10.9%- monthly increase was recorded. Ecotype 3.Colle Pisciano showed the lowest vegetation cover in both sowing methods. For the broadcasting method ecotype 4.Monte Acuto achieved the highest cover, followed by ecotype 2.Rigo, while for the drilling method ecotype 1.Settecerri and 4.Monte Acuto showed the highest indexes. Apart from the mentioned differences, the vegetation cover of all ecotypes achieved an average value of 100% in winter 2004.

Considering the mean % values of the vegetation cover (Table 2), the comparison between the ecotypes within the sowing methods highlighted significant differences both in broadcast and in drill sowing. With regard to the broadcast method, ecotype 4. Monte Acuto showed the highest vegetation cover (52%). Concerning the drill method, ecotypes 4. Monte Acuto and 5. Montemonaco recorded the highest values; ecotype 3. Colle Pisciano the minimum (about 33%). The comparison between the sowing methods and the ecotypes with both sowing did not highlight significant differences.

Concerning the phenology study, the initial development was slow in the juvenile stage (emergence, 2–3 leaves stage, tillering). *Bromus erectus* reached 2–3 leaves phase from middle March and tillering occurred on middle May. From this time until winter 2004 the plants remained in vegetative stage.

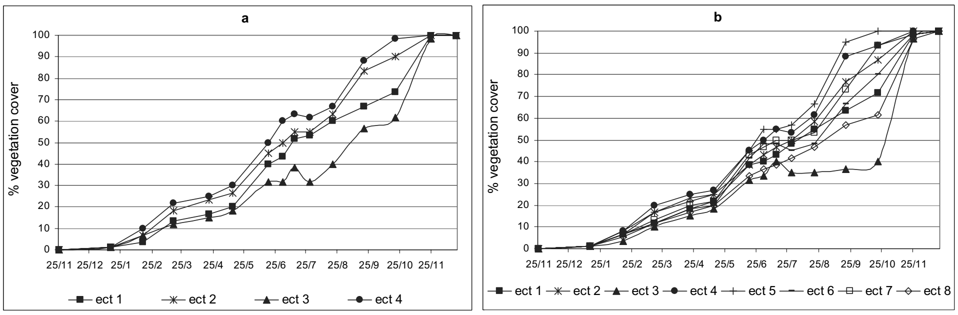

Figure 1. Evolution of vegetation cover of ecotypes in broadcast a) and drill b) sowing

Phenology evolution was slow and there were not significant differences between ecotypes considering the temperature sum necessary to the attainment of the different phases.

Table 2. Mean % vegetation cover of the different ecotypes and sowing methods

Ecotype	Sowing			
	Broadcast	Drill		Mean
1. Settecerri	42.9 C	41.2 C	C	42.0
2. Rigo	47.8 B	44.8 B	B	46.3
3. Colle Pisciano	36.2 D	33.1 D	E	34.6
4. Monte Acuto	51.7 A	48.5 A	A	50.1
Mean	44.7	41.9		43.3
5. Montemonaco	–	49.7	A	–
6. Pretare	–	42.3	BC	–
7. Prati di Ragnolo	–	44.7	B	–
8. Fonte Spicchi	–	37.8	D	–
Mean	–	41.6		–

In general, *Bromus erectus* reached the emergence phase at about 390 °C, the 2–3 leaves phase at about 780 °C and the tillering phase at about 1,520 °C-temperature sum. Probably due to the late sowing and the late emergence, *Bromus erectus* did not attain the temperature for vernalization and the reproductive phase did not occur. In relation to this, 529 and 759 hours with temperatures varying between 0 and 5°C and between 5 and 10 °C respectively were recorded in the study area.
In the columns, means with no common superscript letters differ significantly at 0.01 level and compare ecotypes within each sowing method (SNK test).

Conclusions

For the same sowing method, significant differences in the % seedling emergency and vegetation cover among the studied ecotypes were recorded. The most precocious ecotypes were those collected in grasslands characterised by more xerophilous conditions compared to the more mesophilous ones. The conditions referred to could have been provided those individuals a greater drought resistance and emergence ability. On the contrary, no significant differences among the ecotypes were observed concerning the phenological evolution.

All ecotypes of *Bromus erectus* did not reach the fructification phase probably due to not completed vernalization caused by a late sowing and emergence.
No significant effect on the studied characteristics could be assigned to the different sowing method adopted. In fact, the lower emergence values recorded by drill method were very probably due to the high sowing depth adopted. But, at the same time it could not justify the adoption of broadcasting method for large-scale cultivation especially because of the high difficulty in mechanical weed control. Besides, despite the low and variable emergence recorded and apart from the sowing method adopted, all ecotypes in winter 2004 reached a uniform and complete vegetation cover due to the high tillering ability of the species.

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Seed production of *Bromus erectus* Hudson from spontaneous permanent grasslands of Monti Sibillini (Central Italy) assessed by different methods

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Abstract

In Monti Sibillini, large meadowlands currently abandoned or occasionally utilised, could be used for seed production of native grasses for restoration of disturbed areas. In this context, the research aims to assess the seed production of *Bromus erectus* during different harvesting times to avoid high seed losses due to shattering. At the same time, it attempted to compare different methods to predict the seed yield. Starting from the ripeness of the caryopses, four seed harvests were performed at weekly intervals. Number and weight of the caryopses of *Bromus erectus* were assessed based on the total number of culms, both counted and estimated by sampling within 3 quadrates in each plot. Among the main results, starting from the ripeness of caryopses, a significant decrease in both the number and weight of ripe seeds per culm due to high seed losses was recorded. An underestimation of about 41% of the culms number per unit area was recorded by using manual counting. A significant decrease in seed number and weight per unit area was recorded only by using mean values of the culms counted in the entire plot area and assessed by sampling within 3 quadrates in each plot.

Key words: *Bromus erectus*, permanent grassland, seed production

Introduction

In Monti Sibillini National Park (Central Apennines, Italy) there are large meadowlands abandoned or only used occasionally. In addition to the traditional usage, these grasslands could be also used for harvesting seeds of native plants to use for ecological restoration of disturbed areas located in the protected area. Timing of seed harvest is one of the most important decisions to adopt in order to avoid high seed shattering over short time periods which could result in major seed losses (Berdahl and Frank, 1998). At the same time, the reliability of the method used for the assessment of seed yield is essential in order to evaluate the time of harvest, considering the cost of the commercial varieties is low (Scotton *et al.*, 2001).

The aim of the present research was to evaluate the seed production of *Bromus erectus* in *Bromus erectus*-dominated grasslands in different harvest times starting from the ripeness of the caryopses and by adopting different yield assessment methods.

Materials and Methods

The research was performed in a grassland at Colle Fronte nearby Rigo (13°20´ E latitude and 42°49´N longitude, Ascoli Piceno province), located in the southern area of Monti Sibillini National Park (Central Apennines, Italy). Up to fifty years ago the study site was regularly cultivated. After the abandonment of the agricultural practice, the meadow that spontaneously grew was regularly harvested as recent as five years ago. Harvest was suspended and cows occasionally graze only a few areas.

The field trial area of about 2.25 ha was located at 875 m above sea level, on arenaceous-pelitic deposits (Centamore *et al.*, 1991), with E-SE exposure, 20° inclination and vegetation

cover index of 100%. The region is ascribed to the oceanic temperate macrobioclimate, low supratemperate and upper humid bioclimate (Rivas-Martinez *et al*., 1999).
Vegetation surveys were performed in the summer of 2004 in order to identify plant association and phenological evolution of *Bromus erectus*. The vegetation study was carried out according to the phytosociological method proposed by Braun-Blanquet (1964). Species were determined according to Pignatti (1982) and Tutin *et al.* (1993; 1964–1980).
In the studied grassland, to be referred to the association *Centaureo Bracteatae-Brometum erecti* Biondi *et al*. (1986), *Bromus erectus* was the dominant species. Other abundant species were *Brachypodium rupestre*, *Briza media* and *Carex flacca*.
A uniform area was identified in the meadow and subdivided into 12 plots of 1 m^2 (1 × 1 m) in a completely randomised experimental design with three replicates. Four seed harvests were performed at weekly intervals from July13th to August 3rd, starting from the ripeness of the caryopses which was assigned when at least 66 % of the individuals reached the stage according to Jouglet *et al*. (1981).
Number and weight of the ripe caryopses were determined based on the culms of the plants of *Bromus erectus* collected within 0.2 m quadrates positioned in three pre-fixed points in each plot and carefully harvested by hand and stored for laboratory assessments.
The number of culms of *Bromus erectus* was assessed by:
(i) counting in the field the total culms of the plants present in the entire plot of 1 m^2;
(ii) counting the number of culms present within 0.2 m quadrates positioned in three pre-fixed points in each plot and used for laboratory assessments.
The potential seed production (expressed as amount and weight of seeds per unit area) was calculated by multiplying the number of ripe caryopses and their weight – obtained on the base of the thousand seed weight (TSW) – per culm for:
(i) the number of culms counted in the field in the entire plot of 1 m^2;
(ii) the number of culms present within 0.2 m quadrates positioned in three pre-fixed points in each plot;
(iii) the mean number of culms counted in the entire plot of 1 m^2 during the different harvesting dates;
(iv) the mean number of culms assessed within 0.2 m quadrates positioned in three pre-fixed points in each plot during the different harvesting dates.
The TSW of *Bromus erectus* was determined according to the International Seed Testing Association (ISTA) (1985). The mean TSW was 4.8638 g (Standard deviation: 0.0091).
The data was subjected to ANOVA analysis and to the Student-Newman-Keuls (SNK) test by means of SAS software (1985) and according to Gomez and Gomez (1984).

Results and Discussion

The data analysis showed significant effects of the harvest date on the number of ripe seeds per culm (Table 1).
As expected, no significant effects were observed on the number of culms both counted within the entire plot area and estimated by sampling within 3 quadrates. A mean global undervaluation of 41% of the manual counting within the entire plot area (Table 1) was observed, probably due to the high influence of different aspects such as canopy structure, assessed species morphology and different climatic and environmental conditions on the assessment.

Table 1. Number of ripe seeds/culm, culms/m² and ripe seeds/m² in the different harvest dates

Date	N° of ripe seeds per culm	Number of culms m^{-2}		Number of ripe seeds m^{-2} calculated on culms number			
		Counted within entire plot	Estimated within 3 quadrates	Counted within entire plot	Estimated within 3 quadrates	Mean of culms	
						Counted within entire plot	Estimated within 3 quadrates
13/07	19.5 a	54	136	1,083	2,532	1,378 a	3,512 a
21/07	12.4 ab	71	183	844	2,288	879 ab	2,240 ab
26/07	11.5 ab	77	150	875	1,620	815 ab	2,077 ab
03/08	7.5 b	81	253	594	1,918	533 b	1,360 b
Means	12.7	71	181	849	2,090	901	2,297

In the columns, means with no common letters differ significantly at the 0.05 level (SNK test)

No significant effects of the harvest time were observed on the seed yield when it was calculated on the number of culms, both counted within the entire plot area and estimated by sampling within 3 quadrates (Table 1). The analysis showed a significant effect of the harvest time on the seed yield when it was calculated on the mean number of culms both counted within the entire plot area (71 culms m^{-2}) and estimated by sampling within 3 quadrates (181 culms m^{-2}). The adoption of the mean values of the culm numbers to calculate the potential seed yield seems to be justified by their not significant variations during the different harvest dates (Table 1). High seed losses were recorded in *Bromus erectus* due to seed shattering starting from the ripeness of caryopses. The highest ripe seed yields, calculated on the mean numbers of culms per m², were obtained in the first harvest (Table 1): from July 13th to August 3rd , the number of ripe seeds m^{-2} decreased significantly on average from 1,378 to 533 and from 3,512 to 1,360 respectively, considering the two assessment methods adopted.
From July13th to August 3rd, the ripe seeds weight per culm decreased on average from about 0.095 g to less than half of it. A mean value of 0.062 g of ripe seeds per culm was recorded (Table 2).

Table 2. Seeds weight per culm and per unit area in the different harvest dates

Date	Seeds weight per culm	Seeds weight per unit area (g m^{-2}) calculated on culms number			
		Counted within entire plot	Estimated within 3 quadrates	Mean of culms	
				Counted within entire plot	Estimated within 3 quadrates
13/07	0.095 a	5.27	12.32	6.70 a	17.08 a
21/07	0.060 ab	4.10	11.13	4.27 ab	10.89 ab
26/07	0.056 ab	4.26	7.88	3.96 ab	10.10 b
03/08	0.037 b	2.89	9.33	2.59 b	6.61 b
Means	0.062	4.13	10.16	4.38	11.17

In the columns, means with no common letters differ significantly at the 0.05 level (SNK test)

As recorded for the seed numbers per unit area, no significant effect of the harvest time were observed on the seed weight per unit area when it was calculated on the number of culms, both counted within the entire plot area and estimated by sampling within 3 quadrates (Table

2). On the contrary, the analysis showed a significant effect of the harvest time on the seed yield when it was calculated on the mean number of culms, both counted within the entire plot area and estimated by sampling within 3 quadrates.

Starting from the ripeness of caryopses, also the seeds weight significantly decreased. The highest seed yields, calculated on the mean numbers of culms per m^2, were obtained in the first harvest (Table 3): from July 13th to August 3rd, the weight of the ripe seeds m^{-2} decreased significantly from 6.70 to 2.59 and from 17.08 to 6.61 g m^{-2} respectively for the two assessment methods adopted.

Conclusions

The results highlight the significant effect of the harvest time on the decrease of the number and the weight of ripe seeds per culm of *Bromus erectus* due to high seed losses, starting from the ripeness of caryopses. The results suggest the need to adopt the proper timing of seed harvest in order to avoid high seed shattering over short time periods. In order to complete the data results, further research is needed to test germination and viability of the seeds collected at the different harvest times.

A significant effect of the harvest time on the seed yield (expressed as number and weight of ripe seeds per unit area) was observed only when it was calculated on the mean number of culms both counted within the entire plot area and estimated by sampling within 3 quadrates. The different values obtained were due to a mean undervaluation of 41% observed by manual counting within the entire plot area compared to the sampling method. This should be further verified and compared with other similar studies.

The experiment should compare the potential seed yield of *Bromus erectus* obtained from spontaneous grasslands and from conventional seed production systems.

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Biodiversity and multifunctional value of seminatural grasslands in the Emilian Apennines (Italy)

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Abstract

In addition to their traditional agricultural use, grasslands can play a multifunctional role both from an environmental and an economic point of view. In a protected area of the Emilian Apennines (Monte Sole Park, Bologna province) a thorough analysis of grassland communities was performed by means of 101 field relevés following the Braun-Blanquet method. Five grassland typologies, depending on the management treatment, were recognised. Each typology was characterised by the specific biodiversity, the content of rare species, as well as by the presence and quantitative importance of officinal species (medicinal, biocide, dying, aromatic, bee attracting). Some typologies, such as the forage crops have a low specific biodiversity and quite good officinal values; some others, such as the abandoned grasslands, on the contrary, have a higher specific biodiversity and lower officinal values. When choosing the type of grassland management to adopt, the different characteristics of the grassland communities present in the area should be taken into account, in order to maintain in the territory an adequate balance between the different potentialities and functions offered by each of them.

Keywords: grasslands, specific biodiversity, grassland multifunctionality, officinal species, Emilian Apennines, grassland management

Introduction

In addition to their traditional agricultural use, grasslands can play a multifunctional role both from an environmental and an economic point of view, contributing to the conservation of the biodiversity (European Commission, 1992) as well as to the economic development (recreation, tourism, quality productions) of many marginal zones (Wytrzens and Mayer, 1999; Wytrzens and Neuwirth, 2004). Different approaches to management may, in turn, favour one or more of the various roles played by the grasslands, with consequential modifications in the composition of the flora (Koch and Masé, 2001; Jeangros and Bertola, 2002). Apart from the species of forage interest, grasslands can also provide space for rare species, of conservation interest, and species with various kinds of officinal properties. Officinal species could be of particular interest for many reasons. The presence of compounds, such as terpenes, improves, for example, the traceability of dairy products and meat originating from animals raised in specific geographic areas (Dumont *et al*., 1981; Viallon *et al*., 1999).
By analysing in detail the floristic composition of the grassland communities in a protected area of the Emilian Apennines, the present study aims to assess their different potentials, with a view to facilitating the management choices to be adopted in the area.

Materials and Methods

The study was conducted in the Monte Sole Park, a protected area of the Emilia-Romagna region, which is also a Site of Community Importance (SCI) following the 92/43/EEC Habitat Directive (European Commission, 1992). The Monte Sole Park extends over 6476 ha, its maximum elevation reaches 825 m a.s.l. and the climate is submediterranean, with 990 mm total annual rainfall, a mean annual temperature of 11.5 °C and absence of a real xerothermic

period. Grassland communities cover 6.8% of the whole territory and are characterised by different ways of management: some of them are periodically ploughed and sowed and then mown and fertilised, some were abandoned recently or for a longer time, others are irregularly grazed.
A detailed survey of the grassland communities present in the area was carried out by means of 101 phytosociological relevés. On the basis of data from the literature (Bruneton, 1995; Ricciardelli D'Albore and Intoppa, 2000) and evaluations based on direct experience, each of the species found was assigned to one of the following use categories: medicinal, biocide, dying, aromatic, bee attracting, with a score from 0 to 10, corresponding to the progressively rising importance of a species in a given category of use. For each relevé the van der Maarel (1979) transformation to the Braun-Blanquet cover values of the species was applied and separately, for each use category, the corresponding officinal value of each relevé was calculated, following the procedure used in the evaluation of the grazing value of grassland communities (Delpech, 1960; Daget and Poissonet, 1969). The officinal value indexes range from 0 (plant community where all the species have no officinal importance) to 100 (plant community where all the species are excellent officinal species (medicinal, biocide, dying, aromatic or bee attracting plants).
The relevés were also processed by an average linkage *cluster analysis* (Sokal and Michener, 1958) performed on the Euclidean distance matrix to identify the main vegetation typologies. Dynamic relationships among plant community types were defined and for each grassland typology the average specific content was calculated, as well as the average officinal value. Data were processed by STATISTIX for Windows package.

Results

The average linkage *cluster analysis* performed on the 101 relevés identified five groups corresponding to five different types of grassland communities at 0.30 value of the Euclidean distance: 1) Very recent forage crops in meso-xeric habitat (VR, 10 relevés); 2) Less recent forage crops in mesic habitat (LR, 28 relevés); 3) Semi-ruderal mesophilous grasslands of the *Salvio-Dactyletum* (SD, 14 relevés); 4) Semi-natural meso-xerophilous grasslands of the *Centaureo bracteatae-Brometum erecti* (CB, 27 relevés) ; 5) Semi-ruderal and meso-xerophilous grasslands of the *Agropyro-Dactyletum* (AD, 22 relevés). Within these five typologies we can delineate the following two dynamic sequences, the first in mesic habitats, the second one in meso-xeric habitats: 1) Less recent forage crops → (periodical mowing) → grasslands of *Salvio-Dactyletum* → (abandonment or grazing) → grasslands of the *Centaureo bracteatae-Brometum erecti*; 2) Very recent forage crops (abandonment) → grasslands of the *Agropyro-Dactyletum* → (abandonment or grazing) → grasslands of the *Centaureo bracteatae-Brometum erecti***.**
Floristic characterisation of the five typologies is reported in Table 1. A total of 283 species, belonging to 51 families, were found in these communities; 8 of these species are rare for the regional flora, and some of them, such as *Orchis militaris* L., *Dianthus seguierii* Vill., *Serapias vomeracea* (N.L. Burm.) Briq., *Gentiana cruciata* L. are very rare in the Emilia-Romagna region (Alessandrini and Bonafede, 1996). Floristic richness varies considerably: from 11 species/relevé (very recent forage crops) to 35 species/relevés in the *Centaureo bracteatae-Brometum* communities. It can be noted that both the total number of species and the number of rare species, and the average number of species/relevé increases according to the two dynamic sequences identified, and that the grasslands of the *Centaureo bracteatae-Brometum erecti* have the highest values of specific biodiversity as well as the highest number of rare species.

Table 1. Floristic characterisation of the five seminatural grassland typologies

Forage Crops / Communities *	VR	LR	SD	CB	AD
Total number of species	52	114	160	185	168
Total number of rare species	0	0	2	8	2
Average number of species	11.0±6.0	19.5±6.8	30.4±11.2	35.1±6.8	33.0±7.8
Average number of medicinal species	5.2±3.9	9.0±3.5	11.4±4.9	11.3±3.0	11.2±3.2
Average number of bee attracting species	8.6±6.0	14.8±5.1	23.4±8.5	26.0±4.9	25.0±5.5

* VR: very recent forage crops; LR: less recent forage crops; SD: *Salvio-Dactyletum* communities; CB: *Centaureo bracteatae-Brometum* communities; AD: *Agropyro-Dactyletum* communities.

As far as the species of officinal interest are concerned, the categories best represented are those of medicinal species and bee attracting species, while the biocide, dying and aromatic species are poorly represented. The latter are not indicated in Table 1 because of their very low scores. The total number of medicinal and bee attracting species is higher in the communities of *Salvio-Dactyletum*, *Centaureo bracteatae-Brometum* and *Agropyro-Dactyletum* compared to the more or less recent forage crops. The differences between the averages are statistically significant (medicinal species: F = 7.24, P = 0.0001; bee attracting species: F = 27.85, P = 0.0000). On the other hand, the number of medicinal and bee attracting species, comparing the average number of species/relevé, is a little higher in the forage crops than in the communities of *Salvio-Dactyletum*, *Centaureo bracteatae-Brometum* and *Agropyro-Dactyletum.*
In Table 2 the average medicinal and bee attracting values of the five grassland typologies are reported. The forage crops have the highest medicinal and bee attracting values. The old fields of *Agropyro-Dactyletum* maintain fairly good bee attracting and medicinal values that are quite comparable to those of more recent crops. On the other hand, the grasslands of *Salvio-Dactyletum*, and especially those of *Centaureo bracteatae-Brometum*, show medicinal and bee attracting values that are notably lower than those of the previously mentioned groups. (medicinal value: F = 5.80 P = 0.0004; bee attracting value: F = 10.61, P = 0.0000).

Table 2. Average medicinal and bee attracting values of the five grassland typologies

Forage Crops / Communities *	VR	LR	SD	CB	AD
Average medicinal value	16.1±17.9	10.5±5.0	8.3±6.4	4.6±3.9	16.3±13.9
Average bee attracting value	26.8±18.7	27.3±8.8	16.1± 8.5	12.2±7.2	17.9±7.7

* VR: very recent forage crops; LR: less recent forage crops; SD: *Salvio-Dactyletum* communities; CB: *Centaureo bracteatae-Brometum* communities; AD: *Agropyro-Dactyletum* communities.

Discussion

The forage crops, more or less recent, in the investigated territory present quite a small number of species, with good coverage values and mostly with officinal properties (medicinal, bee attracting). The periodically mown grasslands of *Salvio-Dactyletum*, and even more so the abandoned grasslands of *Centaureo bracteatae-Brometum* and *Agropyro-Dactyletum*, are made up of a greater number of species, each with a more modest quantitative importance; moreover, compared to the forage crops, a lower percentage of these species have officinal properties. Specific diversity correlates negatively with the average medicinal value (R = –0.530) as well as with the bee attracting value (R = –0.929). On the contrary, specific diversity correlates positively with the number of species of naturalistic and conservation interest (R = 0.734), such as the rare species. Finally, it can be noted that the variation pattern of medicinal values and bee attracting values of the five grassland typologies along the dynamic sequence, is very similar to the variation pattern of grazing values of the same typologies (Tonioli *et al*., 2004).

Conclusions

It is well known (Moog *et al*., 2002; Jacquemyn *et al*., 2003; Pavlu *et al.*, 2003) that the species composition of grassland communities is strongly dependent on the type of management. As far as the grassland communities considered here are concerned, the suspension of ploughing and sowing practices, and the adoption of management involving mowing or the complete abandonment of any type of farming practice, bring about important modifications to the overall specific diversity, as well as to the presence and quantitative importance of species of economic (officinal species, forage species) and/or conservation interest. Given that the specific biodiversity and the officinal and grazing values of the grassland communities under study are negatively correlated, their corresponding functions and potentialities are quite different. The management approaches to be adopted should therefore be aimed at reaching a balance between the different grassland types (forage crops, periodically mown grasslands, abandoned grasslands) so that the various functions, characteristic of each type, can be adequately represented in the investigated territory.

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Some results of the grassland monitoring scheme in Flanders (North Belgium)

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Abstract

In this study the species cover of 188 plots, measured in the first two years (2003 and 2004) of a grassland monitoring scheme, was used to describe the groups of grasslands found using a TWINSPAN analysis. Three groups of grasslands, the *Alopecurus geniculatus* group, the *Alopecurus pratensis* group and the *Arrhenaterum elatius* group, were identified. They are all poorly developed forms of known plant communities, respectively *Lolio-Potentillion* Tüxen 1947, *Alopecurion pratensis* Passarge 1964 and the *Arrhenaterion elatioris* Koch 1922. The first group can be found on wet, different soil types while the *Alopecurus pratensis* group is mainly situated on wet clay or loam soils. The *Arrhenaterum elatius* group is mostly located on dry or wet sand loam or loam soils. In the three groups cutting is the most common management regime, sometimes followed by aftermath grazing. Only in the *Alopecurus geniculatus* group is grazing also used as a management treatment. In most cases farmers are involved with the management.

Key words: grassland, Flanders, monitoring, vegetation-relevé

Introduction

Semi-natural grasslands have become very rare in Flanders (North Belgium). Due to the intensification of agriculture, many of these vegetation types are replaced by intensively used grasslands. As a consequence, many meadows and pastures in nature reserves are former intensively used grasslands or even fields. In order to optimize restoration policy and conservation practice, more information about the evolution of these grasslands is necessary. Therefore a grassland monitoring scheme was launched in 2003. Our objective in this study was to detect different groups of grasslands from similarities between the first set of measurements from the grassland monitoring scheme, as indicated by the use of TWINSPAN (Hill, 1979)

Materials and Methods

To record vegetation changes 48 permanent quadrats (in 2003 and 2004) were set up in several, formerly intensively used grasslands on different soil types and with different management practices (mowing, grazing or aftermath grazing). To cover the variation in each grassland, four vegetation plots (3m x 3m), which were considered as replicates, were set up in each permanent quadrat. The Londo scale for permanent plots was used for estimating the cover of the plant species (Londo, 1976). Every three years the quadrats will be monitored, 2006 being the first year all plots will be repeated. Data from the plots were processed in Turboveg (Hennekens, 1995) and TWINSPAN (Hill, 1979) was used to derive several groups. Data on soil conditions were obtained by using the Belgian Soil Map and Geographic Information System. For taxonomic identification Turboveg (Hennekens, 1995) was used, together with Zwaenepoel *et al.* (2002) to adjust for Flemish conditions.

Results and Discussion

Table 1 describes the groups identified by the use of TWINSPAN, and the soils and current management of the grasslands in these groups. The first group, the *Alopecurus geniculatus group*, consists of wet meadows, dominated by grasses that can tolerate waterlogging like *Alopecurus geniculatus*, *Agrostis stolonifera* and *Poa trivialis*. High productive grasses, such as *Lolium perenne* and *Holcus lanatus,* occur frequently. Common herbs like *Ranunculus repens* and *Trifolium repens* appear regularly. *Glyceria fluitans* and *Cardamine pratensis* are sporadically found. This group shows similarity to poorly developed forms of *Lolio-Potentillion anserinae* Tüxen 1947. These grasslands are situated on a number of wet soil types like clay, loam and loamy sand. In contrast with the other two groups, described below, grazing is frequently used as management treatment, but cutting is also a common management regime.

In the meadows and pastures of the second group, the *Alopecurus pratensis* group, *Poa trivialis, Holcus lanatus, Lolium perenn*e and *Alopecurus pratensis* are the dominant grasses. Two variants were distinguished. In one variant *Elymus repens*, *Agrostis stolonifera* and *Alopecurus geniculatus* occur frequently. *Ranunculus acris* is often abundantly present and *Phleum pratense* appears commonly. These species are lacking in the other variant, where *Bromus hordeaceus*, *Dactylus glomerata* and *Cirsium arvense* are found regularly. The grasslands of both variants belong to poorly developed forms of *Alopecurion pratensis* Passarge 1964. They are mostly found on wet clay or loam soils, which are sometimes flooded. Generally the management consists of cutting, sometimes followed by aftermath grazing. Grazing is seldom used as the management practice.

The third group, the *Arrhenaterum elatius* group, is characterised by less productive grasses like *Agrostis capillaris*, *Anthoxanthum odoratum*, *Arrhenaterum elatius* and *Festuca rubra. Poa trivialis, Bromus hordeaceus* and *Dactylis glomerata* occur frequently. Compared with the other two groups, the *Arrhenaterum elatius* group has the highest species diversity. Common herbs like *Ranunculus acris*, *Rumex acetosa, Cardamine pratensis* and *Lotus corniculatus* can often be found. *Plantago lanceolata*, *Heracleum sphondylium* and *Hypericum perforatum* appear sporadically and indicate affinity to the *Arrhenaterion elatioris* Koch 1922. The grasslands of this group are mostly situated on dry or wet sand loam or loam soils. Cutting or cutting with aftermath grazing are the common management regimes; grazing is seldom used.

Table 1. Different vegetation groups of the grassland monitoring scheme with their main characteristics

	Alopecurus geniculatus group	*Alopecurus pratensis* group	*Arrhenaterum elatius* group
Soil	different soil types: clay, loam, loamy sand	mostly on clay or loam	mostly sandloam, loam
Hydrology	wet	wet, sometimes inundation	dry or wet
Management	grazing, cutting	cutting, sometimes aftermath grazing, seldom grazing	cutting, aftermath grazing
Phytosociology	poorly developed *Lolio-Potentillion anserinae* Tüxen 1947	poorly developed *Alopecurion pratensis* Passarge 1964	poorly developed *Arrhenaterion elatioris* Koch 1922

Conclusions

TWINSPAN (Hill, 1979) analysis of the first set of measurements from the grassland monitoring scheme indicated three groups of grasslands: the *Alopecurus geniculatus* group, the *Alopecurus pratensis* group and the *Arrhenaterum elatius* group. They all belong to poorly developed forms of known plant communities, respectively *Lolio-Potentillion* Tüxen 1947, *Alopecurion pratensis* Passarge 1964 and the *Arrhenaterion elatioris* Koch 1922. Cutting is the most common management regime, sometimes followed by aftermath grazing. Only in the *Alopecurus geniculatus* group grazing is frequently used as management treatment. This group can be found on wet, different soil types while the *Alopecurus pratensis* group is mainly situated on wet clay or loam soils. The *Arrhenaterum elatius* group is mostly located on dry or wet sand loam or loam soils.

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An expert model for predicting species richness in grasslands: Flora-predict

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Abstract

Expert models are a novel modelling approach in order to evaluate the impact of agricultural practices on biodiversity. These models are based only on the knowledge of some biological characteristics of animal or plant species and only on field observations and biometric measurements to build a database. An expert model that predicts plant species presence in any herbaceous ecosystem has been developed. This model is based on a database of 17 life traits or biological characteristics already identified in the literature for 2912 plant species. In order to predict the presence probability of grassland plant species, the information of the traits and characteristics was aggregated with data on farming practices and environment factors by fuzzy logic associated with an expert system. This model allows predicting a list of plant species with their patrimonial value, without realizing floristic site-inspection.
This model approach has been the first concrete application of functional groups theory based on life traits of plant species to predict plant presence according to human activities and environmental factors.

Keywords: agricultural practices, biodiversity, livestock farming, grasslands, model, species richness

Introduction

For 50 years, in western countries land has been exclusively considered as a generator of production and has been cultivated in order to guarantee food security. There has been great pressure on farmers to increase agricultural productivity. They succeeded in doing so due to the progress in mechanization and chemical treatments (fertilizers and pesticides). This resulted in increasing pollution of natural sites and impoverishment of biodiversity (Arondel and Girardin, 2000). For example, the excess of nitrogen spread on grasslands decreased the floristic diversity (Foster and Gross, 1998) and led to the disappearance of protected species or habitats. The impact of farming systems on the environment needs tools that can help decision makers or farmers to decide how to account for agri-environmental criteria. In order to improve the sustainability of grassland husbandry, it is necessary to take into account the environmental risk through agricultural practices. Among them, agro-ecological indicators have been successfully developed for decision-making and environment diagnostics (Girardin *et al.*, 2000). Our objectives were to apply this method to evaluate the impact of agricultural practices on the floristic diversity of grasslands at fields scale.

Materials and Methods

Floristic diversity is restricted to species richness of grasslands and meadows, and species dominance was not utilised in the prediction. In order to predict species richness, we elaborated a mechanistic model based on the response of each plant species to cultural practices, according to its biological characteristics. The biological characteristics considered in this model were plant attributes *sensu* Lavorel and Garnier (2002) and development preferences with Ellenberg indicator values (Ellenberg *et al.*, 1991). The mechanistic model we propose is based on an expert system using a collection of fuzzy membership functions and decision rules. This technique is a robust one when uncertain or imprecise data are used (Bockstaller *et al.*, 1997). We used 12 indices based on plant responses to agricultural practices and their effects (e.g. grazing, mowing, flooding) and to the abiotic environment (e.g. soil acidity, temperature, fertility, stress salinity) in order to calculate the probability presence of 2912 species (Pervanchon, 2004). For example, exploitation intensity index used three species characteristics: sensibility to defoliation, sensibility to grazing and sensibility to stocking rate.

In this paper, we describe the construction of the sensibility index to defoliation (I_d), which was the result of the aggregation of species vulnerability index (I_{Vul}) and the index of species sensibility to cutting (I_{Cut}). The I_{Cut} were the Ellenberg indicator values of cutting sensibility frequencies (Ellenberg *et al.*, 1991). The I_{Vul} was constructed with an expert system in association with a fuzzy logic method and it takes into account three biological characteristics of plant species involved in herbivore behaviour: leaf area, leaf anatomy and degree of leaf senescence. These biological data have been obtained from bibliographic data bases (i.e. Kleyer, 1995; Plantureux, 1996).

Results and Discussion

For the three biological characteristics, the membership to a fuzzy set favourable (F) and a fuzzy set unfavourable (U) has been defined (Table 1). For each class of these biological characteristics, the probability may take values between 0 (species absent) or 1 (species maximum presence probability). The expert model and decision rules applied in the construction and aggregation of these three biological characteristics are presented in Table 2.

Table 1. Description of the favourable and unfavourable probability values retained for leaf area, leaf anatomy and degree of leaf senescence

Biological characteristics	Values	Favourable (F)	Unfavourable (U)
Leaf area	>100 cm²	1	0
	20–100 cm²	1	0
	10–20 cm²	0.8	0.2
	5–10 cm²	0.6	0.4
	2–5 cm²	0.4	0.6
	1–2 cm²	0.2	0.8
	0.2–1 cm²	0.4	0.6
	0.04–0.2 cm²	0.8	0.2
	<0.04 cm²	1	0
Leaf anatomy	microphyllous	0.9	0.1
	hygrophytic leaf	0.5	0.5
	grass leaf	0.2	0.8
Lignification	ligneous species	1	0
	semi-ligneous	0.5	0.5
	herbaceous	0	1

Table 2. Decision rules applied in the aggregation of leaf area, leaf anatomy and degree of leaf senescence used in the construction of species vulnerability index (F: favourable, U: unfavourable)

Leaf anatomy	F				U			
Leaf area	F		U		F		U	
Lignification	F	U	F	U	F	U	F	U
Species vulnerability index value	**1**	**2**	**2**	**5**	**4**	**6**	**6**	**10**

In order to propose I_{Defol}, we created decision rules and utilized the fuzzy logic method to calculate the values of I_{Vul} and I_{Cut}. The values of I_{Cut} were continuous, and with discontinuous values in the case of I_{Vul}. For I_{Cut} we proposed the presence probability of species in relation with the index values (Table 3). For I_{Vul}, we used fuzzy logic sinusoidal functions (Equations 1 and 2) to exclude the problem of discontinuous values and obtain the presence probability of species:

$$D_{a\,F} = 0.5+0.5*SIN[\Pi*((I_{Vul} - Lim_{low})/(Lim_{upp} - Lim_{low}) - 0.5))] \quad \text{eq. 1}$$
$$\text{if } I_{Vul} < Lim_{low}, D_{a\,F} = 0$$
$$\text{if } I_{Vul} > Lim_{upp}, D_{a\,F} = 1$$

$$D_{a\,U} = 0.5+0.5*COS[\Pi*(I_{Vul} - Lim_{low})/(Lim_{upp} - Lim_{low})] \quad \text{eq. 2}$$
$$\text{if } I_{Vul} < Lim_{low}, D_{a\,U} = 1$$
$$\text{f } I_{Vul} > Lim_{upp}, D_{a\,U} = 0$$

with $D_{a\,F}$: degree of membership of favorable class, $D_{a\,U}$: degree of membership of unfavourable class, I_{Vul}: species vulnerability index value, Lim_{low}: lower limit of species vulnerability index value, Lim_{upp}: upper limit of species vulnerability index value.

Table 3. Description of the favourable (F) and unfavourable (U) probability values retained in the species sensibility to cutting index

Species sensibility to cutting index	Probability values	
	favourable (F)	unfavourable (U)
0	0.7	0.3
1	0	1
2	0	1
3	0.1	0.9
4	0.3	0.7
5	0.5	0.5
6	0.7	0.3
7	0.8	0.2
8	1	0
9	1	0
10	1	0

With our propositions, the presence probability of species in relation to I_{Vul} and I_{Cut} was obtained. Decision rules were proposed in order to aggregate these two indices (Table 4). For each species, I_{Defol} was calculated with the final equation of the fuzzy logic method as follows:

$$I_{Defol} = \Sigma[min(Ri)*(Ri)] / \Sigma[min(Ri)] \quad \text{eq. 3}$$

with I_{Defol} sensibility index to defoliation, min(Ri): lower limit of decision rules i, Ri: conclusion rules i.

Table 4. Decision rules applied in the aggregation of species sensibility to cutting index and species vulnerability index (F: favourable, U: unfavourable).

Index	Decision rules			
Species vulnerability index	F		D	
Species sensibility to cutting index	F	D	F	D
Conclusion rules	10	7	1	1

Conclusion

Information on biological characteristics has been aggregated with data on farming practices and environmental factors using fuzzy logic associated with an expert system and decision rules. This prediction method allows forecasting a list of grassland plant species predictable under conditions of agricultural practices and environment without requiring floristic site-inspection.

Acknowledgements

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Plant functional types approach: a tool to analyze sward structure and vegetation dynamics in wet grasslands?

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Abstract

We tested the relevancy of using a plant functional types approach to analyse the effect of grazing on the sward structure and the vegetation dynamics of marsh grassland. We compared plant traits along a gradient of three grazing intensities crossed with four topographic levels within grazing sites, integrating a gradient in flooding duration. In these 11 communities (one plot as only three levels) the measured traits were: specific leaf area, leaf dry matter content, vegetative and reproductive plant heights, leaf thickness, leaf nitrogen concentration, leaf angle, leaf/stem biomass ratio, as well as plant phenology. These measurements were carried out on 13 species which together contributed 80% of spring herbage mass.

Grazing intensity varied between sites but also within sites, and thus between topographic levels. Specific leaf area, leaf dry matter content, and vegetative plant height, calculated at the community level, were able to differentiate the variation in grazing intensity between sites and within sites. Variation in grazing intensities between topographic levels was so important that the flooding gradient was not discriminated by plant traits.

We conclude that the plant functional types approach is useful for analysing sward structure and vegetation dynamics in these marshes and proposing a more experimental design.

Keywords: plant traits, marshlands, grassland, sward structure, vegetation dynamics

Introduction

The remarkable biodiversity of French Atlantic marshlands is strongly linked with sward dynamics, this latter being itself related to livestock husbandry and water management practices. We are interested in the effect of livestock husbandry practices on sward structure (grass height and its spatial and temporal heterogeneity) and their consequences for the management of habitats for migratory and breeding wader birds (Tichit *et al*., 2004). We think that a grassland vegetation approach based on plant functional types (Cruz *et al*., 2002) would be useful to understand and predict the evolution of both the floristic composition and the structure of grassland vegetation under grazing. In 2004, an exploratory design on the Rochefort marsh (Charente-Maritime, France) was carried out in order to give a first characterisation of the variability in plant functional traits along two gradients: grazing pressure and increasing flooding durations.

Material and Methods

The design consisted of three grassland plots (B = 2.97 ha, L = 2.90 ha G = 6.50 ha) characterised by a medium fertility level (Nitrogen Nutrition Index: 60, 50, 47% respectively) and a strong topographic heterogeneity. These plots were grazed by cattle at various grazing pressures (130, 200, 300 DLU ha^{-1} year^{-1} respectively). This grazing index, expressed in Days Livestock Unit [Σ (stocking rate x days)] per hectare and per year, was calculated following

Hodgson (1979). In each plot, an exclosure (10 m x 10 m) was established along a topographic transect covering four different zones of various flooding durations: the mesophilous level (M) (no winter flooding), the meso-hygrophilous level (MH) (two months of flooding, 2 cm of water), the upper hygrophilous level (Hs) (five months, 10 cm) and the lower hygrophilous level (Hi) (eight months, 15 cm) (Bouzillé *et al*., 2001). Only the L plot had no Hi level. We then analysed plants in eleven different environments.
We took into account nine plant traits: specific leaf area (SLA), leaf dry matter content (LDMC), vegetative (VegH) and reproductive (RepH) plant heights, leaf thickness (LT), leaf nitrogen concentration (dry matter) (LNC), leaf angle (LA), leaf/stem biomass (dry matter) ratio (LSBR), as well as ear emergence stage (EES). These traits were measured for the more abundant species of each community (their summation constitute at least 80% of aerial biomass available to cattle in spring). This resulted in thirteen species being considered.
The analytic method used followed those proposed in Lavorel *et al*. (1999) and shows the emergent groups (typology of species based on traits similarity) as well as response attributes groups (groups of sensitive traits) to flooding and grazing pressure.

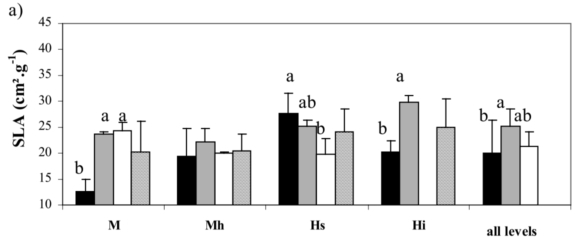
Results

A Principal Component Analysis (PCA, Statistica6) performed on all traits at both community and species levels, showed the importance of LDMC, SLA and VegH for the emergent groups discrimination. An Ascendant Classification (AC) and the study of the PCA allowed us to distinguish and characterise five groups of species (Table 1): 1 – *Carex divisa*, *C. riparia*, *Juncus gerardi*, *Festuca rubra* (low SLA, high LDMC and high LSBR), 2 – *Lolium perenne*, *Dactylis glomerata*, *Elytrigia repens* (medium SLA, medium LDMC, low LSBR), 3 – *Alopecurus bulbosus* (medium SLA, medium LDMC, low VegH, high LA), 4 – *Agrostis tenuis*, *A. stolonifera*, *Hordeum secalinum* (high SLA, low LDMC and LSBR, late EES, low LT), 5 – *Oenanthe fistulosa*, *Eleocharis uniglumis* (very low LDMC).
For the response attributes, the mean traits at the community level, balanced by the relative abundance of species were compared using ANOVAs or Kruskal-Wallis tests. These comparisons showed that LDMC, SLA and VegH were the most sensitive to the gradients (grazing pressure and hydromorphy). Only VegH gave a significant discrimination of all communities.
Comparing the SLA, LDMC and VegH values by plot, all topographic levels together (Figure 1), we observed a positive relationship between SLA and grazing intensity, and a negative one between LDMC, VegH and grazing intensity. However these differences beetwen plots were mainly due to the effect of M and Hi levels. The intermediate levels (Mh, Hs) generally showed no significant differences.

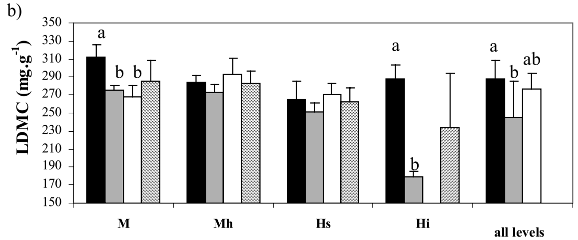
Table 1. Emergent groups of species from a Principal Component Analysis and an Ascendant Classification on all plant functional traits (SLA: specific leaf area, LDMC: leaf dry matter content, LSBR: leaf/stem biomass ratio, LNC: leaf nitrogen concentration, VegH: vegetative plant height, RepH: reproductive plant height, LA: leaf angle, EES: ear emergence stage, LT: leaf thickness). [Tabulated data expressed as $_{nb}$ MEAN $^{standard\ deviation}$]

Group	Species	SLA cm² g⁻¹	LDMC mg g⁻¹	LSBR	LNC mg g⁻¹	VegH cm	RepH cm
1	*Carex divisa*	$_{84}$ 144 $^{26.8}$	$_{84}$ 309 $^{29.7}$	$_{120}$ 2.59 $^{1.16}$	$_{12}$ 28 $^{2.7}$	$_{120}$ 25 $^{7.4}$	$_{120}$ 39 $^{12.5}$
	Carex riparia	$_{21}$ 142 $^{13.4}$	$_{21}$ 311 $^{16.3}$	$_{30}$ 5.06 $^{1.77}$	$_{3}$ 25 $^{3.0}$	$_{30}$ 42 $^{8.8}$	$_{30}$ 72 $^{6.6}$
	Juncus gerardi	$_{42}$ 108 $^{25.9}$	$_{42}$ 283 $^{19.6}$	$_{60}$ 1.74 $^{1.00}$	$_{6}$ 29 $^{2.2}$	$_{60}$ 26 $^{5.4}$	$_{60}$ 39 $^{7.2}$
	Festuca rubra	$_{42}$ 90 $^{32.7}$	$_{42}$ 327 $^{15.5}$	$_{60}$ 3.96 $^{1.34}$	$_{6}$ 23 $^{5.1}$	$_{60}$ 49 $^{10.8}$	*
2	*Lolium perenne*	$_{84}$ 218 $^{49.3}$	$_{84}$ 275 $^{25.4}$	$_{120}$ 0.55 $^{0.70}$	$_{12}$ 18 $^{2.8}$	$_{120}$ 44 $^{7.9}$	$_{120}$ 65 $^{10.6}$
	Dactylis glomerata	$_{21}$ 234 $^{27.3}$	$_{21}$ 270 $^{19.8}$	$_{30}$ 0.85 $^{0.39}$	$_{3}$ 27 $^{1.9}$	$_{120}$ 26 $^{6.3}$	$_{120}$ 94 $^{15.3}$
	Elytrigia repens	$_{63}$ 225 $^{58.6}$	$_{63}$ 282 $^{32.0}$	$_{90}$ 0.48 $^{0.45}$	$_{9}$ 34 $^{4.0}$	$_{90}$ 53 $^{12.5}$	$_{90}$ 70 $^{12.8}$
3	*Alopecurus bulbosus*	$_{84}$ 209 $^{62.0}$	$_{84}$ 263 $^{23.1}$	$_{120}$ 1.13 $^{0.95}$	$_{12}$ 31 $^{9.8}$	$_{120}$ 9 $^{5.7}$	$_{120}$ 29 $^{12.8}$
4	*Agrostis tenuis*	$_{21}$ 331 $^{63.0}$	$_{21}$ 246 $^{19.7}$	$_{30}$ 0.31 $^{0.05}$	$_{3}$ 28 $^{1.2}$	$_{30}$ 41 $^{3.8}$	$_{30}$ 41 $^{5.9}$
	Hordeum secalinum	$_{84}$ 297 $^{63.0}$	$_{84}$ 256 $^{20.1}$	$_{120}$ 0.30 $^{0.30}$	$_{12}$ 31 $^{5.2}$	$_{120}$ 43 $^{8.3}$	$_{120}$ 66 $^{14.4}$
	Agrostis stolonifera	$_{126}$ 284 $^{66.5}$	$_{126}$ 256 $^{35.2}$	$_{180}$ 0.39 $^{0.30}$	$_{18}$ 38 $^{7.5}$	$_{180}$ 41 $^{11.0}$	$_{180}$ 56 $^{14.8}$
5	*Eleocharis uniglumis*	$_{21}$ 142 $^{16.6}$	$_{21}$ 134 $^{13.9}$	*	$_{3}$ 33 $^{2.4}$	$_{30}$ 27 $^{4.0}$	$_{30}$ 31 $^{3.8}$
	Oenanthe fistulosa	$_{21}$ 316 $^{86.9}$	$_{21}$ 157 $^{20.4}$	*	$_{3}$ 47 $^{1.9}$	$_{30}$ 32 $^{4.8}$	$_{30}$ 37 $^{5.0}$

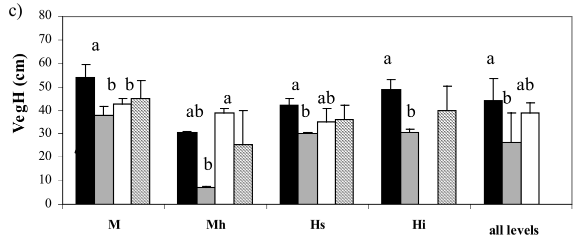
Group	Species	LA	EES days	LT µm
1	*Carex divisa*	$_{120}$ 23 $^{8.1}$	$_{4}$ 107 $^{9.4}$	$_{3}$ 259 $^{12.8}$
	Carex riparia	$_{30}$ 14 $^{5.0}$	$_{1}$ 104 $^{0.0}$	$_{5}$ 333 $^{50.0}$
	Juncus gerardi	$_{60}$ 20 $^{5.6}$	$_{2}$ 136 $^{4.2}$	$_{3}$ 393 $^{6.3}$
	Festuca rubra	$_{60}$ 11 $^{5.0}$	*	$_{3}$ 207 $^{35.1}$
2	*Lolium perenne*	$_{120}$ 22 $^{7.4}$	$_{4}$ 152 $^{7.2}$	$_{5}$ 212 $^{19.7}$
	Dactylis glomerata	$_{120}$ 36 $^{11.8}$	$_{1}$ 118 $^{0.0}$	$_{2}$ 191 $^{37.9}$
	Elytrigia repens	$_{90}$ 24 $^{8.7}$	$_{3}$ 157 $^{5.8}$	$_{4}$ 160 $^{5.5}$
3	*Alopecurus bulbosus*	$_{120}$ 44 $^{9.6}$	$_{4}$ 110 $^{5.9}$	$_{4}$ 238 $^{19.2}$
4	*Agrostis tenuis*	$_{30}$ 19 $^{10.8}$	$_{1}$ 161 $^{0.0}$	$_{5}$ 189 $^{60.3}$
	Hordeum secalinum	$_{120}$ 24 $^{15.2}$	$_{4}$ 158 $^{4.0}$	$_{5}$ 166 $^{12.7}$
	Agrostis stolonifera	$_{180}$ 25 $^{10.8}$	$_{6}$ 161 $^{0.0}$	$_{3}$ 186 $^{18.0}$
5	*Eleocharis uniglumis*	*	$_{1}$ 118 $^{0.0}$	$_{5}$ 1103 $^{137.6}$
	Oenanthe fistulosa	*	$_{1}$ 154 $^{0.0}$	*



	M	Mh	Hs	Hi
B	c	bc	c	b
G	bc	c	b	a
L	a	ab	b	-
BGL	b	ab	ab	a



	M	Mh	Hs	Hi
B	a	b	b	ab
G	a	a	ab	b
L				-
BGL				



	M	Mh	Hs	Hi
B	a	c	bc	ab
G	a	b	ab	ab
L	a	ab	b	-
BGL	a	b	ab	ab

Figure 1: Repartition of community traits by plot (B, G, L) and by topographic level (M, Mh, Hs, Hi).
a) SLA ; b) TMS ; c) VegH.
On graphics : two plots with the same letter are not significantly different.
In tables : two topographic levels with the same letter are not significantly different ($\alpha = 0.05$) (ANOVAs and Kruskall -Wallis tests).

Discussion

At the species level, these preliminary results give an idea of the range of value of traits for the main species in these type of treatments. They suggest a possible organisation of graminoids species in three main groups according to SLA and LDMC values.
At the community level, the relationship beetwen SLA, LDMC at the plot level and grazing pressure by plot are in agreement with the literature (Cruz *et al*., 2002): high grazing pressure promotes high SLA and low LDMC. However, these relations were given at Mh and Hs levels. We can interprete this result as an effect of spatial and temporal variability of grazing pressure within the plots, variability linked with grazing behaviour of cattle in these very heterogeneous environments (Loucougaray *et al*., 2004). The selective forage intake by cattle is more important at low stocking rates. The attractiveness to animals of a community at a particular topographic level especially depends on overall stocking rate at the plot level, relative area of this community, its floristic composition (some species are more palatable than others), or its accessibility at particular periods (flooding). All these factors induce a very heterogeneous spatial distribution of grazing pressure within the plots. VegH seems to illustrate in a coherent manner these grazing pressure variations.

Conclusion

In this environment, LDMC, SLA and VegH are indicators of the variability in grazing pressure. The plant functional types approach thus seems to be adaptable for our purpose on wet grasslands. The interferences between the grazing pressure and topographic levels within the plots does not allow the identification of a specific effect of hydromorphy on plant traits. A more experimental design, controlling both factors at the community level would be more efficient to analyse this complex environment. This functional approach on wet grasslands, based on an analysis of mean values for plant traits at the community level would probably be improved by an analysis of intra-community variability of plant traits.

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Cattle management for biodiversity conservation in an alpine pasture

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Abstract

The aim of this work was to evaluate different management techniques of dairy farming on alpine pastures in order to ensure grassland biodiversity conservation in a Central-East Alps alpine mountain barn (Malga Juribello, Trento, Italy). The experimental area was 40 ha, and its altitude ranged between 1,820 and 2,230 m a.s.l. The pasture was divided in two 20 ha paddocks and each was grazed by 12 cattle for 40 days. One group (paddock B) received 2 Kg of supplementary feeding per day, while the other group (paddock A) received 6 Kg per day. To analyze vegetation dynamics, 13 exclusion cages were placed in each paddock. Phytomass samples inside and outside the cages were collected to determine herbage utilisation rates. Vegetation was analysed inside and outside the cages to assess animal selectivity. Species composition and grassland grazing were strongly influenced by the two different feeding rates. Low rates of supplementary feeding seemed to force the cows to graze higher phytomass rates (68% in paddock B and 47% in paddock A), while high concentrate rates allowed the cows to make preferential choices. Low-fed animals were less selective and ate the less palatable plants such as *Deschampsia caespitosa* and *Nardus stricta* resulting in an increase of the number of species in paddock B.

Keywords: alpine pasture, supplementary feeding, plant selection, biodiversity conservation

Introduction

The primary role of grazing animals in grassland biodiversity management is maintenance and enhancement of sward structural heterogeneity by selective defoliation due to dietary choices. The impact of grazing on vegetation is influenced significantly by management factors, such as the type of animals and their stocking rate, as well as additional environmental factors. The effects of grazing on vegetation are very controversial within the scientific community. Some authors demonstrated that the extensive use of pastures favour the maintenance of biodiversity (Bornard and Dubost, 1992). Others showed that intensive pasture grazing, concentrated in short periods, is better, and could perhaps avoid having to keep animals on grassland for long periods (Jans and Troxler, 1990). A critical review of the effects of extensification on biodiversity has been published recently by Marriott *et al*. (2004). One of the practices commonly used in pastures is supplementation of cattle with concentrates. The genetic improvement of dairy breeds, even of the non-specialized ones, has caused a general increase in the animal's nutritional requirements; grass ingested by dairy cattle grazing on alpine pastures cannot normally satisfy these nutritional requirements (Andrighetto *et al*., 1996).

In this context, the aims of this project were:

i) to test replacement between supplementary feeding and pasture utilization in two experimental areas in which cattle were integrated with different levels of feeding;

ii) to test if cattle differently selected the main plant species in these two circumstances;

iii) to evaluate the possible vegetation dynamics.

Materials and Methods

This work aims at evaluating different management techniques of dairy farming on alpine pastures in order to ensure grassland biodiversity conservation in the Central-Eastern Alps (P.sso Rolle, Trento, Italy). The site investigated is characterised by a climate with long, cold winters and warm wet summers. The pasture is a typical *Nardetum alpigenum* association, which has replaced the native woodland and shrub land. This replacement has happened due to a continuous human and animal action (Orlandi *et al.*, 2000). The experimental area was 40 ha, and its altitude ranged between 1,820 and 2,230 m a.s.l. The pasture was divided into two 20 ha paddocks, each of them grazed by 12 cattle for 40 days. One group, paddock B, received 2 kg of supplementary feeding per day, while the other group, paddock A, received 6 kg. To analyse vegetation dynamics, 13 exclusion cages of 1 square meter were placed in each paddock during the summer of 2004. Biomass and necromass samples inside (at the end of the grazing period) and outside (at the beginning and end of the grazing period) the cages were completely collected to determine herbage utilisation rates. The average species composition of the cattle diet was evaluated by means of comparison (visual estimation and manual separation and weighing of species or groups of species of a sub-sample of harvested material) between the vegetation inside and outside the cages at the beginning and end of the grazing period. Differences between the two plots were assessed using t-tests.

Results and Discussion

The primary production of the pasture was equivalent in both enclosures (Table 1), with a higher quantity of necromass in the low cow-feed integration area due to the previous years' differing pasture management (in 2003 the two areas were managed as in 2004).

Table 1. Biomass and necromass in the two experimental areas (Paddock A: high cow-feed integration. Paddock B: low cow-feed integration)

Date	Biomass (g m^{-2})		Necromass (g m^{-2})	
	Paddock A	Paddock B	Paddock A	Paddock B
06/23/2004 (outside)	19.65	21.26	31.90*	14.87*
08/09/2004 (inside)	71.90	68.96	13.16	8.11
08/09/2004 (outside)	43.95	36.32	11.70**	4.55**
Herbage utilisation (%)	47**	68**		

* < 0.05 ,** p < 0.01.

At the end of the growing season a significant difference in the utilization of the two areas (Table 1) was found, even though the development of the two pastures was similar (Table 1, biomass and necromass inside the cages). Comparing the phytomass percentages grazed by cattle, a higher grazing rate (Table 1) was found in the pasture with the lower integration. In the enclosure with a high integration, the cattle grazed less, causing an increase of necromass at the end of the growing season (Table 1; 9 August).

Table 2. Use of the main species (cover > 1%) of the two areas (Paddock A: heigh cow- feed integration. Paddock B: low cow- feed integration). Utilisation has been calculated based on weight

Species or groups of species	Utilisation (%)	
	Paddock A	Paddock B
Grasses with high/medium forage values		
Agrostis tenuis	45.7	57.2
Anthoxanthum alpinum	58.6	65.3
Festuca rubra (group)	52.8	60.1
Phleum alpinum	82.7	77.4
Grasses with low forage values		
Carex sp.	37.9	46.9
Deschampsia caespitosa	36.7	40.9
Nardus stricta	29.3*	50.4*
Legumes		
Trifolium sp.	59.3	70.1
Forbs		
Alchemilla vulgaris	63.2	63.6
Leontodon autumnalis	53.8	54.1
Leontodon hispidus	63.0	68.5
Potentilla aurea	65.6	59.5
Potentilla erecta	30.2*	68.9*
Ranunculus montanus	40.8	45.5
Other forbs	43.0*	77.3*

* < 0.05

The vegetation, at the beginning of the growing season, was the same in both areas. The only statistical difference was the presence of legumes, which were higher in the plot with lower cow – feed integration (9.3 vs. 1.2 %, $p<0.01$), due to the higher cover of *Trifolium* sp. All the main grasses showed no cover differences between the two plots. According to the analyses of grazing of the individual species (Table 2), all grasses with high /medium forage value and legumes were grazed intensively in both areas. Some differences were found for forbs (especially *Potentilla erecta*) which were utilised more intensively from cattle in paddock B. These animals seemed to be less selective by also eating more species with low forage value such as *Nardus stricta* (Table 2). No differences were found in the utilisation of *Deschampsia caespitosa***.** However, where it covered more than the 10 %, *Deschampsia* was grazed more intensively by the cattle with the lower integration (59.3 vs. 30.0, $p<0.05$).

Conclusions

The two paddocks were characterised by the same productivity and cattle reduced biomass in both of them at the end of the grazing period. A clear relation was observed with the quantity of concentrates offered. In fact, in the area with the low integration rate, a higher grazing rate and a less selective behaviour of cattle in relation to plant species was observed. In this area, cattle also grazed species with lower forage value such as *Nardus stricta* and *Deschampsia caespitosa* (species which are becoming invasive in many subalpine pastures) substantially reducing their cover. In paddock A, feed integration partially substituted grazing activity and resulted in both an increased necromass at the end of the vegetation period and a strong selective behaviour of cattle.

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Possibilities for beef production on grasslands situated in nature conservation areas

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Abstract

In 2000–2004 an experiment was carried out to investigate beef production from heifers under extensive grazing conditions on pastures situated in a nature conservation area (B. Papi Reserve near Brody Experimental Station, Poland). The area is under legal natural protection and requires special extensive agricultural management. Mineral fertilization of pasture was restricted to 50 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5 and 90 kg ha^{-1} K_2O applied in spring. Experimental animals (118–133 heifers) were purchased in spring, grazed 24 hours per day during a grass-growing season lasting 177–196 days and then sold in November. The botanical composition of the sward and dry matter yield of pastures were estimated. Daily gains of heifers were measured by weighing and an economic evaluation of the effectiveness of beef production was carried out. Extensive grazing of heifers appeared to be an economically justified and ecologically optimal method of agricultural utilization of nature conservation areas with positive effects on grassland biodiversity. During the pasturing season daily liveweight gains of animals ranged from 405 to 730 g depending on weather conditions. Beef production from heifers on this type of grassland can be improved by adjusting the stocking rate to the yield potential of the pasture.

Keywords: economical efficiency, extensive pasture, heifers, nature conservation area

Introduction

Under conditions of low-input grassland management, grazing with beef cattle is considered an appropriate method of sward utilization (Jilg and Briemle, 1993). This method of cattle rearing is also advised from a nutritional point of view, being an environment-friendly technology for high quality meat production (Troxler and Jans, 2000). For both organizational and economic reasons, it is recommended that grazing animals are kept on pastures for as long as possible during the day, and for a prolonged pasturing season. In searching for balanced, environmentally and landscape-friendly forms of management of permanent grassland (Nösberger *et al.*, 1994), an experiment was carried out on the possibilities for beef production from pasture on areas under legal protection. The objective of this work was to evaluate the effectiveness of beef production on extensive pasture situated in the nature conservation areas.

Materials and Methods

During 2000–2004, studies were carried out to evaluate the effectiveness of beef production from heifers under extensive grazing conditions on pastures in a nature conservation area, the B. Papi Reserve near the Brody Experimental Station of August Cieszkowski Agricultural University Poznań, Poland (52º26´N, 16º18´E). Since the area is under legal natural protection, it requires special extensive agricultural management. Therefore, the pasture established here was intended for 24-hour grazing using heifers. The area of pasture (42.4 ha) was divided into 6 paddocks which were fenced using traditional concrete posts and three rows of barbed wire. Experimental animals (118–133 heifers) of the black and white lowland breed were purchased in spring from among animals which were selected as unsuitable for milk production and grazed during a grass-growing season lasting 177–196 days. One person was employed to service the herd for 4 hours per day. Forage from the pasture was the only feed the heifers received. Fresh water was brought to the animals twice a day and they also received straw and mineral supplements. At the end of the pasturing season in November all the animals from the herd were sold.

The pasture had been was established in 1988 on a muck soil formed from low-bog peats (pH_{KCl} 6.5, N_t – 0.68%, P_2O_5 – 53.2 mg 100 g^{-1}, K_2O – 37.0 mg 100 g^{-1}, Mg – 7.8 mg 100 g^{-1}) and the following mixture sown (% values based on seed numbers): *Bromus inermis* (10%), *Dactylis glomerata* (10%), *Festuca pratensis* (15%), *Lolium perenne* (20%), *Phleum pratense* (15%), *Poa pratensis* (20%), *Trifolium repens* (10%) in the total seed rate of 35 kg ha^{-1}. Additionally, in 1993 and 1998 white clover seed was oversown at 3 kg ha^{-1}. Mineral fertilization of pasture was restricted to 50 kg ha^{-1} N, 50 kg ha^{-1} P_2O_5 and 90 kg ha^{-1} K_2O applied in spring.

The botanical composition of the sward was estimated using the point method (Levy, 1933) and dry matter yield of pasture (Filipek, 1983). Daily liveweight gains of heifers were measured by weighing. The evaluation of the economic effectiveness of beef production was performed using the method of differential computation and calculation of total costs (Ströbel, 1987). All calculations were made on the basis of 2004 prices, assuming the purchase and sale price on the same level of 3.15 PLZ kg^{-1} (1 PLZ = 0.25 EUR).

Results

Changes in botanical composition of the sward were observed over successive years of pasture utilization (Fig. 1). The dominant sward component was *Poa pratensis.* Its proportion of the botanical composition ranged from 42.5% in 2003 to 45.0% in 2001. The remaining grasses sown in the mixture occupied 3.0–8.6% depending on the year. *Festuca rubra* appeared in the sward spontaneously and its share reached 9.0%. *Agropyron repens* and *Taraxacum officinale* occurred in significant quantities reaching 30.0% in 2002. *Trifolium repens* decreased from 13.5% of the sward in 2001 to 7–8% in the last year of studies. The remaining sward components of the pasture were occupied by various species of herbs and forbs. An increase of the number of species in the pasture sward was observed and during the years of the investigation this ranged from 28.3 (on average) in 2000 to 36.5 in 2004.

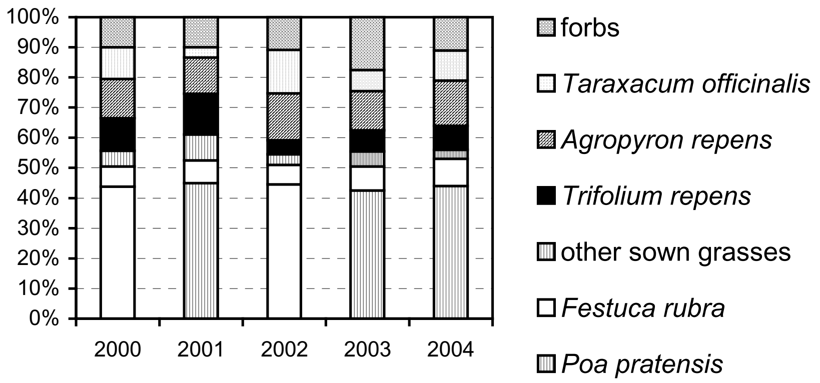

Figure 1. Changes in botanical composition of the sward over successive years of utilization

The dry matter yield of pasture showed small variations between individual years and ranged from 4,520 to 5,080 kg ha^{-1}. Data on beef production from the pasture are presented in Table 1. In 2000–2004 heifers for fattening were purchased in spring and were sold at different body weights in the autumn after the pasturing season. The highest liveweight gains (730 g day^{-1}) were recorded in 2000, the lowest (405 g day^{-1}) in 2002. Higher gains were associated with the size of herd and age of grazing animals. The stocking rate ranged from 1.52 to 2.31 LU ha^{-1}.

Table 1. Characteristics of heifers beef production on extensive pasture, 2000–2004

Item	Unit	Years of pasture utilization				
		2000	2001	2002	2003	2004
Number of heifers in the herd	heifers	133	118	120	125	118
Buying weight of heifer – mean	kg	296	269	244	314	331
Selling weight of heifers – mean	kg	439	380	316	405	433
Grazing period	days	196	190	177	180	193
Daily liveweight gain	g	730	582	405	507	528
Stocking rate	LU ha^{-1}	2.31	1.81	1.58	2.12	2.07
Labour engagement per grazing period	lh	784	760	708	720	772
Average capital engaged in production	PLZ	123,753	99,987	92,232	123,590	122,932

In order to improve the efficiency of extensive grazing of heifers, both the stocking rate and age of animals at the beginning of the pasturing season were changed during the investigations. In years 2000–2004, with the increase of stocking rate on the pasture, the production of beef increased from 202.9 to 448.8 kg ha^{-1} (Table 2). Similar dependence was observed in relation to labour productivity and capital involved in production. Productivity factors expressed in economic terms confirmed the importance of the higher stocking rate and favourable weather conditions in 2000. The highest return of beef production inputs were recorded in 2000 (Table 3) and for pasture, labour and capital, reached 679.0 PLZ ha^{-1}, 50.9 PLZ lh^{-1} and 33.6 PLZ 100 PLZ^{-1}, respectively.

Table 2. Productivity of production inputs on extensive pasture, 2000–2004

Production input	Unit	Years of pasture utilization				
		2000	2001	2002	2003	2004
Natural productivity – beef						
Pasture	kg ha^{-1}	448.8	307.7	202.9	269.0	283.6
Labour	kg lh^{-1}	24.2	17.3	12.2	15.8	15.6
Capital	kg 100 PLZ^{-1}	15.4	13.1	9.3	9.2	9.8
Financial productivity – money						
Pasture	PLZ ha^{-1}	1413.7	969.3	639.1	867.8	893.3
Labour	PLZ lh^{-1}	76.2	54.5	38.4	51.1	49.1
Capital	PLZ 100 PLZ^{-1}	48.5	41.3	29.3	29.8	30.8

Table 3. Return of beef production inputs on extensive pasture, 2000–2004

Production input	Unit	Years of pasture utilization				
		2000	2001	2002	2003	2004
Pasture	PLZ ha^{-1}	679.0	430.1	141.5	264.7	338.7
Labour	PLZ lh^{-1}	50.9	32.2	15.4	23.5	28.4
Capital	PLZ 100 PLZ^{-1}	33.6	25.3	13.2	17.0	18.8

Discussion

Pasturing of heifers can be treated as an economically justified and ecologically optimal form of utilization of grasslands situated in areas protected by law. According to Nösberger *et al.* (1994) it is possible to integrate the objectives of agriculture and environmental conservation to a high degree. Beef production efficiency on a low-input pasture is most affected by purchase price. Following Poland's accession into the European Union in 2004 the economic effectiveness of beef production on extensive grasslands will be increasing. Additionally, since 2004 the farmers have had the opportunity to receive financial compensation when they integrate nature conservation objectives into their grassland systems. Wytrzens and Neuwirth (2004) reported that there is a correlation between field-based subsidies and the use of grassland, its multifunctionality and nature conservation.

Conclusions

Extensive grazing of heifers appears to be an economically justified and ecologically optimal method of agricultural utilization of nature conservation areas with positive effects on biodiversity of the grassland. During the pasturing season daily liveweight gains of animals ranged from 405 to 730 g, differences depending on the weather conditions in the years of the investigations. Beef production from heifers on this type of grassland can be improved by adjusting the stocking rate to the yield potential of the pasture.

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Attitude of Austrian farmers towards agro-environmental programs and aspects of nature conservation

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Abstract

Regarding the guidelines of the mid-term review (according to the EU-ordinance 1257/99), empiric studies were planned to evaluate the programs for the development of rural space. A comprehensive interrogation study was therefore carried out in 8 representative test regions in Austria in 2002. Beside basics production and management data, 274 conventional and organic farmers were asked detailed questions concerning the Austrian agro-environmental program "OEPUL". Both the general satisfaction with that program and the decision reasons for choosing distinct measures were evaluated including the acceptance level of measures with a high value for nature conservation. Furthermore, the farmers were asked about their consciousness of environmental and agro-ecological problems.
The study clearly pointed out, that two third of the farmers are basically satisfied with the Austrian agro-environmental program "OEPUL", which in general has a very high acceptance, but about 30% of them wish to simplify the program and to reduce its bureaucracy. More than 80% of the interviewed farmers felt they were well informed about the relationship between agriculture and nature conservation, but detailed questions on that topic showed some contradiction. This clearly indicates an information gap, which has to be filled for improving the awareness for nature and the environment.
On 60% of the investigated farms succession is not ensured and this result clearly indicates dramatic changes for the agricultural structure and for the development of rural areas. Therefore strong efforts, both concerning competitiveness of farms by increasing horizontal and vertical cooperation and improvement of regional development by shifting agrarian subsidies have to be made in the next future.

Keywords: mid-term review, environmental conscious, nature conservation, rural development

Introduction

In addition to the official criteria and questions of the mid-term review, which mainly focused on ecological and economic aspects, a comprehensive and representative interrogation study was carried out in Austria (Poetsch, Groier, 2003). The main target of this project was to point out the personal view, ideas, standpoints and fears of farmers concerning the Austrian agro-environmental program "OEPUL" and aspects of environment and nature protection. The results will also be considered for the development and improvement of the coming agro-environmental program and should provide a basic impulse for agrarian policy.

Materials and Methods

The interrogation study was based on a structured random sample in eight test regions, covering the main agrarian production areas of Austria. 274 farmers, representing 13% of the total number of farms in the test regions were personally interviewed to ensure high data quality and to avoid misunderstandings. The questionnaire design included ten thematic units with at all 97 questions both open and closed, partly having a dynamic dimension. The data set was analysed regarding farm location (eight regions), farm size (<5 ha, 5–30 ha, >30 ha), farm type (conventional and organic) and participation in the agro-environmental program.

In addition to the official questions, personal impressions and statements were also recorded and worked out in an anonymous way.

Results and Discussion

Past and future changes on farms

Investments in building measures and adaptation of production techniques were the most frequent changes on farms in the last decade. An expansion of farms was only noticed in some small scaled grassland regions, whereas both an intensification and extensification tendency was recorded in regions with product processing and mixed arable farming. In pure arable, intensive processing and in periphery grassland regions a strong extensification tendency could be detected.

In general, farmers demanded higher and fairer prices, higher subsidies for small enterprises, maintenance of subsidies, more extensive and organic farming, information of the society and compensation for benefits in favour of the environment and society.

Most of the farmers expressed a desire to keep the status quo in future but 60% either don't have a successor or the potential successor is uncertain because of low income, high work load and lack of competitiveness. To improve this dramatic situation, which primarily exists on small scaled farms, a revaluation, modernisation and a new orientation of the occupational image of farmers has to be pushed in future.

Acceptance and effects of the agro-environmental program "OEPUL"

Compared to some other European countries, there is a very high acceptance of the agro-environmental program in Austria. More than 75% of the farms and more than 85% of the total agricultural used area are included in "OEPUL" with its 31 different measures. Beside numerous analyses of the participation structure, qualitative aspects like motivation for and satisfaction with the program are of great interest for its further development (Table 1).

75% of the participating farmers are generally satisfied with the program, 12% are indecisive and only 13% are displeased. The main suggestions for an improvement of the program are the simplification and reduction of bureaucracy, the consideration of regional conditions and the exaltation of subsidies. About half of the farmers would still continue farming without any "OEPUL"-payments, on small enterprises this percentage is even at 64%!

Table 1. Selected questions on the Austrian agro-environmental program "OEPUL" (answers in % of n = 229)

	Satisfaction with OEPUL	Continuance of farms without OEPUL	Problems with implementing OEPUL	Problems with the control of OEPUL	Repayment of OEPUL-premium
Yes	75	52	31	15	19
No	13	42	69	85	81
Indecisive	12	6	–	–	–

One third of the farmers had some fundamental problems with the implementation of "OEPUL", mainly concerning pest management, deadlines and bureaucracy at all. 15% of the farmers told about problems with the control organisation AMA (Agrarian Market Austria), caused by deficient measurement of field size and by unfamiliar terms with the controlling person. About 20% of the "OEPUL"-participants had to repay premium for incorrect field size declaration, non-compliance of guidelines and failures of the controlling body.

As main reasons for the non-attendance at “OEPUL”, management restrictions, bureaucracy, length of the contract period, repayment obligation, control and low financial inducement were indicated.

Changes in the use of external farm resources

Agro-environmental programs are aiming at an ecologically and environmentally friendly agriculture, so therefore changes in the use of external farm resources are of great importance and can be seen as an efficiency indicator. 37% of the interviewed farmers don’t apply any mineral fertiliser and the results clearly indicate a significant reduction in the use of mineral nitrogen, phosphorus and potassium. Different measures within “OEPUL”, such as organic farming and cessation or reduction of yield increasing farm resources have a very high acceptance and a therefore strong and positive effect on soil nutrient excesses, water quality and biodiversity.

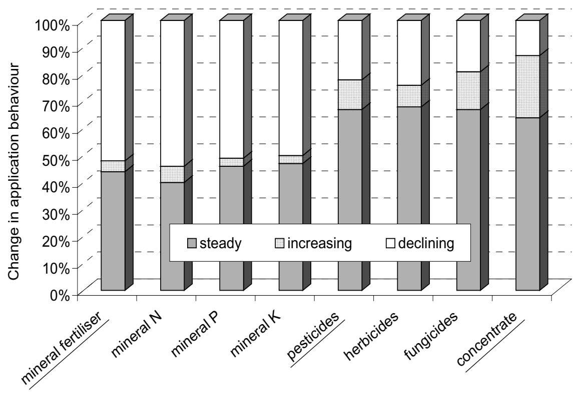

Figure 1. Relative change in the use of external farm resources (n = 274)

One third of the interviewed farmers don’t use any pesticides, herbicides or fungicides and on the remaining farms, especially those participating in “OEPUL”, a decreasing tendency was noticed. These results are in agreement with published data concerning the consumption of mineral fertiliser and pesticides in Austria (BMLFUW, 2004).

Farm manure and forage from pastures and meadows are the main production resources on grassland and dairy farms in Austria (Taube, Poetsch, 2001). 25% of the interviewed farmers generally dispense with the use of concentrates, which in obligatory grassland regions have to be seen as an external resource. Statements pointing out an increase in concentrates input exceeded those indicating a reduction. These results show that some farmers try to compensate for yield losses caused by the reduction or cessation of mineral fertiliser usage. Nevertheless, this strategy of utilising concentrates as an alternative to mineral fertiliser seems to be much more ecological (Kühbauch, 2000).

Attitudes towards aspects of environment and nature protection

The “OEPUL” program covers some special measures, aimed at the specific protection of nature and diversity. The acceptance of these nature protection measures is relatively low, even though the premiums are higher than for other measures. The main reasons for the non participation are the non-existence of valuable areas, participation in other nature protection programs, smallness of the farm, long contract period, risk, bureaucracy and the high expense with relatively low financial benefit.

Table 2. Selected questions on the attitude towards environment and nature protection (answers in % of n = 229)

	Well informed about relationship between agriculture and nature	Stronger consideration of nature protection in agriculture is positive	Change in the awareness of agro-ecological problems within the OEPUL period
Yes	83	78	31
No	14	20	67
Indecisive	3	2	2

More than 80% of the interviewed farmers feel to be well informed about the relationship between agriculture and nature conservation, but detailed questions on requirements of certain measures or Natura 2000 show some contradiction. This clearly indicates an information gap, which has to be filled to improve the awareness of nature and the environment. The majority of the farmers agree to a stronger consideration of nature protection in agriculture, but only one third of them have changed their awareness of agro-ecological problems within the "OEPUL" period.

In Austria the participation in organic farming, which strongly considers aspects of environment and nature protection is at around 10%. Regarding the general demand for expanding organic farming in Europe, the conventional interviewees were asked for their incitements for not joining this valuable measure. The inalienability for chemical pest management, high workload, bureaucracy, lowly product prices and insufficient subsidies were named as main reasons. Many farmers, participating in measures with requirements for cessation or reduction of yield increasing resources, already appear to be "organic farmers" in practice.

Conclusions

The Austrian agro-environmental program "OEPUL" is highly accepted by the farmers and significantly meets most of the evaluation criteria. In agreement with other studies, this interrogation project pointed out, that environmental awareness, information level and quality of advice are the main drivers of the program efficiency and the efficiency of the financial public investment.

But there are still some deficits both in the conception and administration of the program and in the information and advice service, which should be done more in a partnership with a stronger reference to the agricultural practice. If farmers understand the objectives, coherences and consequences of an agro-environmental program, their appreciation and awareness for agro-environmental problems and their readiness for participating in special measures will increase.

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Spatial and temporal variation of grasshopper assemblages recorded in 1981–83 and 2002–03 in Grindelwald, Northern Swiss Alps

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Abstract

Changes in grassland management are expected to occur in the Swiss Alps. To evaluate detrimental and beneficial factors for biodiversity, we compared grasshopper assemblages of differently managed grasslands recorded between 1981–83, with records made in 2002–03, using the same twenty plots in Grindelwald (Central Swiss Alps) and the same method. The plots were situated in three different altitudinal zones between 900 and 2000 m. The assemblages in the upper montane zone (UM = 1100–1500 m) are the most species rich. Altitude and slope had a significant effect on the composition of the assemblages. The overall statistical test indicated a significant change in species composition between 1981–83 and 2002–03. Shifts over time in the composition characterised by an altitudinal zone were not observed. The same result was found for the shifts of the species composition determined by slope. The high number of species in UM can be explained by extensive management. It was also shown that grasshoppers profit from extensive management in steep plots. The comparison of the species composition over time indicated no general change of land use with detrimental effects on grasshoppers. Therefore, the shifts may be due to metapopulation dynamics. In conclusion, the focus should especially be on the upper montane zone for maintaining grasshopper diversity and for planning conservation activities.

Keywords: grassland management, biodiversity, grasshopper conservation, Swiss Alps

Introduction

The Alps are known to be a hotspot of biodiversity. Land use change is expected to occur in mountain regions due to changes in the economical and political situation. To plan the future development of mountain agriculture, policy makers and conservation biologists need information about the effects of these changes on biodiversity. The spatial information of species diversity is crucial for planning conservation activities. Furthermore, the temporal development of species diversity has to be investigated to identify detrimental and beneficial factors, which led to the actual biodiversity.

The aim of the present study was to evaluate the driving factors for biodiversity in agriculturally managed grasslands. Grasshoppers were chosen as indicators. We investigated changes of species assemblages comparing data of 1981–83 with data of 2002–03. We asked whether a loss of species has occurred over the last two decades in a small area in the Central Swiss Alps and if it was due to an intensification of management.

Investigation area and Methods

The study was conducted in the surroundings of Grindelwald, a village in the Northern Swiss Alps. The grasshopper assemblages were re-assessed in 2002–2003 on twenty plots selected by Schiess (1988) in 1981–83. Seven plots were situated in the lower montane zone (LM = 900–1100 m) on highly productive areas in the valley bottom. The remaining ones were on the south slopes: four unfertilised pre-alpine pastures and four unfertilised meadows were in the upper montane zone (UM = 1100–1500 m) and five alpine pastures in the subalpine zone (SA = 1500–2000 m). Slope varied in each zone from lightly inclined to very steep.

In 1981–83 the plots were sampled once with a transect method. In 2002–03 the same method was used, but the plots were sampled twice in 2002 and five times in 2003. For the analyses presence-absence data were used. Because of the different sampling effort in 1981–83 and in 2002–03, the species absent in 2002–03 and the species newly found in a plot were analysed separately (absence analysis, presence analysis). Redundancy Analysis (RDA) and partial RDA (Ter Braak *et al*., 1994; 2002) were used to test for the influence of the following nominal explanatory variables: time (1981–83, 2002–03), altitudinal zone (LM, UM, SA), plot (7 in LM, 8 in UM, 5 in SA) and the cross-classification zone x year (LM1981–83, LM2002–03, UM1981–83, UM2002–03, SA1981–83, SA2002–03). Altitude and slope of the plots were introduced as quantitative variables. Monte Carlo permutations were used to test for statistical significance.

Results

Spatial variation: In our study, the grasshopper assemblages in the upper montane zone were the richest. In total, twenty species were found here in 2002–03. The mean species number per plot was fourteen (Table 1).

Table 1. Total number of grasshopper species in the lower montane zone (LM), the upper montane zone (UM) and in the subalpine zone (SA) as well as mean species number per plot observed in 2002–03

Altitudinal zone	LM (n = 7)	UM (n = 8)	SA (n = 5)
Total number of species	16	20	15
Mean species number per plot	9	14	9.4
Standard deviation	±2.9	±0.6	±2.8

In the absence and in the presence analyses assessed by a Monte Carlo test, altitude and slope had a significant effect on the composition of grasshopper assemblages. This is stressed by their high values of mean squares (Table 2). Together they account for about 30% of the spatial variation in the absence analysis and 32% in the presence analysis.

Table 2. Decomposition of the total variance in the species data (Absence, Presence) obtained by Redundancy Analysis

Type of analysis Source	Absence df[1]	ss[2]	ms[3]	Presence df[1]	ss[2]	ms[3]
Space (plot)	19	0.95	0.05	19	0.85	0.045
-Altitude	1	0.16	0.16*	1	0.14	0.14*
-Slope	1	0.13	0.13*	1	0.13	0.13*
-Residual	17	0.66	0.039	17	0.58	0.034
Time (year)	1	0.005	0.005*	1	0.031	0.031*
Space x time	19	0.045	0.002	19	0.119	0.006
-Zone x year	2	0.004	0.002[ns]	1	0.019	0.001[ns]
-Slope x year	1	0.006	0.006[ns]	2	0.004	0.004[ns]
-Residual	16	0.035	0.002	16	0.096	0.006
Total	39	1		39	1	

[1] degrees of freedom, [2] sum of squares, [3] mean square, * $p < 0.005$ by Monte Carlo permutation, ns: not significant

Temporal variation: The overall statistical test of the changes in species composition between 1981–83 and 2002–03 indicated a significant change (Table 2). However, the proportion of variance explained by time was very low, i.e. 0.5% in the absence analysis and 3% in the presence analysis. In nine plots seven different species disappeared locally. In contrast, twenty species newly appeared locally in nineteen plots (Table 3). In eleven plots, all grasshoppers present in 1981–83 were also found in 2002–03.
The analyses indicated that the species composition characterizing an altitudinal zone did not significantly change between 1981–83 and 2002–03. Furthermore, the changes over time of the species composition determined by slope were not significant either.

Table 3. Number of plots occupied by a particular species in 1981–83 (Schiess, 1988) and number of plots without (absence) and with these species (presence) in 2002–03

	Lower montane (n = 7)			Upper montane (n = 8)			Subalpine (n = 5)		
Altitudinal zone	Plots occupied 1981–83	Abs.[1] 2002–03	New Pres.[2] 2002–03	Plots occupied 1981–83	Abs.[1] 2002–03	New Pres.[2] 2002–03	Plots occupied 1981–83	Abs.[1] 2002–03	New Pres.[2] 2002–03
Chorthippus parallelus	7	0	0	8	0	0	5	0	0
Decticus verrucivorus	3	0	4	8	0	0	4	0	1
Omocestus viridulus	4	0	2	6	0	2	5	0	0
Chorthippus biguttulus	2	0	3	8	0	0	3	0	1
Metrioptera roeseli	6	0	1	7	0	1	3	0	0
Stenobothrus lineatus	3	0	2	8	0	0	0	0	1
Euthystira brachyptera	0	0	2	6	0	2	3	0	1
Metrioptera brachyptera	0	0	1	3	0	3	5	0	0
Gomphocerippus rufus	3	0	0	3	0	2	2	1	0
Tettigonia cantans	5	2	2	2	1	4	0	0	0
Pholidoptera griseoaptera	3	1	0	3	0	1	0	0	0
Acryptera fusca	1	0	1	4	1	3	0	0	1
Gomphocerus sibiricus	0	0	0	1	1	0	3	1	1
Chorthippus dorsatus	1	0	1	1	1	4	0	0	1
Miramella alpina	0	0	0	1	1	2	1	1	3
Chorthippus montanus	0	0	0	2	0	0	0	0	1
Chorthippus brunneus	1	0	1	0	0	3	0	0	0
Stethophyma grossum	0	0	0	0	0	2	1	0	1
Tettigonia viridissima	0	0	0	0	0	7	0	0	0
Platycleis albapunctata	0	0	3	0	0	1	0	0	0
Omocestus rufipes	0	0	0	0	0	3	0	0	0

[1] Absence, [2] Presence, Scientific names of the grasshopper species are given according to Coray *et al.* (2001).

Discussion

Spatial variation: Compared to the intensively managed area in the lower montane zone, a high species richness is found in the upper montane zone. This can be explained by the predominant management practices here, i.e. grazing and extensive mowing. Grasshoppers profit from the patchy vegetation structures caused by grazing (Detzel, 1998). The unfertilised meadows are mown late in the year and therefore many grasshopper species find suitable habitat conditions (Detzel, 1998). The subalpine pastures are managed extensively too, but in this zone only the species tolerant to cold temperatures can occur. This change of species composition along the altitudinal gradient is consistent with the results of other similar studies on grasshoppers (Wettstein, 1999). The influence of slope on grasshopper assemblages is almost as strong as the well-known effect of altitude. Steeper plots are difficult to manage. Thus, with increasing slope, the management pressure decreases. Therefore, grasshopper species, sensitive to intensive mowing or grazing, profit (Detzel, 1998).

Temporal variation: The detailed statistical analyses show that the shifts in species composition are not indicative for any general changes in land use in Grindelwald, i.e. the (weak) correlation of management, altitudinal zone and slope, means that no intensification of management in any particular zone could be detected. On the other hand, the high amount of grasshopper species, newly present in the plots in 2002–03, is striking. Walter *et al*. (2004) found an increase in size of grasshopper populations due to habitat improvement, but, of course, only in areas where a source for these populations existed. From all this we must assume that the increase of species number observed between 1981–83 and 2002–03 is mainly due to the differences in sampling effort in these two time periods.

On the other hand, a turnover of grasshopper assemblages in some of the plots can be observed. Absences and new records of species take place in the same plots (Table 3). These changes may be due to the dynamics of metapopulations (Hanski, 1997).

Conclusions

The agriculturally managed grasslands on the south slopes near Grindelwald are hotspots of grasshopper diversity. The pastures and the unfertilised meadows in the upper montane zone are the most important habitats for the grasshoppers occurring in the area. The study shows that the agricultural management practised in Grindelwald plays an important role in maintaining this grasshopper diversity. Therefore, special focus should be on the upper montane zone and its predominant management types for planning conservation activities for grasshoppers.

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Revealing changes in biodiversity pattern by means of PFTs

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Abstract

One of the most profound effects of privatization on Slovak agriculture, after 1989, was the abandonment of marginal areas with low soil quality. Land use types that exhibit highest biodiversity, like pastures and meadows, are mostly affected. The overall impact of the changes in agriculture may be depicted in the upset of structural components of land use types. The objective of the study was to compare land use types of grasslands (meadows, hedges, pastures, orchards, crop fields) and management intensity groups (intensive, extensive, abandoned grasslands, crop fields) by the means of relative importance of each plant functional type (PFT). The Shannon-Wiener index (H´) served to quantify the level of biodiversity of each management intensity group. We proved that extensively managed grasslands preserve the highest biodiversity and in particular the highest species richness of forbs and grasses.

Keywords: vulnerability, grasslands, Shannon-Wiener, land use types, Slovakia

Introduction

The biodiversity of semi-natural grasslands is being depleted due to increasing intensity of management on one hand and abandonment on the other (Hellström *et al.*, 2003; Cousins and Linborg, 2004). Many studies have been performed to reveal the changes in biodiversity patterns. A recent approach, which is considered by some authors as more effective in evaluating vegetation changes associated with management activities, is the approach of plant functional types (PFTs) (Gillison and Liswanty, 2004).

Materials and Methods

The study was conducted in spring/summer of 2003 and 2004 in a marginal, sub-mountainous region, cadastre Malá Lehota, central Slovakia (400–818 m a.s.l., 48°30´N, 18°34´E). A total of 78 phytosociological reléves were performed on intensively managed to abandoned meadows, pastures, hedges, orchards, and fields, in order to include all the habitats of grassland. In each land use type of grasslands, six relevés for each level of management intensity (i.e. extensive, intensive, and abandoned) were chosen, except the crop fields with only a single category. Extensive grasslands were represented by traditionally managed, mowed and moderately grazed sites; intensive grasslands by ploughed and/or seeded, fertilized or intensively grazed sites; abandoned grasslands by grasslands that had experienced a period of abandonment and crop fields by sites with cultivated varieties of grasses (e.g. *Hordeum* sp., *Triticum* sp.), managed with none or low-input chemical treatment. The phytosociological method of Kent and Coker (1994) was followed. Relative abundance of species was estimated according to Braun-Blanquet scale, 25 m^2 plots within of each. The Shannon-Wiener index (H´) served to quantify the level of biodiversity of each management intensity group. Plants were classified into two PFTs groups by considering their 1) life cycle (annuals, perennials) and 2) vegetative type (grasses, legumes, forbs, shrubs/trees) using a deductive approach (Gitay and Noble, 1997).

Results

Extensive grasslands showed the highest value of Shannon-Weiner index (H´), highest equitability and species richness (Table 1). In contrast, crop fields had the lowest value of these attributes. However, the H´ value and mean species richness of abandoned grasslands were in between of intensive and extensive grasslands, which relates to a process of secondary succession of extensive grasslands, leading to dominance of fewer species.

Table 1. Mean value of Shannon index, equitability and species richness per grassland type

	Type of management	Shannon index (H´)	Equitability	Species richness
A.	Extensive grasslands	3.40	0.88	47.04
B.	Intensive grasslands	3.04	0.84	36.33
C.	Abandoned grasslands	3.09	0.83	41.42
D.	Crop fields	2.35	0.69	30.50

In Table 2 are listed values of mean species richness per PFTs for management type and land use type and they are statistically compared. Annual cultivation of the soil and frequent disturbances are requirement of many annual plant species. Therefore, the highest annual species richness, expressed as the mean number of annual species, was found in crop fields and intensively managed grasslands. Within land use types, hedges followed the crop fields. Perennials, however, were found to be higher in extensively managed grasslands. This is indicative of fewer disturbances to soils.

Table 2. Mean species richness per PFTs

	Type of management	Life cycle		Vegetative type			
		Annuals	Perennials	Shrubs/ Trees	Legumes	Forbs	Grasses
A	Intensive grasslands	4.5^{CD}	30.6^{BD}	1.3^{C}	3.6^{D}	23.4^{B}	8.9^{BD}
B	Extensive grasslands	2.8^{D}	42.1^{AD}	1.6	4.5	29.9^{ACD}	10.8^{AD}
C	Abandoned grasslands	2.2^{AD}	36.6^{D}	2.6^{AD}	3.3^{D}	25.4^{B}	9.9^{D}
D	Crop fields	18.7^{ABC}	11.5^{ABC}	0.3^{C}	6.3^{AC}	21.8^{B}	3.0^{ABC}
	Land use types						
A	Meadows	2.1^{BE}	38.8^{E}	0.9^{D}	4.1^{E}	25.9	11.6^{BCDE}
B	Hedges	5.7^{ACDE}	33.7^{E}	1.7^{D}	3.6^{E}	28	8.5^{AE}
C	Pastures	2.4^{BE}	37.2^{E}	1.9^{D}	4.2^{E}	25.6	9.5^{AE}
D	Orchards	2.5^{BE}	36.1^{E}	2.8^{ABCE}	3.4^{E}	25.3	9.8^{AE}
E	Crop fields	18.7^{ABCD}	11.5^{ABCD}	0.3^{D}	6.3^{ABCD}	21.8	3.0^{ABCD}

* Means followed by the letter(s) are significantly different at $P<0.05$.

Within four *a priori* groups of vegetative type (Table 2), grasses showed the highest mean species richness within extensive grasslands, being significantly different from the intensive grasslands and crop fields. When comparing the land use types, species richness of grasses was highest in meadows, which showed clear statistical difference from all the other groups. Forbs showed similar results, the highest mean species richness was found in extensive grasslands. However, land use types had no influence on species richness of forbs. Legumes' richness was in both cases highest in the crop fields. Species richness of shrubs and trees was highest in abandoned grasslands, and from land use types in orchards, followed by pastures and hedges.

In Table 3 are listed values of mean species abundances per PFTs for management type and land use type and they are statistically compared. Abundance of annual species increased with intensity of management, due to frequent disturbances. We found highest abundance of annual species in the crop fields and intensive grasslands. In land use types, hedges followed the crop fields. A high amount of perennial species was found in extensively managed grasslands, indicating fewer disturbances to soils. From land use types, meadows have possessed significantly higher abundance of perennials, compare to hedges.
The situation in four *a priori* groups was as follows: abundance of trees and shrubs was highest in abandoned grasslands; which is indicative of natural succession from grassland to woodland, occurring when grasslands are unmanaged. Legumes did not show any statistical difference within the type of management groups, but particularly in pastures they reached the highest abundance. Abundance of forbs showed clear statistical difference within extensive grasslands. Intensive grasslands and crop fields had highest abundance of grasses; from land use types, the highest abundance was in meadows.

Table 3. Mean abundance value per PFTs

	Type of management	Life cycle			Vegetative type		
		Annuals	Perennials	Shrubs/ Trees	Legumes	Forbs	Grasses
A	Intensive grasslands	13.8^{BD}	182.2^{D}	7.4^{C}	17.8	99.6^{B}	80.0
B	Extensive grasslands	7.0^{AD}	220.7^{D}	9.9^{C}	22.7	136.5^{AD}	69.8
C	Abandoned grasslands	8.2^{D}	195.0^{D}	22.5^{ABD}	15.5	116.4	72.4
D	Crop fields	146.5^{ABC}	54.0^{ABC}	0.7^{C}	22.2	94.2^{B}	86.5
	Land use types						
A	Meadows	4.9^{BE}	224.1^{BE}	2.5^{D}	16.7	117.5	94.9^{BCD}
B	Hedges	18.6^{ACDE}	173.1^{AE}	10.8^{D}	13.4^{C}	120.8	60.2^{AE}
C	Pastures	8.6^{BE}	199.3^{E}	8.0^{D}	24.3^{B}	116.4	69.1^{A}
D	Orchards	6.7^{BE}	200.7^{E}	31.7^{ABCE}	20.2	115.3	72.1^{A}
E	Crop fields	146.5^{ABCD}	54.0^{ABCD}	0.7^{D}	22.2	94.2	86.5^{B}

* Means followed by the letter(s) are significantly different at $P<0.05$.

Discussion

Results proved that species diversity and equitability (Table 1) was highest in extensively utilized grasslands. This finding supports studies of Rosenzweig (1995), and Austrheim *et al.*, (1999) claiming that diversity peaks at intermediate disturbance levels. High diversity of extensive grasslands is due to low-input management, e.g. regular hay cutting, extensive grazing, no fertilization and no soil disturbance. The fact that the abandonment results in loss of grassland species from vegetation owing to the invasion of woodland species Bakker *et al.,* (1997) was proved also by our study, but because extensive grasslands were abandoned, the mean biodiversity after the abandonment was still quite high (Table 1).
Annual species were found to be higher in their abundance and richness toward increasing management intensity (Table 2 and 3). Annual species, by their nature, prefer disturbances, and dislike competition [corresponds to R-strategy sensu Grime (2001)]. Results from Kitazawa and Ohsawa (2002), and Gondard *et al.*, (2003) confirm that cultivated and heavily trampled sites were commonly dominated by annuals. Among the land use types, hedges, after the crop fields were the leading group in number and abundance of annuals. This fact can be explained by the ecotonic character of hedges, comprising the annuals from adjacent fields. Pastures and meadows did not show significant difference in species richness of

annual species as confirmed also by (Stammel *et al.*, 2003). However, pastures had higher abundance of legumes and compared to meadows and orchards, also higher abundance of annuals (Table 3). This is confirmed by Dupré and Diekmann (2001) who found that grazed sites had high proportions of legumes, therophytes (mainly annuals), and species with basal leaves. Contrary to results of Stammel *et al.*, (2003), we found a higher proportion and mean species richness of grasses in meadows compared to pastures. This disparity could be caused by underestimating the abundance of grasses on pastures due to grazing. Moreover, intensive management gave rise to a greater abundance of grasses, this was also found in the study by Lavorel *et al.*, (1999). Finally, the research proved that extensive management of grasslands preserves the highest species richness of forbs and grasses.

Conclusions

1. Species diversity (Shannon-Weiner index) was found to be highest in extensively managed grasslands and lowest in crop fields and intensively utilized grasslands.
2. Annual species were found to be higher in their abundance and richness with increasing intensity of management.
3. Extensive management of grasslands preserves the highest species richness of forbs and grasses.
4. Abundance of grasses was highest in intensively managed sites; among land use types of grasslands, meadows had highest abundance and species richness of grasses.
5. Patterns of diversity in rural landscape should continue to be studied, to assess the affects of various human impacts, in order to preserve biodiversity of semi-natural grasslands.

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Effect of different fertilisation regimes on species composition and habitat in a long-term grassland experiment

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Abstract

To study the effect of long-term grassland management on yield and botanical composition an experiment was set up on a mountain meadow in 1968. There were 7 treatments. Four of them comprised a 2×2 factorial with two nitrogen fertiliser forms (ammonium and nitrate) at two rates (90 and 180 kg N $ha^{-1}year^{-1}$). The P and K fertilisation rates were 39.5 and 124.5 kg·$ha^{-1}year^{-1}$ respectively. One treatment was fertilised with 90 kg N $ha^{-1}year^{-1}$ only, one with P, K only and one with P only. Half of each plot was limed in 1985 and 1995, and half left without liming. After 35 years of the experiment, the yield and botanical composition of sward (Braun-Blanquet method) were assessed. The number of species and Ellenberg`s indicator values were calculated. It was found that high rates of N fertilisation reduced the number of species and simplified the botanical composition. In these treatments *Holcus mollis*, *Alchemilla* sp. and *Chaerophyllum aromaticum* were dominant. Species characteristic of poor habitats such as *Festuca rubra* and *Anthoxanthum odoratum* were abundant in the treatments with no N fertilisation. The highest number of species with considerable proportion of acid soil species (e.g. *Nardus stricta* and *Vaccinium myrtillus*) was found on plots fertilised with 90 kg N $ha^{-1}year^{-1}$ only. A significant effect of fertilisation and liming on habitat (on the basis of indicator values) was observed.

Key words: long-term experiment, mountain grassland, fertilisation, botanical composition

Introduction

Plant species present in grasslands are a result of habitat conditions and meadow management. Each change in the management method (e.g. frequency of cutting or fertilisation level) has an impact on botanical composition of sward. Effects of some management methods may be revealed only after many years. That is why long-term experiments are of considerable importance for discovering long-term impact of applied treatments on plants and habitats. The main purpose of the work was to assess the impacts of different fertilisation regimes on botanical composition of sward and habitat conditions of mountain meadows over a 35 year period.

Materials and Methods

The experiment was set up in Krynica (49°24´N, 20°55´E) in 1968 on permanent grassland dominated by *Festuca rubra* and *Nardus stricta* (Kopeć, 2000). The site is located at an altitude of 720 m a.s.l. in the Beskid Sądecki Mts. The annual mean temperature at the site is 5.7 °C, the mean annual rainfall is 820 mm, and the soil is acid brown. The experiment consisted of seven treatments in five replicates: 1) N-0, P – 39.5 kg $ha^{-1}year^{-1}$, K – 124.5 kg $ha^{-1}year^{-1}$; 2) N ammonium nitrate – 90 kg $ha^{-1}year^{-1}$, P – 39.5 kg $ha^{-1}year^{-1}$, K – 124.5 kg $ha^{-1}year^{-1}$; 3) N ammonium nitrate – 180 kg $ha^{-1}year^{-1}$, P – 39.5 kg $ha^{-1}year^{-1}$, K – 124.5 kg $ha^{-1}year^{-1}$; 4) N urea – 90 kg $ha^{-1}year^{-1}$, P – 39.5 kg $ha^{-1}year^{-1}$, K – 124.5 kg ha^{-1} $year^{-1}$; 5) N urea – 180 kg $ha^{-1}year^{-1}$, P – 39.5 kg $ha^{-1}year^{-1}$, K – 124.5 kg $ha^{-1}year^{-1}$; 6) N ammonium nitrate – 90 kg ha^{-1}year^{-1}, P – 0, K – 0; 7) N – 0, P – 39.5 kg ha^{-1}year^{-1}, K – 0. The plots were 42 m^2. Half of each plot was limed in 1985 and 1995 (+Ca), and half left without liming (0 Ca). All treatments were cut twice a year. In June 2003, all plots were harvested. Botanical composition of the sward was estimated (Braun-Blanquet method). Frequency of occurrence and cover coefficient for each species were estimated for all treatments and used as grouping criterion. The Ellenberg indicator values (Ellenberg *et al.*, 1992) for light (L), moisture (F), reaction (R) and soil nitrogen (N) were calculated.

Results and Discussion

Thirty five years of different management methods brought about changes in habitat conditions and formation of different plant communities. Four groups of treatments have been differentiated on the basis of botanical composition (Table 1). No differentiation between groups was attributable to nitrogen fertiliser form.

Table 1. Effect of treatment on botanical composition of sward. F – frequency of occurrence; CC – cover coefficient

Group	A				B				C				D	
Treatment	3 F	CC	5 F	CC	2 F	CC	4 F	CC	1 F	CC	7 F	CC	6 F	CC
Species														
Holcus mollis	10	5350	10	5100	8	2980	8	2530	7	725	6	30	3	185
Alchemilla sp.	10	1685	10	1640	10	3155	10	2750	7	1530	10	2750	9	1355
Chaerophyllum aromaticum	9	690	10	1186	10	1015	10	1760	9	260	6	75	5	240
Ranunculus repens	8	1255	9	1751	8	515	9	720	7	790	10	490	7	295
Festuca pratensis	7	1656	9	1706	9	3400	9	3975	10	3105	10	2005	6	985
Ranunculus acris	4	110	5	70	8	310	9	360	10	1375	9	1450	8	310
Poa trivialis	8	1380	7	850	7	125	9	780	5	240	8	345	7	555
Dactylis glomerata	7	256	6	1325	9	1555	9	1150	9	1060	5	156	6	63
Urtica dioica	6	630	8	470	2	10	2	10						
Festuca rubra					2	6			9	1960	8	2075	10	3125
Anthoxanthum odoratum	1	1			6	165	7	295	10	1775	10	3350	10	2550
Rumex acetosa	2	10	5	21	6	75	6	165	9	360	9	270	9	135
Achillea millefolium	1	5	5	70	4	110	3	60	10	275	7	35	4	20
Trifolium repens					1	50	5	195	10	2950	10	1000	7	170
Vicia cracca	3		4		7	295	7		7	260	9	225	8	85
Veronica chamaedrys			2	55	3	15	4	20	7	80	10	455	8	85
Hypericum maculatum	1	5			7	35	4	20	5	111	9	430	9	225
Luzula multiflora					1	5	1	5	7	166	9	780	10	570
Pimpinella saxifraga			1	5	2	10	2	10	7	121	8	40	10	140
Plantago lanceolata									3	56	10	185	9	350
Briza media									3	105	9	935	8	595
Carex pilulifera											1	5	5	160
Nardus stricta									1	5	8	595	7	635
Hieracium pilosella											6	26	4	110
Potentilla erecta									3	11	2	55	7	960
Prunella vulgaris									1	5	5	115	5	70
Viola canina													3	230
Vaccinium myrtillus													3	105

The main differentiating factor was level of nitrogen fertilisation. Application of high rates of nitrogen fertiliser (group A), resulted in high mass sward with *Hollcus mollis* as the dominant species. Over fertilisation manifested itself by lodging of plants and a considerable share of dicotyledonous species of ruderal character (e.g. *Chaerphyllum aromaticum*, *Urtica dioica*) with little feeding value. Usually it is observed when the management method has not been matched to soil and climatic conditions (Zimmermann *et al.*, 1997). High nitrogen fertilisation gave high yield, but limited species diversity (Table 2), which was reflected in high, negative correlation coefficients between the number of species, height of plants and yield (Table 3).

This is a commonly observed interdependence (e.g. Dodd *et. al*., 1994, Willems and van Nieuwstadt, 1996).

Table 2. Mean height of sward, yield, number of species and Elenberg`s indicator values for different treatments

		+ Ca							0 Ca						
Treat-ment	Group	mean height [cm]	yield [dt·ha^{-1}]	no. of species	L	F	R	N	mean height [cm]	yield [dt·ha^{-1}]	no. of species	L	F	R	N
3	A	35.0	6.3	11.8	6.5	6.1	3.8	5.8	33.0	6.1	9.8	5.4	5.4	2.3	4.1
5	A	39.0	6.1	15.0	6.6	5.9	4.2	6.0	35.0	5.7	12.6	5.5	5.5	2.3	4.3
2	B	40.0	5.7	15.8	7.1	5.7	4.4	5.7	38.0	5.3	15.8	6.3	5.6	3.0	5.0
4	B	41.0	5.8	14.8	7.3	5.9	5.2	6.1	35.0	5.8	15.2	6.6	5.9	3.5	5.5
1	C	29.0	4.8	21.8	7.5	5.6	5.7	5.7	28.0	3.8	22.2	7.1	5.7	5.1	5.4
7	C	18.0	2.9	25.6	7.3	5.7	5.2	4.8	16.6	3.2	28.8	7.3	5.7	5.2	4.7
6	D	16.6	3.1	28.6	7.1	5.9	5.2	4.6	14.0	2.8	26.0	6.7	5.8	4.8	3.1
LSD		4.47	1.17	3.09	0.43	–	0.90	0.56	5.86	1.20	3.62	0.51	–	0.77	0.83
mean		31.2*	4.9	19.1	7.1*	5.8	4.8*	5.5*	28.5*	4.7	18.6	6.4*	5.7	3.7*	4.6*

Means for Ca treatment marked with* differ significantly ($P<0.05$) according to Fisher test.

Table 3. Correlation coefficients of measured variables for two liming treatments (N = 35)

Treatment		yield	no. of species	L	F	R	N
+ Ca	mean height	0.75*	–0.76	0.29	0.05	–0.40*	0.62*
	yield		–0.68*	0.22	0.28	–0.26	0.69*
	no. of species			0.42*	–0.23	0.46*	–0.65*
	L				–0.19	0.74*	0.02
	F					0.11	0.39*
	R						0.13
0 Ca	mean height	0.71*	–0.65	–0.43	–0.06	–0.58*	0.47*
	yield		–0.60*	–0.37*	–0.06	–0.55*	0.32
	no. of species			0.77*	0.33	0.80*	–0.03
	L				0.53	0.84*	0.36*
	F					0.47*	0.54*
	R						0.22

Coefficients marked with * are significant (P = 0.95)

Treatments fertilised with moderate rates of nitrogen fertiliser and P and K (group B) were characterised by a relatively uniform sward, not dominated by a single species. In these swards there were many species characteristics of meadows of *Mollinio-Arrhenatheretea* class, such as *Festuca pratensis* and *Dactylis glomerata*, however the proportion of species, dominating in group A, was considerable. The yield and sward height were moderately high (Table 2).

Treatments with no N fertilisation (group C) had a higher number of species. Long-term lack of nitrogen fertilisation led to domination by species of poor and medium fertility habitats, such as *Festuca rubra* and *Anthoxanthum odoratum* or *Festuca pratensis,* and a low sward mass, giving a small dry matter yield (Table 2). These treatments had a high proportion of

Trifolium repens, connected with high phosphorus fertilisation (in relation to N fertilisation), promoting the development of legumes.

Fertilisation with nitrogen only (group D) gave rise to considerable crop reduction and sward height (Table 2). *Festuca rubra* and *Anthoxanthum odoratum* were dominant in sward. The treatment was characterised by the occurrence of many species each with small cover values. Plants typical of very poor habitat of the *Nardo-Callunetea* class accounted for a high proportion of the cover. The number of species was high and similar to treatments not fertilised with nitrogen. *Alchemilla* species were common across all treatments, which are common in all grasslands in the area.

Significant dependence of indicator values on fertilisation methods and liming were found (Table 2). No dependence was found between moisture conditions (F) and the fertilisation method and the impact of liming on the yield and number of species. The analysis of habitat conditions based on Ellenberg Indices shows a considerable impact of liming. In the +Ca option, sward yield and height were most highly correlated with the Ellenberg N value, but in the 0 Ca option, with the Ellenberg R value. There was also a clear drop in the R value, in the 0 Ca option, for treatments fertilised with nitrogen. This suggests that when there is no liming, soil reaction is a factor limiting plant productivity, and after fertilisation, habitat fertility. A similar dependence for the number of species results from shading out less competitive species by high competitive ones in high fertility treatments. The smallest yield was received with one-sided application of nitrogen fertilisers (group D). It seems that when there is long-term removal of nutrients with the cut crop, stimulated by nitrogen fertilisation, lack of other nutrients, phosphorus in particular, was the main factor limiting plant growth. Availability of this element is particularly small in acid soils. A similar effect of nitrogen fertilisation was found by Willems *et al.* (1993).

Conclusions

Long-term application of different fertilisation methods results in formation of plant communities with highly differentiated floristic composition and habitat requirements. Liming is of considerable importance on acid soils. Where liming was used, level of fertilisation was a factor limiting plant yield in the conditions of this experiment.

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Plant communities of meadows situated on former arable land in the Pieniny National Park

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Abstract

During the last four decades changes in farming in the Polish mountains have led to a significant shift in the use of agricultural land. In the Pieniny National Park the area of arable land has decreased substantially and has been transformed mainly into permanent grassland. The purpose of the work was to compare the botanical composition and biodiversity of plant associations within the former arable land and the existing grassland. A vegetation map of the Park from the 1960s and a phytosociological relevé from the late 1990s were used. The vegetation of former arable land formed quite a distinct group in the numerical classification. It was quite similar to typical lowland meadows (*Arrhenatheretum elatioris* and *Campanula patula – Trisetum flavescens* community). Almost no characteristic species typical for the Pieniny and the most valuable plant community *Anthyllidi-Trifolietum montani* were found. The biodiversity (number of species, Shannon-Wiener and Simpson`s indices) was moderate, similar to that of lowland meadows and lower than in *Anthyllidi-Trifolietum montani*.

Keywords: mountain grassland, biodiversity, grassland management, grassland communities

Introduction

In the Pieniny National Park (PNP) the non-forest plant communities belong to the most valuable communities, *Anthyllidi-Trifolietum montani* in particular, that include many thermophilous species distinguishing this association from other communities common on mountain meadows. Therefore, one of the main objectives of nature protection in the PNP is to preserve this community that has been formed by extensive use. Social and economic changes (low profitability of agricultural production and the possibility of obtaining revenues from outside agriculture) resulted, however, in a limitation to agricultural management within the Park. Likewise in other regions of the Polish mountains, parts of meadows and pastures were abandoned from agricultural use and arable land was converted into grassland. The purpose of the work was to conduct floristic analysis and assess the natural value of meadow plant communities that emerged in the fields that were arable land in the 1960s in the Pieniny National Park.

Materials and Methods

The Pieniny National Park is situated in the West Carpathians at an altitude of 430–982 m a.s.l. Grasslands are located on brown soils, slightly acid, with a low phosphorus and a moderate potassium concentration. The average annual temperature is 5.5 °C, and precipitation approximately 800 mm. For the analysis 19 phytophysiological relevés were used that were done in grasslands on sites which were used as arable land in the early 1960s. The manner of management of those lands was determined on the basis of a vegetation map of the 1960s (Grodzińska *et al.*, 1982). Phytophysiological relevés used to prepare a vegetation map of PNP in the late 1990s (Kaźmierczakowa *et al.*, 2004) were used for comparison purposes. The analysis of similarity between communities was done on the basis of frequency of plant occurrence with the use of the Euclidean distance formula; for grouping the method according to Ward was used. Comparisons of species diversity were conducted using the Shannon-Wiener index, and the Simpson dominance index (Magurran, 1988).

Results and Discussion

Based on an analysis of the vegetation maps of the PNP in the 1960s (Grodzińska *et al.*, 1982) and in the late 1990s (Pancer-Koteja and Kaźmierczakowa, 2004), a considerable decrease in the area of arable land and grassland was found: from 715 ha to 449 ha. The main reason was that arable land was not managed any longer, and this area had decreased from 334 ha to only 20 ha. A comparison of both maps reveals that a considerable part of the former meadows and pastures had been subjected to successional change or had been reafforested. Former arable land had been transferred into hay meadows. Therefore, a considerable percentage of the present meadow communities had been developed on arable land by seeding of simple meadow mixtures (usually *Dactylis glomerata* and *Trifolium pratense*) or by self-seeding. Phytophysiological relevés done on the meadows that were arable land in the 1960s constituted a rather uniform group. Regarding the botanical composition (Table 1), tall grasses such as *Trisetum flavescens* and *Arrhenatherum elatius,* dominated.

Table 1. Frequency of occurrence [F] and mean cover [C] of main species in relevés done on former arable land

Grasses	F [%]	C [%]	Legumes	F [%]	C [%]	Herbs	F [%]	C [%]
Trisetum flavescens	97	34.8	Trifolium repens	79	8.1	Rumex acetosa	86	3.7
Dactylis glomerata	90	8.5	*Trifolium pratense*	72	7.0	*Galium mollugo*	83	3.6
Arrhenatherum elatius	76	13.9	*Vicia cracca*	76	1.2	*Veronica chamaedrys*	86	3.2
Alopecurus pratensis	72	6.1				*Ranunculus acris*	86	2.3
Phleum pratense	76	1.1				*Heracleum sphondylium*	97	0.9
						Plantago lanceolata	76	5.2
						Taraxacum officinale	79	3.3
						Campanula patula	72	1.6

Among the legumes, *Trifolium pratense* and *Trifolium repens* were the dominating species. In the group of herbs, there were many common meadow plants. A common feature of the relevés is a scanty number of rare species and thermophilous species typical for the Pieniny. Comparisons of meadows on ex-arable land (Fig. 1) with meadow communities described in the PNP (Kaźmierczakowa *et al.*, 2004) showed that on the former arable fields a community similar to the *Arrhenatheretum elatioris* and *Campanula patula – Trisetum flavescens* communities developed. They all had similar values of diversity indices and number of species. Analysing the botanical composition with regard to the habitat conditions, higher Ellenberg indicators of reaction (R = 6.4) and fertility (N = 5.9) for communities on ex-arable land were found (Table 1). They are the typical of the lowland and foothill hay meadow communities (*Arrhenatheretum* and *Trisetetum*) found in in Europe (Ellenberg, 1996). Unfortunately, newly created communities, as regards botanical composition and biodiversity, did not reveal similarities to *Anthyllidi-Trifolietum* – the most valuable community of Pieniny meadows.

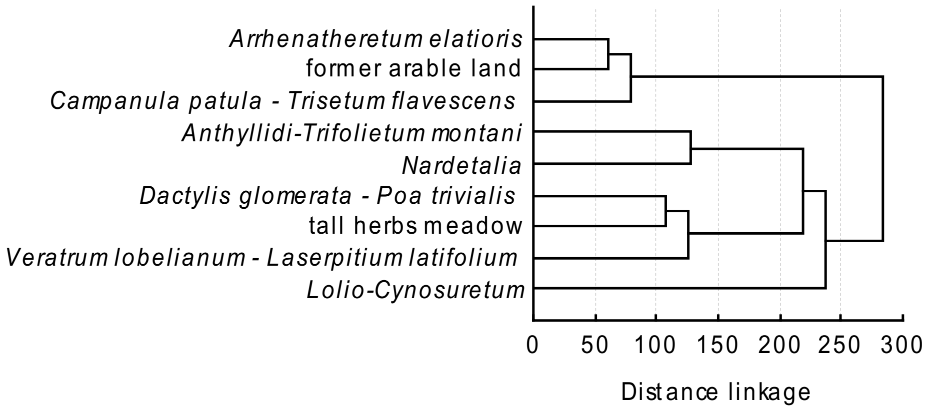

Figure 1. Classification (Euclidean distance and using the Ward method) of plant communities in the Pieniny based on species frequency

Transformation of arable lands into grasslands is beneficial because of environmental reasons, and hence supported in agricultural and environmental programmes of the EU. From the point of view of retaining biological diversity, both at the level of the species and the community, the newly created meadows are characterised by a much lower biodiversity and number of rare species than grasslands on sites which were not ploughed. Similar data were obtained by Ejrnæs and Bruun (1995).

Meadow communities of the forest zone in the mountains emerged as a result of man's long-term activity (Pott, 1988). That is why they can appear on former arable lands now. Usually the obstacle in the re-creation of multi-species meadow plant communities is excessive soil fertility (Jansens *et al*., 1998) and lack of diaspores of meadow species (Hutchings and Booth, 1996).

Table 2. Comparison of all meadow plant communities in Pieniny with relevés done on the former arable land. Diversity indices: L – mean number species (per 100 m^2), H – Wiener-Shannon, C – uniformity, J – dominance. Habitat indicator values: F – moisture, R – reaction, N – soil nitrogen. Number of relevés – n

Plant community		Diversity indices				Habitat indicator values		
	n	L	H	C	J	F	R	N
Former arable land	19	37.0	2.42	0.67	0.16	5.3	6.4	5.9
Arrhenatheretum elatioris	10	39.8	2.43	0.66	0.17	5.2	6.6	5.7
Campanula patula – Trisetum flavescens	10	39.5	2.62	0.72	0.12	5.2	6.1	5.6
Anthyllidi-Trifolietum montani	10	49.3	2.96	0.76	0.08	4.7	6.2	3.8
Dactylis glomerata – Poa trivialis	9	31.1	2.20	0.64	0.18	5.3	5.9	5.7
Veratrum lobelianum – Laserpitium latifolium	10	33.5	2.38	0.68	0.14	5.4	5.0	4.4
Tall-herb meadow	18	33.1	2.30	0.66	0.18	5.7	5.6	4.9
Lolio-Cynosuretum	10	29.1	1.91	0.57	0.25	5.4	6.6	6.0
Nardetalia	11	37.5	2.33	0.65	0.17	5.0	4.1	3.3

Although in case of the Pieniny, species-rich meadows were created on ex-arable land, this did not lead to the creation of the desired community. The *Anthyllidi-Trifolietum* community exists also in the neighbourhood of newly created grasslands, thus there is a possibility of species migration. That is why it is argued that in the case of the Pieniny the period that has passed since the time of changing arable lands into grasslands (less than 40 years) is too short for meadow communities typical for the region to be re-created. Another important factor is the remaining high fertility of habitats of former arable land, facilitating the strong growth of common species.

Conclusions

Meadow communities that were formed on ex-arable land are characterised by multi-species floristic composition, not significantly different from meadow communities common in the whole forest zone in the West Carpathian, while *Anthyllidi-Trifolietum montani* community, typical for the Pieniny, was not created.

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Biodiversity and agro-zootechnical value of seminatural grasslands in the Northern Apennines (Emilia-Romagna), Italy

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Abstract

Grassland vegetation, particularly in protected areas, requires careful management in order to preserve biodiversity as well as pastoral resources. In this study, different grassland communities within a protected area (SCI, Site of Community Importance, following the Habitat Directive 92/43/EEC) of the Emilian Apennines were considered. These grassland communities differ in the degree of exploitation, ranging from ones where agricultural practices are still performed to those where these practices have been long abandoned. A wide survey of these different grassland communities was performed by means of 101 field surveys following the Braun-Blanquet method. Survey data were then processed by cluster analysis in order to recognize the main vegetation typologies present in the studied area. For each survey and for the main vegetation typologies, some biodiversity parameters were calculated, along with the sustainable animal charge based on the grazing value obtained using the Daget-Poissonet method. This information represents interesting and useful knowledge for the management and conservation of grassland communities. Conservation of these grasslands needs, in fact, to calibrate the animal charge with precision in order to prevent degradation or afforestation.

Keywords: biodiversity indices, conservation, grassland, grazing values, protected area, sustainable animal charge

Introduction

Over the last few decades, calcareous grasslands have become rare habitats in Europe owing to their low agricultural productivity. This scarcity is strictly linked to the resulting abandonment of agricultural practices, which usually leads, in the hill and sub-montane belt of the Northern Apennines (Italy), to afforestation. Grassland communities are also important, among other things, for their biodiversity value. For many years, in fact, European grasslands have been the subject of many ecological studies demonstrating their importance for biodiversity. The richness in plants and animals of grasslands and pastures, and the remarkable variability innate in these communities, confer a considerable importance to these resources for the conservation of biodiversity at all levels, i.e. genetic, species and ecosystem. Floristic biodiversity in grasslands, as in all agricultural landscapes, is essentially dependent on the former and current communities, and intensity, pattern and dynamics of land use present in these grasslands (Waldhart *et al.*, 2000). For some decades, however, many such traditional practices have diminished and some have ceased completely, especially in marginal lands. The environmental consequences of these changes are not all favourable in terms of diversity. Grazing, in particular, has decreased over the years and, in the past, was of particular importance for the maintainence of the herbaceous structure in grasslands. Biodiversity and human activities are not irreconcilable: the former confers the ecosystems a certain stability which can be improved by the latter. This study has the purpose of proposing the exploitation of some biodiversity and grazing indices for the management and conservation of grassland communities.

Materials and Methods

The study was carried out in the Monte Sole protected area (SCI, Site of Community Importance, following the Habitat Directive 92/43/EEC), in the Emilian Apennines (Northern Italy).The area extends over 6476 ha, with an altitude ranging from a minimum of 96 m a.s.l to a maximum elevation of 825 m a.s.l. The area has a total annual rainfall of 990 mm, a mean annual temperature of 11.5 °C and the absence of a xerothermic period. Surveys (101) were performed by means of the Braun-Blanquet phyto-sociological method. They were then processed by average linkage cluster analysis (Sokal and Michener, 1958) to identify the main vegetation typologies and their dynamic relationships. The grazing value of each of the 101 communities was calculated following the method proposed by Delpech (1960) and then adopted by Daget and Poissonet (1969), applying the van der Maarel (1979) transformation to the Braun-Blanquet cover values of the species. The grazing value of the species, used for the calculation of the grazing value index of Daget and Poissonet (1969), comes from the data-base realised by Roggero *et al.* (2002). The grazing value community index ranges from 0 (plant community where all the species have no grazing importance) to 100 (plant community where all the species are excellent forage plants). The sustainable animal charge (SAC) was calculated on the basis of the grazing value (GV), with the following formula: SAC = GV*0.02 (or 0.06) where 0.02 is a coefficient for cows or horses, while 0.06 is for sheep and goats (Daget and Poissonet, 1969). For each survey and for all the grassland typologies, the main biodiversity parameters (Margalef's richness index, Shannon-Weaver diversity index, Pielou equitability index) were calculated by means of the STADIV software (Ganis, 1991).

Results

Five different grasslands typologies were recognised by means of the cluster analysis: very recent forage cropping (VR) in meso-xeric habitats; less recent forage cropping (LR) in mesic habitats; semi-ruderal meso-xerophilous grasslands of *Agropyro-Dactyletum* (AD); semi-natural, semi-mesophilous grasslands of *Salvio-Dactyletum* (SD); semi-natural, meso-xerophilous grasslands of *Brometalia erecti* (B). Two dynamic sequences were delineated: 1) very recent forage cropping → less recent forage cropping → (abandonment or grazing) → grasslands of *Agropyro-Dactyletum* → (abandonment or grazing) → grasslands of *Brometalia erecti*; 2) very recent forage cropping → less recent forage cropping → (periodical mowing) → grasslands of *Salvio-Dactyletum* → (abandonment of grazing) → grasslands of *Brometalia erecti*. Table 1 shows the mean grazing values (Daget and Poissonet, 1969) and the resulting sustainable animal charge of the grassland community typologies found in Monte Sole. The grazing value and the correlated sustainable animal charge seem to decrease along the succession (F = 5.23, d.f. = 100, P = 0.008).

Table 1. Mean and standard deviation of the grazing values (GV) and the resulting sustainable animal charge (SAC) for cows/horses and sheep/goats of the five grassland typologies found in Monte Sole

	GV	SAC cows/horses ($ha^{-1}year^{-1}$)	SAC sheep/goats ($ha^{-1}year^{-1}$)
VR	50.0±31.0	1.0±0.6	3.0±1.9
LR	46.5±18.9	0.9±0.4	2.8±1.1
AD	36.5±17.6	0.7±0.3	2.2±1.1
SD	31.3±8.6	0.6±0.2	1.9±0.5
B	29.3±9.0	0.6±0.2	1.8±0.6

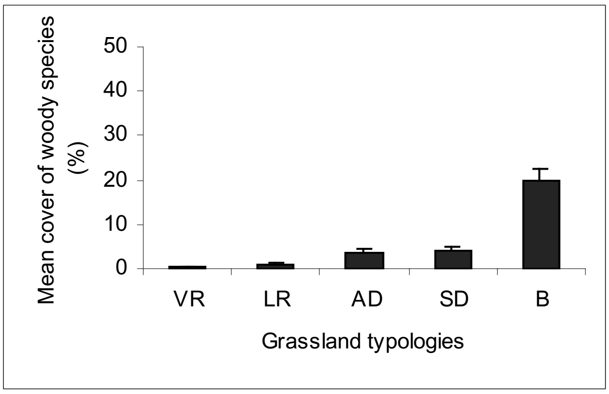

Figure 1. Mean cover values (%) and standard deviation of woody species in the five grassland typologies found in Monte Sole

These lower values are also due to the higher cover of woody species in the *Brometalia erecti* communities, which are less palatable for ruminants, especially cows and horses, as shown in Figure 1 ($F = 7.30$, d.f. = 100, $P = 0.002$).
The results of the biodiversity parameters are shown in Table 2. An opposite trend compared to the grazing value and sustainable animal charge can be observed in these parameters.

Table 2. Mean and standard deviation of the biodiversity parameters of the five grassland typologies found in Monte Sole

	Margalef's richness index	Shannon's diversity index	Pielou's equitability index
VR	2.1±1.4	1.3±0.8	0.5±0.2
LR	3.9±1.2	1.5±0.5	0.7±0.1
AD	6.4±2.1	1.6±0.4	0.5±0.1
SD	6.1±2.0	2.0±0.6	0.6±0.2
B	7.1±1.3	2.7±0.3	0.5±0.1

Biodiversity, like species richness (Margalef's index), significantly increases along the succession ($F = 21.60$, d.f. = 100, $P < 0.001$). Shannon's diversity index indicates that the early stages of succession present the lowest diversity, probably because of competition between species ($F = 7.20$, d.f. = 100, $P < 0.001$). Pielou's equitability index, ranging from 0.5 to 0.7, highlights a medium/high equilibrated distribution of the species in all grassland typologies, demonstrating a good prospect for conservation of these communities.

Discussion

The results obtained in this study as regards to grazing value show that the agronomic value of the five grassland typologies found in Monte Sole, even though quite low, is somewhat higher where agricultural practices are still performed, while, with abandonment, it decreases. These data are in line with other studies (Bagella, 2001) in similar grassland typologies. However, the *Brometalia erecti* communities present a higher richness in Margalef's index and the lower agronomic value is compensated by the naturalistic value. Comparable data are available for old fields with *Brometalia erecti* communities in the alpine zone, with values of 3.0 for Shannon's index and 0.5 for Pielou's index, quite close to ours (Bassignana, 2002).

These results suggest different possibilities for reconciling exploitation of these grasslands and conservation objectives. Grazing can be managed as regards the type of animal and the time of grazing in the area according to the different grassland typologies. On account of their good grazing values, the early stages of the succession can be considered as good pastures for a longer stay of cows and horses, followed by sheep and goats. In the *Brometalia erecti* communities, where the species richness is high but the presence of woody species threatens the maintenance of a herbaceous structure, a longer grazing by sheep and goats is recommended, due to their feeding habits which need a lower nutritional value compared to cows and horses but which also include shrubs.

Conclusions

The aim of this study was to demonstrate that the conservation of grassland communities can also occur through the promotion of traditional agricultural practices such as pasture. At a local level, initiatives of private enterprise land reorganisation and/or joint private and public management are necessary in order to support such a project economically.

Acknowledgements

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Changes in components of floristic diversity in three adjacent rangeland types

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Abstract

The anthropogenic impact on the natural rangelands in the Mediterranean zone has been profound. The age-long impact of the land use practices is reflected in the different degree of complexity of these ecosystems. Floristic diversity is an indicator of this complexity. The purpose of this study was to investigate the differences in floristic diversity in three adjacent rangelands of different type. The research was conducted in late spring 2004 in the mountainous area of Karpenisi, central Greece. The rangeland types were: grassland, *Juniperus*-shrubland and fir-forest dominated by *Abies borisii – regis*. In the past, the area was extensively used by livestock, while grasslands were agricultural lands. The line intercept method was applied and a total of 1500 contacts were taken. In all rangeland types *α*-diversity indices were calculated and diversity ordering diagrams were produced. In addition, as rangeland types were adjacent, *β*-diversity indices were calculated. It was found that grassland sustained the highest *α*-diversity among the other vegetation types, and the highest species turnover was observed between grasslands and fir-forests. The evolutionary consequence of land use changes, inferred by the present status of diversity, is discussed.

Key words: *α*-diversity, *β*-diversity, grassland, *Juniperus*-shrubland, fir-forest

Introduction

The modern biodiversity-functioning research (*sensu* Naeem *et al.,* 2002) is directed towards a synthetic ecological framework, where major ecosystem functions will be effectively combined and determined. Diversity is closely related with ecosystems' stability, but just a simple inspection of the *α*-diversity indices into the components of complex ecosystems (such as Mediterranean) is rather an inadequate effort to the direction of the stability integration; *α*-diversity depicts the diversity of species within a community or habit (Southwood and Henderson, 2000). Given the high complexity of Mediterranean ecosystems, originated from variable climate and human intervention, an integrated approach of their stability demands the inclusion of higher order diversity indices. Among them *β*-diversity depicts changes of diversity along a gradient, and consequently is better suited to Mediterranean conditions. Indices of both *α*- and *β*-diversity are suggested for use in the assessment of the diversity of an area (Southwood and Henderson, 2000). The objectives of the study were to infer about floristic diversity of a forested Mediterranean landscape by studying the changes in community level (*α*-diversity), and to quantify the response of diversity along a vegetative gradient; a gradient imposed by human intervention (*β*-diversity).

Study area and Methods

The research was conducted in *Margarita* forested land of Karpenisi (21°37', 38°43'), central Greece, in late of May 2004. The area was 400 ha in size and had a mean elevation of 1100 m a.s.l. The climate is characterized as (bioclimatically) humid Mediterranean with cold winters (mean air temperature 10.4 °C, mean annual precipitation 1321 mm, mean relative humidity 74.2%). Limestone is the parent rock material; soils are of medium to low fertility, and the pH is lower than 5.5. The area is mostly forested with firs (*Abies borisii-regis* Mattf., and the Greek endemic *A. cephalonica* Loudon.). The continuity of the landscape is disrupted by *Juniperus* shrublands derived from clearings in order to sustain goat-husbandry, and cold-season grasslands that occupy abandonment (formerly cultivated) lands. Nowadays, the main human activities in the area are forestry and husbandry. Specifically, the grasslands and shrublands of the Margarita are used by a mixed flock of 300 small ruminants (sheep and goats); a very low number in respect to the 1500 small ruminants that were grazing the area until the decade of 1970.

Five experimental plots of 0.1 ha were randomly located in three vegetation types of the area and one transect of (50-m) was assigned on the ground of each plot. Floristic information was obtained by the use of the line-intercept method (Bonham, 1989). Contacts were obtained every 50 cm (100 contacts per transect) and taxa intercepted were recorded according to their name given by Flora Europea (Tutin *et al*., 1964–1980). Bare ground records were excluded from the analysis. A total of 1500 contacts were finally taken (3 vegetation types x 5 transects x 100 contacts).

Floristic *α*-diversity was determined separately for each vegetation type (namely, grasslands, *Juniperus*-shrublands, and fir-forests) by Shannon-Weiner index of *α*-diversity, evenness of Shannon-Weiner index of diversity, Berger-Parker index of dominance, and the first order jackknife plant richness estimator. This way, the *α*-diversity profile for each vegetation type is obtained. Finally, the diversity ordering of the three communities based on Renyi index was made. The formulae of the indices are found in Vrahnakis *et al.* (this volume).

Floristic *β*-diversity was expressed as species turnover, from one vegetation type to another, and measured by Cody's β_C (Magurran, 2004). The index is given by the formula:

$$\beta_C = \frac{g(H) + l(H)}{2} \qquad (1)$$

where $g(H)$, and $l(H)$ are the number of taxa gained and lost, respectively.

Finally, similarity was expressed by two indices, the Sørensen's quantitative index C_N, modified by Bray and Curtis (1957), and the widely used Morisita-Horn's *P* (Magurran, 2004). The indices are given by the formulae:

$$C_N = \frac{2jN}{(N_\alpha + N_b)} \qquad (2)$$

$$P = 100 - 0.5\sum_{i=1}^{S}\left|P_{\alpha i} - P_{bi}\right| \qquad (3)$$

where $2jN$ is the sum of the lower of the two abundances for taxa found in both vegetation types, N_α, N_b are the total number of individuals found in vegetation types A, and B respectively, and $P_{\alpha i}$ and P_{bi} are the percentage abundances of taxon *i* in vegetation types A and B, respectively.

Results and Discussion

Floristic α-diversity

A total of 71 taxa were identified in Margarita; seven of them were identified at the genus level. Taxa richness attained its maximum value in grasslands (46 taxa recorded), followed by *Juniperus*-shrublands (39 taxa), and fir-forests (15 taxa). Half of the taxa found in grasslands (23) were present in *Juniperus*-shrublands; grasslands and fir-forests shared four taxa (*Juniperus oxycedrus*, *Campanula spatulata*, *Poa bulbosa*, and *Trifolium pratense*); six taxa were common in *Juniperus*-shrublands and fir-forests (data not shown). All the components of α-diversity revealed that grasslands sustained the higher diversity, followed by *Juniperus*-shrublands and fir-forests. Shannon-Weiner's index of α-diversity (H´) and the index of evenness (E (H´)) has the maxima in grasslands, while the Berger-Parkers' index of relative (d) dominance has the lowest value in grasslands (Table 1). As it was expected, *J. oxycedrus* was the dominant species in shrublands (41% of the total number of contacts); *Abies borisii-regis* was the dominant species in fir-forests (51%), and *Bromus hordeaceus* was the dominant one in grasslands (16%). The first-order jackknife non-parametric taxa richness estimator (S_{max}) indicates that the maximum potential taxa richness is 101.7 as we move from grasslands to fir-forests.

Table 1. Main components of floristic α-diversity of the three vegetation types of the Margarita area

Vegetation type	H´	Variance (H´) (x 10^{-3})	E (H´)	d	S_{max}	St. Dev. (S_{max})
Grasslands	3.190	2.275	0.748	0.160	46.0	0.0
Juniperus-shrublands	2.468	4.787	0.579	0.407	81.5	3.5
Fir-forests	1.856	13.295	0.436	0.511	101.7	8.2

The α-diversity relationship that holds among the three vegetation types is explicitly depicted in the diversity ordering diagram produced by Renyi's family generator. The diversity ordering diagram is used to infer about the comparability of communities in terms of diversity, and in cases that comparability is ensured the ordering of communities according to their diversity is depicted (Vrahnakis *et al.*, this volume). Clearly, the three vegetation types are comparable among each other in terms of diversity, with grasslands' diversity higher than other vegetation types (Figure 1).

Floristic β-diversity

According to Cody's β_c, the highest species turnover is obtained by changing from grasslands to fir-forests, suggesting that along this gradient the less homogenous diversity is obtained (Table 2).

The majority of the proposed indices measuring β-diversity use presence/absence data; as such these focus solely on the taxa richness elements of diversity (Henderson 2003). The use of quantitative data (i.e. taxa' abundances) suggests highest similarity in the vegetation gradient from grasslands to shrublands and lowest from grasslands to fir-forests (Sørenson's and Morisita-Horn's indices in Table 3). The results are in accordance with the taxa' turnover index of Cody (Table 2).

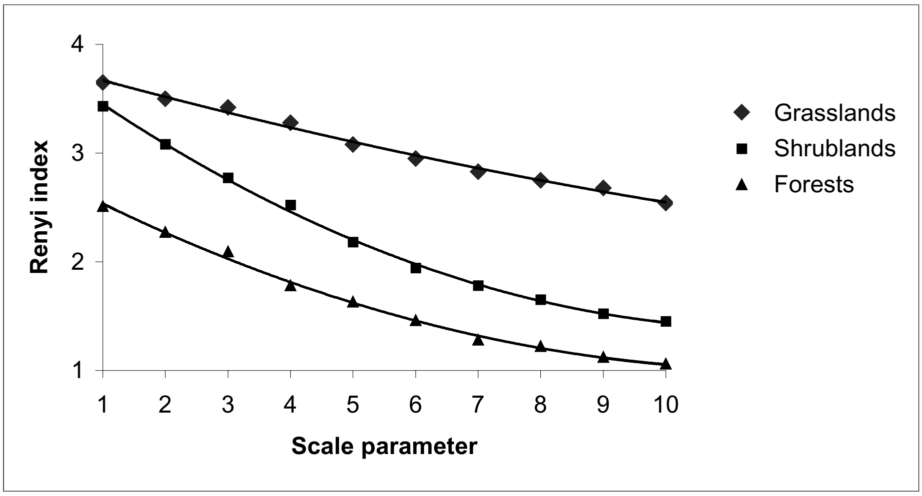

Figure 1. Diversity ordering diagram for the three vegetation types (Grasslands, shrublands, forests) in the Margarita area

Table 2. Cody's β_c index of species turnover for three vegetation types (grasslands: G, *Juniperus*-shrublands: J, fir-forests: F)

Components/indices	G→J	G→F	J→F
Number of taxa gained	15	10	9
Number of taxa lost	24	41	33
Cody's β_c	19.5	25.5	21

Table 3. Sørenson's quantitative index C_N and Morisita-Horn's percentage similarity *P* (in parenthesis)

	Juniperus-shrublands	Fir-forests
Grasslands	0.180 (17.97%)	0.045 (8.46%)
Juniperus-shrublands		0.108 (13.03%)

Vegetation types of Margarita have been determined by a long-lasting human intervention. The abandonment of husbandry in the area of Margarita resulted in the integration of patches of shrublands and grasslands and facilitated the wider commutation of species between them (Vrahnakis *et al*., 2002). Once, the landscape was dominated by small, regular vegetation patches, controlled by grazing from sheep and goats, while nowadays, the landscape is changing to extensive, irregular patches with mixed floristic elements. In addition, the fact that grasslands were prior agricultural lands with high fertilizer inputs probably explains their high taxa richness. The present floristic (and diversity) elements reflect the successive stages, given that the abandonment of cultivated land and the extenuation of grazing pressure initiate the process of secondary succession, which leads to losses in diversity (Giourga *et al*., 1998). This is reflected to the higher number of taxa lost, in respect to the taxa gained, and to the low percentage similarities measured in all vegetation trends (grasslands to *Juniperus*-shrublands, grasslands to fir-forests, *Juniperus*-shrublands to fir-forests).

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Components of floristic diversity in kermes oak shrublands

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Abstract

Kermes oak (*Quercus coccifera* L.) shrublands are valuable land resources in Greece. Despite their low commercial value in terms of wood production they are important feeding resources for domestic and wild animals, provide fuel to local people of remote areas and play a significant role in preventing soil erosion. The complexity and stability of kermes oak ecosystems are approached in this research by analysing the components of floristic diversity. Four shrubland sub-types were identified in northern Greece according to their scaling to shrub density. Nine plots (0.1 ha each) of each shrub cover class were randomly selected and two 50-m transects were randomly assigned in each plot. Four quadrats per transect were systematically taken and floral composition and taxa richness were recorded. A total of 288 quadrats were taken and differences among the four shrubland sub-types in terms of Shannon-Weiner index of diversity, evenness, Berger-Parker index of dominance, and the first order jackknife plant richness estimator were explored. Finally, the diversity ordering diagram of the four communities based on the Renyi index was made. A total of 287 taxa were recorded and it was found that as the density of the shrublands increases α-diversity decreases.

Keywords: *Quercus coccifera*, jackknife first order estimator, diversity ordering, shrublands stability

Introduction

The importance of retaining high levels of biodiversity is essential for ecosystem stability (Aarts and Nienhuis, 1999). There are studies demonstrating that in grazed Mediterranean shrubland ecosystems floristic diversity may be a result of the spatial distribution of dominant species. Merou and Vrahnakis (1999) have found that in kermes oak (*Quercus coccifera* L.) shrublands of northern Greece floristic diversity may significantly vary with the distance from the kermes oak plants. In addition, Alados *et al*. (2004), in northern Greece, have found that *Q. coccifera* plants became significantly more random with grazing impact. Consequently, given the importance of kermes oak shrublands for sustaining husbandry in less favoured area of Greece (Papanastasis, 1999), the changes of floristic diversity in relation to kermes oak density is of major scientific concern. The objective of the study was to quantify the components of floristic α-diversity in kermes oak shrublands of northern Greece, and to explore the impact of grazing on these components as it is determined by shrub cover.

Material and Methods

The study was conducted in kermes oak (*Quercus coccifera* L.) shrublands of Lagadas county, Macedonia, northern Greece (23°19’00”, 40°43’36”, WGS84), May/ June 2004. Lagadas county is inhabited by five village communities covering an area of about 25 km^2 and extends from less than 100 to more than 1000 m altitude. The area has a mean annual precipitation of about 500 mm and a mean minimum air temperature of the coldest month below 0 °C, suggesting a sub-humid Mediterranean climate with cold winters. Gneiss is the dominant parent material and soil pH does not exceed 5.5. The main land uses are rangelands (47%), agricultural land (34%) and forests (18%) (Chouvardas *et al*., in press). Shrublands (8515.7 ha, or 73.85% of the total rangeland area) are dominated by kermes oak and used by 14,950 goats. The extensive use of complementary feeding determines the applied husbandry system as semi-intensive, meaning that herbage production in the shrublands is under-used and as a consequence, they are considerably at risk to long-term degradation.

Four rangeland sub-types were distinguished, namely S0 (grasslands with sporadic kermes oak plants), S1 (shrublands with kermes oak cover less than 10%), S2 (shrublands with kermes oak cover 10–40%), and S3 (shrublands with kermes oak cover more than 40%). Nine polygons for each shrubland sub-type were randomly selected from a map of the area, and a plot of 0.1 ha was randomly selected in each polygon. Two transects (50-m each) were randomly assigned on the ground. In each transect four quadrats (50 ×50 cm) were assigned at distances of 5, 20, 35 and 50 m from the edge of each transect. The quadrats were divided in 25 (5 × 5) smaller grids. In order to avoid individual difficulties associated with counting, the relative taxa abundance was determined by the number of grids intercepted by them (Sandra Lavorel, pers. com., 25 May 2004). A total of 288 quadrats were finally used (4 sub-types × 9 plots × 2 transects × 4 quadrats). The scientific names of the taxa were based exclusively on the Flora Europea (Tutin *et al*., 1964–1980).

Floristic diversity was determined by Shannon-Weiner index of *α*-diversity (H´), evenness of Shannon-Weiner index of diversity (*E*), Berger-Parker index of dominance (*d*), and the first order jackknife plant richness estimator (S_{max}). Finally, the diversity ordering of the four communities based on Renyi's family (H_α) was made. The formulae of the indices are given below (Henderson 2003):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

$$E = \frac{H'}{H_{max}} = \frac{H'}{\ln S}$$

$$d = \frac{N_{max}}{N}$$

$$S_{max} = S + \left(\frac{n-1}{n}\right)k$$

$$H_\alpha = \frac{\ln \sum_{i=1}^{S} p_i^\alpha}{1-\alpha} \qquad (1)$$

where *S* is the maximum recorded number of taxa, p_i is the proportional abundance of the *i*-th taxa, N_{max} is the number of records of the dominant taxon, *N* is the total number of records, *n* is the order of the sub-type starting from S0, *k* is the number of taxa only found in one sub-type, and *α* is the order (scale parameter).

Results and Discussion

A total of 287 taxa were recorded in all shrubland sub-types. 237 of them were identified at the species level and five at the subspecies level. Thirty four taxa were identified at the genus level, eight at the family level, two were totally unidentified, while Bryophyta were all summed as a single record (data not shown). In S0 sub-type a total of 165 taxa were recorded. The three dominant taxa in S0 were *Cynodon dactylon* (502 records), *Festuca* cf *valesiaca* (317), and *Trifolium campestre* (204) in a total of 6852 records. *Quercus coccifera* was present with only six records. The number of recorded taxa attained its highest value in S1 sub-type as 188 taxa were recorded. *C. dactylon* was again the dominant taxa with 357 records, followed by *Dactylis glomerata* (354 records), and *Q. coccifera* (335 records) in a total of 5681 records. The latter taxon was the dominant one in S2 sub-type (700 records) followed by *Thymus sibthorpii* (212 records) and *Anthemis parnassica* (203 records). In S2 sub-type 164 taxa were recorded in a total of 4178 records. The lowest number of taxa (139) was recorded in S3 sub-type, with *Q. coccifera* being the dominant taxon (1351) followed by *D. glomerata* (223 records) and *T. sibthorpii* (102 records) in a total of 3554 records. It seems that kermes oak is strongly associated with perennial winter grasses, while it is negatively correlated with warm season grasses; results that are in accordance with prior findings (Merou and Vrahnakis, 1999).

The highest value of Shannon-Weiner index of diversity was found in the S1 sub-type (4.774) and the lowest in S3 sub-type (3.268) (Table 1). The evenness of number of individuals distributed into taxa in the shrublands of S1 sub-type (0.773) was found to approximate the maximum value presented in S0 (0.780). As the results for the Berger-Parker index of dominance suggest, S1 exhibits the highest diversity; in S1 *Cynodon dactylon* has the lowest relative dominance (0.063) in respect to the rest dominant taxa of the other sub-types. The relative importance of dominance increases as the cover of kermes oak increases, resulting in lower diversity. S_{max} indicates the non parametric taxa-richness potentially sustained by a community (Henderson, 2003). The rate of change of S_{max} expresses the potential number of taxa should be added to the S0 sub-type, where kermes oak plants can be found only sporadically, moving to the S3 sub-type, where kermes oak plants dominate. Consequently, the overall number of taxa potentially found in kermes oak shrublands of Lagadas county is estimated as 372 taxa.

Table 1. Main components of floristic diversity of the sub-types of kermes oak shrublands of Lagadas county

Sub-type	H′	Variance (H′) (x 10^{-3})	*E* (H′)	*d*	S_{max}	St. Dev. (S_{max})
S0	4.415	0.163	0.780	0.073	165	0
S1	4.774	0.273	0.773	0.063	295	5
S2	4.107	0.503	0.725	0.168	347	67
S3	3.268	1.138	0.577	0.380	372	13

The results pointed out some discrepancies in the use of different diversity indices. For example, it was found that, by calculating the McIntosh index of diversity, the S0 sub-type exhibited highest diversity in respect to the other sub-type (data not shown) – a result that opposes the one produced by the use of Shannon-Wiener's index . This was in accordance with the arguments of Tóthméresz (1995) that different diversity indices may differ in ranking of communities. The diversity ordering diagram offers a graphical solution for safe interpretations (Henderson, 2003). The diagram is produced from Renyi's family (1), which is based on the concept of entropy. Hill

(1973) demonstrated that for α=0,1,2 the H_α gives the total species number, Shannon-Wiener H´ and Simpson's D respectively. Thus by varying α we may generate a range of diversity measures. To test for non-comparability of communities H_α is calculated for a range of α values and the results presented graphically. It was found that the S0 and S1 sub-types attained highest diversity values followed by the S1 and S2 ones (Figure 1). No safe conclusions concerning the ranking of S0 and S1 sub-types can be drawn as their diversity lines intersected each other; i.e. they are non-comparable in terms of *α*-diversity.

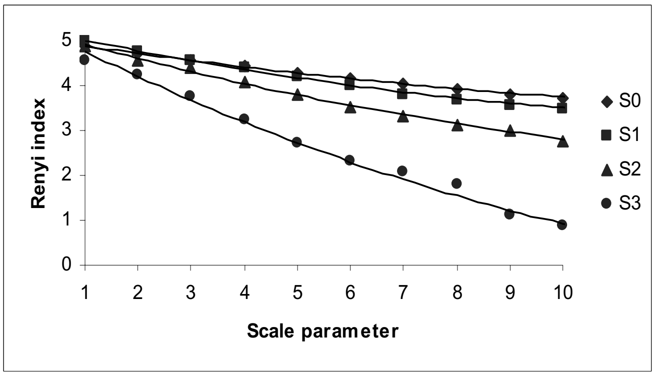

Figure 1. Diversity ordering diagram for the four sub-types (S0-S4) of the kermes oak shrublands of Lagadas county

Conclusions

Shrublands with kermes oak cover of less than 10% sustain high values of diversity and consequently are more stable and well functioning than shrublands with a higher kermes oak cover. The abandonment of the traditional husbandry of the area has resulted in less stable ecosystems and special attention must be drawn to sustain an extensive type of use.

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Recultivation of oil shale semi-coke dumps with grasses and legumes: problems and potential

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Abstract

One of the major problems in the production of oil from oil shale in Estonia is related to the waste product, semi-coke, which presents a hazard to the environment. Results of the previous investigations indicate that increased bioremediation of semi-coke can take place under vegetation. However, the problem is how to establish sustainable vegetation in oil shale semi-coke dumps and what species are the most suitable to grow in such conditions. The experiments revealed that fresh semi-coke strongly inhibits plant growth. Recultivation substance, obtained by the mixing of hot semi-coke immediately after oil shale processing with acid sphagnum peat, at volume ratio 1:1, can be used as a growing substrate for plants after 6–7 months weathering. The results indicated that main criterion determining the suitability of a particular species for use in areas to be recultivated (e.g. semi-coke dumps) is species drought resistance. Therefore, the most suitable species for recultivation of semi-coke dumps in our condtions are: *Festuca ovina var. duriuscula, Bromus inermis, Melilotus albus* and *Medicago sativa.*

Keywords: semi-coke, recultivation, legumes, grasses, phytotoxity

Introduction

Over several decades the solid wastes from the oil shale chemical industry (semi-coke) have been deposited near Kiviõli and Kohtla-Järve cities in the North-East of Estonia. For example, in Kiviõli the Chemical Industry has deposited as much as 22 million tons of semi-coke already and 180–200 thousand tons are added to this amount each year. Semi-coke is classified in Estonia as a hazard waste for the environment and this is due to its high content of organic compounds, including phenolic compounds (up to 22 mg kg^{-1}), polycyclic aromatic hydrocarbons (PAH; up to 13 mg kg^{-1}) and oil products (up to 1700 mg kg^{-1}). Semi-coke is alkaline (pH 12.6) and it has a high content of water soluble sulphides (422–11000 mg kg^{-1}), which could also present a hazard for the environment (Otsa and Tang, 2003). The results of previous experiments have indicated that the degradation of hazard compounds in semi-coke will increase under vegetation in which biodegradative microbes have introduced (Truu *et al*., 2003). The problem is how to establish dense vegetation with well developed root systems on the semi-coke dumps. Previous investigations carried out at the Estonian Agricultural University indicated that fresh semi-coke is toxic the germination and growth of plants (Raave *et al*., 2004). However it is possible to use a recultivation substance after 6–7 months ageing (Raave *et al*., 2004). Besides residual toxicity sustainable growth is hindered by the low nutrient value of the recultivation substance. The recultivation substance contained 17.6–58.2 g of Ca and 0.9–5.0 g of Mg per kg of DM and 13 mg of P and almost 1400 mg of K per kg of DM. The samples also contained 30 mg of B and 10 mg of Mn per kg DM. The low nitrogen content of the substrate limit grass growth and the formation of a dense sward. Therefore it is important to find out possibilities for enrichment of the substrate with nitrogen. Fertilising these areas with mineral fertiliser is uneconomical and impractical due to topographical problems. One solution could be the introduction of legumes which will grow and enrich the substrate with biologically fixed nitrogen. But it is not clear if the conditions in the semi-coke dump are suitable for the *Rhizobium* bacteria to be viable. Several experiments have shown semi-coke toxicity to bacteria and this is probably due to its high phenol and sulphate content (Kahru *et al*., 1997; Kahru *et al*., 1999).

The main aims of the present study were to investigate herbage suitability for growth on semi-coke dumps covered with a thin layer of recultivation substrate, and to identify the optimal sowing rate of seeds for semi-coke dump cultivation.

Materials and Methods

In June 2002, a plot experiment (block design) was established at the base of a semi-coke dump in Kiviõli with *Festuca rubra var. rubra, Lolium perenne, Festuca ovina var. duriuscula, Festuca arundinacea, Bromus inermis, Dactylis glomerata,* and *Trifolium repens.* Where different seed rates were employed germination rate, purity and weight of 1000 grains were taken into account for each species of the assemblage. In spring 2003, the existing swards were assessed and new seedings of *Galega orientalis cv. 'Gale', Medicago sativa* (cultivars 'Juurlu' and 'Karlu'), and *Melilotus albus cv. 'Kuusiku 1'* were introduced into the perished swards.

In 2002, the experiment was divided into four fertiliser treatments: N_0 P_0 K_0, N_{60} P_{11} K_{30}, N_{120}, P_{22} K_{60}, and N_{180}, P_{33} K_{90} kg ha^{-1}. The fertilisation application of the experimental plots was stopped in 2003 to facilitate the inclusion of leguminous species and to render the experimental conditions close to the actual conditions of application. The density of the swards in the plots was assessed in September of 2003 and 2004. The number of plants in all plots was counted at randomly selected sites within an area of 0.2 × 0.2 m (delineated by a wire frame od suitable size. However, in the case of *Festuca ovina var. duriuscula* it was not possible to distinguish between separate plants, and thus he canopy cover (%) was measured at 4 randomly selected sites.

Another experiment was established with a mixture of the above mentioned species (with the exclusion of *Bromus inermis*) where all species were represented with an equal number of seeds. There were used four different sowing rates: 1750, 5250, 10500, 17500 germinating seeds m^{-2}. Each within an area is approximately 1000 m^2.

In 2002, the experiment was fertilised with the rate 90, 8.8 and 37 kg ha^{-1} of N, P and K respectively, of which 55% was given before sowing and 45% after one month. Kemira Power 18:4:9 fertiliser was used. In 2003, the same fertiliser and fertilising rate were used as the previous year, of which 50% was given in May and 50% at the end of July. In 2004, the swards were not fertilised. In September of 2003 and 2004, the canopy cover was measured at 10 randomly selected sites on each seed rate treatment. The relationship between sowing rate and the canopy cover were analyzed with a multiple regression analysis.

The three years of the experiment experienced variable weather conditions. The year 2002 was extremely unfavourable for grass growth due to a summer drought. Germination was uneven as a consequence of water deficit in the soil and plants that sprouted in July perished owing to a late drought. The seeds (mainly *Trifolium repens*) that started to germinate after the beginning of rains in September, had no time to prepare for winter and perished. However, the years 2003 and 2004 were favourable for the growth of grasses as heat and precipitation were distributed evenly throughout the vegetation period.

Results

Among the pure species only *Festuca ovina* and *Bromus inermis* were able to successfully establish a sward (Table 1). Other species perished after germination. In the mixture of six species *Festuca ovina var.duriuscula* was the most competitive one dominating most of the area. All the other seeded species grew only in surface depressions where more moisture was available. Regarding the legume species, seeded in spring 2003, to replace perished pure-grass swards, it became evident that the *Galega orientalis* had low resistance in the experimental conditions. However, the site conditions were suitable for both *Medicago sativa* cultivars and *Melilotus albus*.

In the experiment comparing different seeding rates canopy cover (%) increased with increasing seeding rate (Table 2)

Table 1. Density of the swards in September 2003

Species and cultivar	Density of swards, in 2003 plants m^{-2}	Density of swards, in 2004 plants m^{-2}
Medicago sativa cv. 'Juurlu'	330±46	140±43
Medicago sativa cv. 'Karlu'	425±146	195±51
Festuca ovina var. duriuscula cv.'Crystal'	40±8*	40±12*
Melilotus albus, cv. 'Kuusiku'	330±131	247±37
Bromus inermis cv. 'Lincoln'	312±358	183±60
Festuca rubra var. rubra cv. 'Felix',*Lolium perenne cv.* 'Mondial', *Festuca arundinacea cv.* 'Seine', *Trifolium repens*, *cv.* 'Retor' *Galega orientalis cv.* 'Gale',	Swards perished	Swards perished

* Values represent % canopy cover.

Table 2. Seeding rate influence to canopy cover formation

Seeding rate, seeds m^{-2}	Canopy cover, % in September of 2003	Canopy cover, % in September of 2004
1750	5	10
5250	20	20
10500	20	41
17500	50	72

Discussion

According the results of the first two years the main criterion for the suitability of a particular species for use in recultivation of oil shale semi-coke dumps was drought resistance. Owing to lack of capillary water in the surface layer the water regime in semi-coke dumps depends only on the amount of precipitation and its distribution over the vegetation period. As a consequence, plants suffer water deficit during most of the year. It seems especially important that species are able to survive droughts in the year of seeding. In this respect *Festuca ovina var. Duriuscula*, which grows naturally on dry areas, excels other species. The species *Festuca rubra rubra* and *Dactylis glomerate*, which have been suggested for recultivation of open oil shale minds (Klaar, 1982), only survived in surface depressions where more moisture was available. *Lolium perenne, Festuca arundinacea,* and *Trifolium repens* also only seemed to survive in moist places. Growth of several species on semi-coke dump in places where moisture was available indicated that weathered recultivation substance did not limit selection of species for inclusion in a seeding mixture and could be used as a growth substrate for plants. Clearly, the limits are set by moisture supply in the semi-coke dumps. This conclusion is also indicated by the results of the experiment in which legumes were introduced in 2003. *Melilotus albus* and *Medicago sativa* were more competitive and this was probably due to the deep rooted nature of these species leading to survival in drought conditions. *Melilotus albus* was also found naturally in areas adjacent to the experimental area and this underlines its suitability *Galega orientalis* plants sown at the same time as *Melilotus albus* and *Medicago sativa* perished after sprouting even though its seeds were inoculated with *Rhizobium bacteria*. This could be due to either the very slow initial development of *Galega orientalis*, or the unsuitability of the environment for the successful development of nodule bacteria.

Besides moisture content the species competitiveness could also be influenced by the low nutrient content of the substrate. *Festuca ovina var. duriuscula* grows naturally in sandy soil where plant nutrient content is extremely low. Other species included in the experiment are associated with more fertile soils. The ability to withstand low nutrient content in the soil could be one the reasons why *Festuca ovina var. duriuscula* performed better than other species on the semi-coke dump.

The speed of vegetation formation on the semi-coke dump was strongly influenced by initial seeding rate ($r = 0.99$, $P < 0.01$). Survival rate of plants in semi coke dumps is very low due to difficulties in preparation of the seed bed and thus high seeding rates should be used. The seeding rate has an impact not only on initial plant cover but it also influences future vegetation development. Successful sward development depends on the number of growing plants and seed production. In 2004 the greatest canopy cover was noted in plots where the highest seeding rate was used.

Conclusions

The results of the two first years indicated that the recultivation substance, containing 50% of oil-shale semi-coke, does not limit selection of species for seed mixtures. In favourable growth conditions, e.g. sufficient moisture and nutrient content, it is possible to cultivate most of the species tested in the experiments. The selection of species for seed mixtures for recultivation of semi-coke dumps seems to be limited by soil moisture deficit. Hence the assessment of the suitability of a particular species for recultivation of a semi-coke dump should be based on the drought resistance of the species and seed mixtures should contain only drought resistant species. The most suitable species for growing in semi-coke dumps are *Festuca ovina var. duriuscula* and *Bromus inermis, Melilotus albus* and *Medicago sativa.*

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Agri-environment Schemes in England: identifying and targeting semi-natural grasslands for management and restoration

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Abstract

In 2002 the UK Government instigated a review of England's Agri-environment (AE) schemes prior to the launch of Environmental Stewardship in 2005. This new scheme will be the focus for the maintenance, restoration and re-creation of semi-natural grassland in England. Monitoring has suggested that management under previous AE schemes has not always effectively targeted land of high biodiversity value or potential. The new scheme will therefore require an initial audit of environmental features on any landholding before an application can be made. It will therefore be essential that the scientific community is able to produce materials to help landowners identify grassland of biodiversity value accurately.
In 2003, an expert panel was established to review published scientific literature to identify consistent indicators and use them in keys to the existing and potential value of grassland habitats. These were field-tested by specialists and non-specialists before further simplification and refinement. The keys provide simple criteria, based on scientific research to enable non-specialists to effectively target management for biodiversity.

Key words: environmental audit, habitat indicators, habitat keys, stakeholder participation

Introduction

In 1994 the UK Government, as part of its commitment to the Convention on Biological Diversity, launched the UK Biodiversity Action Plan (Anon, 1994; UK BSG, 1995). This set out targets for the maintenance and re-establishment of semi-natural habitats (two grassland examples are given in Annex 1 – 'coastal and floodplain grazing marsh' and 'lowland calcareous grassland'). Within the Action Plan, Agri-environment (AE) schemes are identified as one of the principal mechanisms for delivering the targets.
Since 1987, the UK Government has operated two major AE schemes in England – Environmentally Sensitive Areas (ESA) and Countryside Stewardship (CS). Both schemes offered ten-year agreements to landowners with payments for managing land to encourage biodiversity. However, in line with findings from across Europe (Kleijn and Sutherland, 2003), results from monitoring of the AE-Schemes in England suggests that they have not consistently met their objectives for habitat maintenance, restoration and re-creation.
For example, ecological classification of land under English AE-agreements undertaken in 1998 demonstrated that a significant proportion of land managed under grassland options was not contributing to maintenance or restoration targets. In surveys of CS agreements that included payments for management of calcareous grassland only 29 out of 48 holdings held areas of semi-natural or semi-improved calcareous grassland, the remaining 40% consisting of improved grassland, species-poor semi-improved grassland or other habitat types with little or no potential for restoration to semi-natural calcareous grassland communities (Short, 1999).
Similar findings were observed where arable land had been taken out of production to re-

establish semi-natural grassland. Kirkham *et al.* (2005) found that grasslands reverted from arable land, even after 12 years in an AE-scheme had significantly lower plant species richness, mean cover of forbs and numbers of stress tolerators compared to semi-natural grassland. Only 11 of 120 fields that had been reverted from arable between 5–12 years previously, had a species richness > 15 sp m^{-2} (Kirkham *et al.,* 2005), equivalent to the least diverse semi-natural grassland types (Critchley *et al.,* 1999). The results on botanical richness are partly explained by differences in soil properties. At over half the sites (59%), soil extractable phosphorus was at higher levels than those found in the most species-rich semi-natural grasslands, i.e. <15 mg/l (Walker *et al.,* 2004; Janssens, 1998).

A review of wet grassland agreements was undertaken in 2004, to assess their contribution to the coastal and floodplain grazing marsh targets (Dutt, 2004). Of the 149 fields receiving a water level payment, 40% (59 fields) were not wet enough to provide conditions for breeding waders and 26% (39 fields) were too enclosed to support breeding waders, even if water levels could be altered. In the study by Kirkham *et al.* (2005), many of the sites in the sample where wet grassland had been created from arable land had yet to develop sufficient variation in sward structure or moisture at the soil surface, to make them suitable for ground nesting birds. Additionally, enclosure by trees and hedges, presence of pylons or disturbance from road traffic rendered a considerable proportion of the fields unsuitable for breeding waders.

Improved targeting in the new AE schemes

The results from the monitoring programme suggest that options that should contribute to the maintenance, restoration and re-creation of semi-natural grassland also contain a proportion of land that is improved or highly improved. To a certain extent this is because the schemes are multi-objective – land may be brought into an option to protect archaeological features or restore landscape character. However, this does not account for such significant areas of unsuitable land, especially land reverted from arable to re-create semi-natural grassland. More fundamentally, because the AE scheme options contain habitats that range in quality, it has not been possible to report on progress towards the maintenance and re-establishment targets set by the UK Biodiversity Action Plans.

Environmental Stewardship (ES) replaced the old schemes in March 2005. ES will retain the principle of establishing voluntary agreements and offer both area and capital payments. ES has several options for managing and re-establishing semi-natural grasslands. In response to the findings from the monitoring programme, ES will provide significantly higher payments for achieving outcomes such as maintenance or re-establishment of semi-natural habitat, but will be much more targeted to areas where the existing value or potential has been clearly demonstrated. The applicant will be required to identify land of existing value or high potential in a Farm Environment Plan. This must be completed or commissioned by the farmer or landowner in advance of submitting an application.

Although some data sets on land of existing biodiversity value in England do exist, for example for coastal and floodplain grassland (e.g. Dargie, 1993) and for other semi-natural grasslands (e.g. English Nature, 2004), such inventories are often several years old, incomplete, and exclude areas with restoration or re-creation potential. In order for the scheme to be a success, it will be essential that applicants are able to identify land of biodiversity value or potential. It therefore follows that the scientific community must effectively communicate how this might be done to the landowning community.

This paper outlines how the Rural Development Service (RDS), on behalf of the UK Government has set about ensuring that applicants have access to simple guidance materials, enabling them to identify existing areas of semi-natural grassland and areas that have potential for restoration or re-establishment. A participatory approach was employed, integrating scientific review, expert opinion and practical application to develop technical information to address these issues. Examples are given for two contrasting key habitats: lowland calcareous grassland (LCG) and coastal and floodplain grazing marsh (CFGM). The former is a low nutrient system of high botanical value, the latter being a higher-nutrient system, where the main interest (with the exception of some peat sites of high botanical value) lies with ground-nesting wading birds and in the amphibian and aquatic invertebrates.

Methodology used to develop guidance materials

In 2003, an expert panel was assembled to develop new options and supporting technical information for the grassland section of ES. The panel consisted of members from the RDS and representatives from the main conservation organisations in England. The panel operated as a steering group and was charged with a four-stage process of developing guidance materials (Figure 1). The four stages were: scientific review, expert evaluation, field testing and interpretation.

Scientific review

Members of the panel undertook a review of the scientific literature to identify those attributes of particular semi-natural grasslands that were either indicative of or unique to that grassland type and could therefore be used to identify either existing or potential value. For example, semi-natural grassland, with the exception of some grazing marsh sites, typically had a species richness > 15 plant species m^{-2} (Critchley *et al.,* 1999). In addition, certain plants were restricted to certain habitat types (e.g. for LCG, horseshoe vetch *Hippocrepis comosa* and carline thistle *Carlina vulgaris*). However, in addition to sward compositions, semi-natural grasslands consistently displayed certain soil characteristics such as, for LCG, high pH and low phosphorus status (Chambers *et al.,* 1998; Critchley *et al.,* 2002).

CFMG differed from other semi-natural grasslands, in that species richness was not a consistent feature. Nonetheless, CFMG sites holding breeding waders, exhibited consistent sward and soil characteristics, although sward structure was more important than composition and soil water was more important than soil nutrient status (Green and Robins, 1993; Milsom *et al.,* 2002). Equally important in determining presence of breeding birds were physical or landscape attributes regulating disturbance or degree of enclosure (Milsom *et al.,* 2000). The attributes characterising LCG and CFGM are given in Table 1.

Expert Evaluation

The sward, soil, physical and historic attributes were then divided into those intrinsic properties that cannot easily be modified (physical, historic and soil attributes) and those more transient properties which could be modified through management. If a site does not have the intrinsic properties it is unlikely to have either existing interest, neither will it have potential to develop that interest. If it has the intrinsic properties, but not the transient properties, it will be possible to re-establish the desired habitat through appropriate management. A site with both intrinsic and transient properties is likely to have existing value.

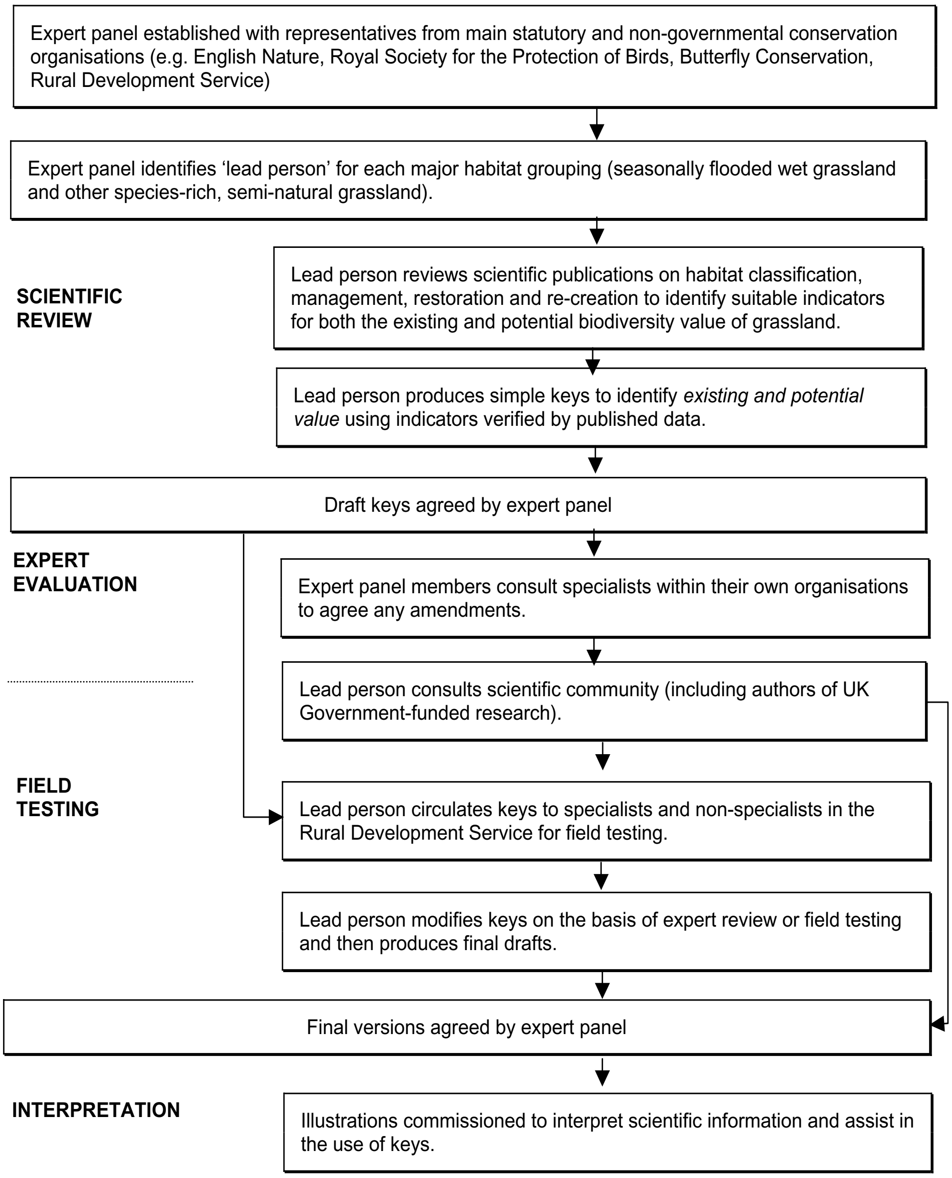

Figure 1. Process used to develop supporting technical information

Table 1. Attributes that indicate or determine the value of existing semi-natural grassland

	Lowland calcareous grassland	
Sward attributes	• Species richness • Cover of wildflowers (grass:herb ratio) • Cover of species indicative of agricultural improvement (e.g rye grass *Lolium* sp. and white clover *Trifolium repens*) • Presence of 'indicator' plant species – those which are uniquely associated with lowland calcareous grassland.	Rodwell, 1992; Critchley *et al.,* 1999; Critchley *et al.,* 2004. Robertson and Jefferson, 2000; Robertson *et al.,* 2002 Rodwell, 1992 Robertson and Jefferson, 2000 Rodwell, 1992; Robertson and Jefferson, 2000, Critchley, 2000
Soil attributes	• pH • Soil nutrient status (especially soil extractable phosphorus)	Critchley *et al.,* 2002 Janssens, 1998; Critchley *et al.,* 2002
Physical attributes	• Proximity to existing lowland calcareous grassland/ availability of a suitable seed source	Pywell *et al.,* 2002; Hutchings and Booth, 1996
Management/ other external factors	• No history of ploughing or re-seeding in living memory • No additions of artificial fertiliser. • Managed by extensive grazing.	} } Fuller, 1987; Rodwell, } 1992 }
	Coastal and floodplain grazing marsh (for breeding waders)	
Sward attributes	• Sward structure (in particular the density of 'tussocks') • Sward height during the bird breeding season	McCracken and Tallowin, 2004; RSPB *et al.,* 1997 Caldow, 1999
Soil attributes	• Area of standing water on soil surface (in winter and during bird breeding season • Timing of surface flooding • Soil wetness/height of water table • 'Probe-ability or penetrability' – having soil wet enough to allow birds to probe the soil for invertebrates.	RSPB *et al.,* 1997 RSPB *et al.,* 1997 } Green and Robins, 1993; } McCracken and } Tallowin, 2004; Caldow, } 1999
Physical attributes	• Location in the floodplain • Proximity to existing wetland/ inter-tidal habitat • Lack of enclosure by trees and hedges • Presence of electricity pylons • Disturbance from road traffic • Disturbance from recreational activities • Surface topography	Dargie, 1992; Mountfield *et al.,* 1999 } } } Milsom *et al.,* 2000; } Milsom *et al.,* 2002; } Caldow, 1999 }
Management/ other external factors	• Trampling pressure from livestock • Level of predation	Hart *et al.,* 2002 Seymour *et al.,* 2003

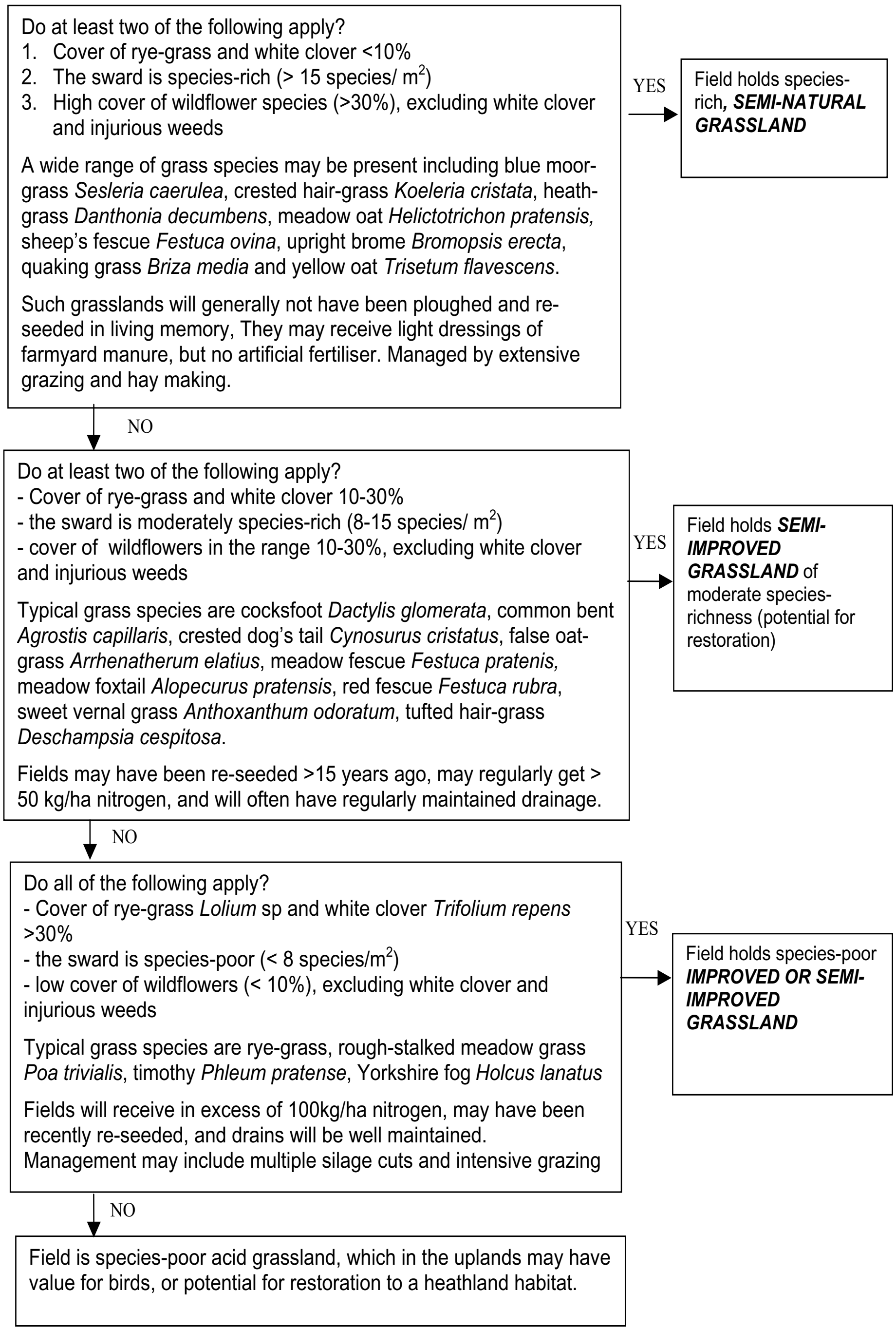

Figure 2. Key to existing biodiversity value: species-rich, semi-natural grassland

A combination of intrinsic and transient properties was used to develop keys for identifying existing biodiversity value (i.e. presence of CFGM or LCG habitat). However, only the intrinsic properties were used in keys to potential biodiversity value.
The panel felt that it was important to use a range of different attributes, rather than rely on one. For example, in the key to semi-natural grassland, cover of rye grass *Lolium* sp and white clover *Trifolium repens,* can be misleading if other *Trifolium* sp are present in the sward. The panel felt that the most useful attribute for defining semi-natural grasslands was the presence of particular indicator species that are restricted to a particular habitat (e.g. *Hippocrepis comosa* for LCG). Indicator species were therefore used extensively in the first iterations of the keys to existing biodiversity value.
Historic attributes were retained in the keys to existing value, although because site-specific historic data could not usually be verified, they used for guidance only (Figure 2).

Field testing

The keys were tested in field situations across England, both by specialist and non-specialists – the former being important to verify the basis on which the keys were founded, the latter to ensure that they could be used by a wide range of users. Field testers wanted keys that were simple, unambiguous and which would fit on one page.
For the keys to existing semi-natural grassland, non-specialist field testers had difficulty with the use of indicator plant species. Keys to existing semi-natural grassland were therefore split into two parts. Part 1 is a generic key to existing semi-natural grassland, using simple attributes to identify land of high, medium or low value based on cover of sown species, species richness and wildflower cover (Figure 2). This acts as a coarse filter to identify all sites which may be of value. As far as the operation of the scheme is concerned, this is the most important piece of information, alerting scheme administrators to sites of existing or potential value which, subsequently, can be verified by a specialist. Part 2 is an optional key to identify specific grassland habitats such as LCG (Table 2) or grassland with restoration potential 'moderately species rich grassland' (Table 3) and these are based on indicator species. Although part 2 requires some identification skills, species that are particularly difficult to identify have either been omitted or amalgamated into groups (e.g. sedges).
Keys to the potential to re-create semi-natural grassland on former arable land were not altered by field testers, as they are based on soil properties that were recognised as easy to measure using standard soil assessments (Figure 3).

Table 2. Key to existing biodiversity value: lowland calcareous grassland (vegetation must first be identified as species-rich, semi-natural grassland using the key in Fig. 2)

Soils and Topography	Wildflower indicator species	Quality threshold	Typical grasses (not counted as indicators)
Calcareous soils over chalk and limestone in the lowlands and upland fringe, generally below 300 m	betony *Stachys officinalis* St. John's wort *Hypericum* sp. bird's-foot trefoil *Lotus* sp. bloody cranesbill *Geranium sanguineum* carline thistle *Carlina vulgaris* clustered bellflower *Campanula glomerata* rockrose *Helianthemum* sp cowslip *Primula veris* dropwort *Filipendula vulgaris* eyebright *Euphrasia officinalis* agg. fairy flax *Linum catharticum* gentians *Gentianella* sp. greater knapweed *Centaurea scabiosa* hairy violet *Viola hirta* harebell *Campanula rotundifolia* hoary plantain *Plantago media* horseshoe vetch *Hippocrepis comosa* kidney vetch *Anthyllis vulneraria* marjoram *Origanum vulgare* milkworts *Polygala* sp. mouse-ear hawkweed *Pilosella officinarum* orchids Orchidaceae ox-eye daisy *Leucanthemum vulgare* purple milk-*vetch Astragalus danicus* rough/lesser hawkbit *Leontodon* sp. salad burnet *Sanguisorba minor* small scabious *Scabiosa columbaria* squinancywort *Asperula cynanchica* stemless thistle *Cirsium acaule* wild basil *Clinopodium vulgare* wild thyme *Thymus polytrichus* yellow-wort *Blackstonia perforata*	At least *2 frequent* and *3 occasional* in the sward	blue moor-grass *Sesleria caerulea* cocksfoot *Dactylis glomerata* common bent *Agrostis capillaris* crested hair grass *Koeleria cristata* hairy oat-grass *Helictotrichon pubescens* meadow oat-grass *Helictotrichon pratensis* quaking grass *Briza media* sheep's fescue *Festuca ovina* tor grass *Brachypodium pinnatum* upright brome *Bromopsis erecta* yellow oat-grass *Trisetum flavescens* Note: Latin names do not appear in version of key for general use.

Table 3. Key to potential biodiversity value: restoration of existing semi-improved grassland to lowland calcareous grassland (vegetation must first be identified as semi-improved grassland of moderate species-richness in the key in Fig. 2)

Soils and Topography	Wildflower indicator species	Quality threshold	Typical grasses (not counted as indicators)
Wide range of soil conditions, often derived from above habitats by a degree of agricultural improvement Moderately species-rich, with typically 8–15 sp/m². Total cover of wildflowers and sedges usually 10–30%, excluding white clover *Trifolium repens* and injurious weeds. Ryegrass *Lolium* sp. cover generally <25%.	autumn hawkbit *Leontodon autumnalis* black medick *Medicago lupulina* cuckoo flower *Cardamine pratensis* bulbous buttercup *Ranunculus bulbosus* common cat's-ear *Hypochaeris radicata* common sorrel *Rumex acetosa* field woodrush *Luzula campetris* germander speedwell *Veronica chamaedrys* lesser trefoil *Trifolium dubium* ribwort plantain *Plantago lanceolata* meadow buttercup *Ranunculus pratensis* red clover *Trifolium pratense* self-heal *Prunella vulgaris* yarrow *Achillea millefolium*	At least *4 occasional* Some of the indicator species from the lowland calcareous grassland key (Table 2) may be present, but only rare or localised in the sward	cocksfoot *Dactylis glomerata* common bent *Agrostis capillaris* crested dog's-tail *Cynosurus cristatus* false oat-grass *Arrhenatherum elatius* meadow fescue *Festuca pratenis* meadow foxtail *Alopecurus pratensis* red fescue *Festuca rubra* sweet vernal grass *Anthoxanthum odoratum* timothy *Phleum pratense* tufted hair grass *Deschampsia cespitosa* Yorkshire fog *Holcus lanatus*

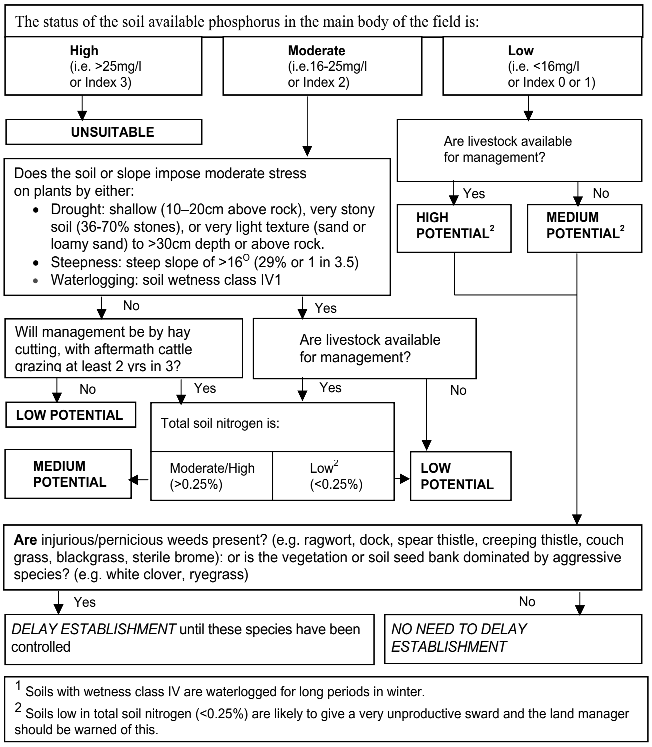

Figure 3. Key to the potential biodiversity value: reversion of arable land to species rich grassland

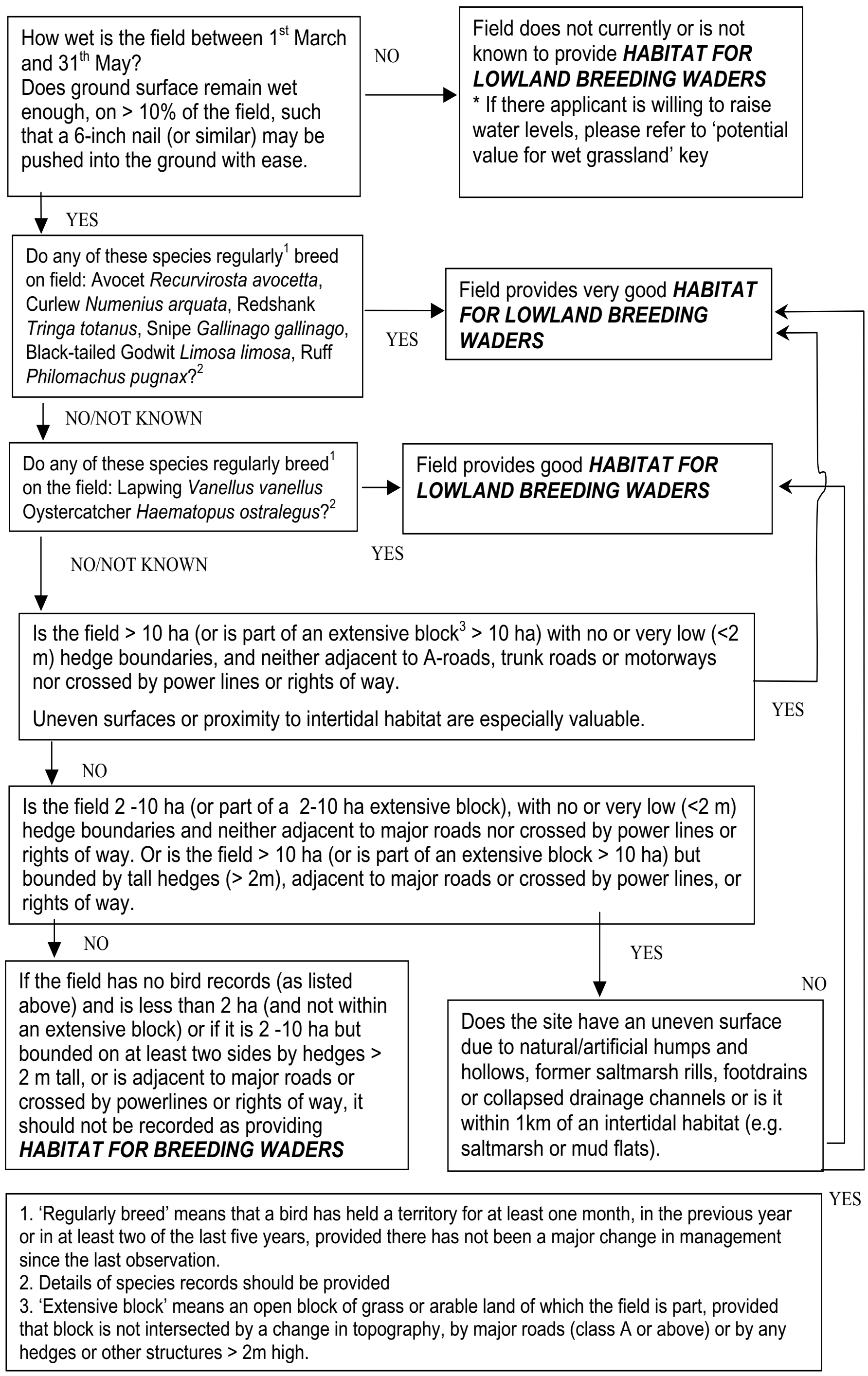

Figure 4. Key to existing biodiversity value: Coastal and Floodplain Grazing Marsh with conditions for lowland breeding waders.

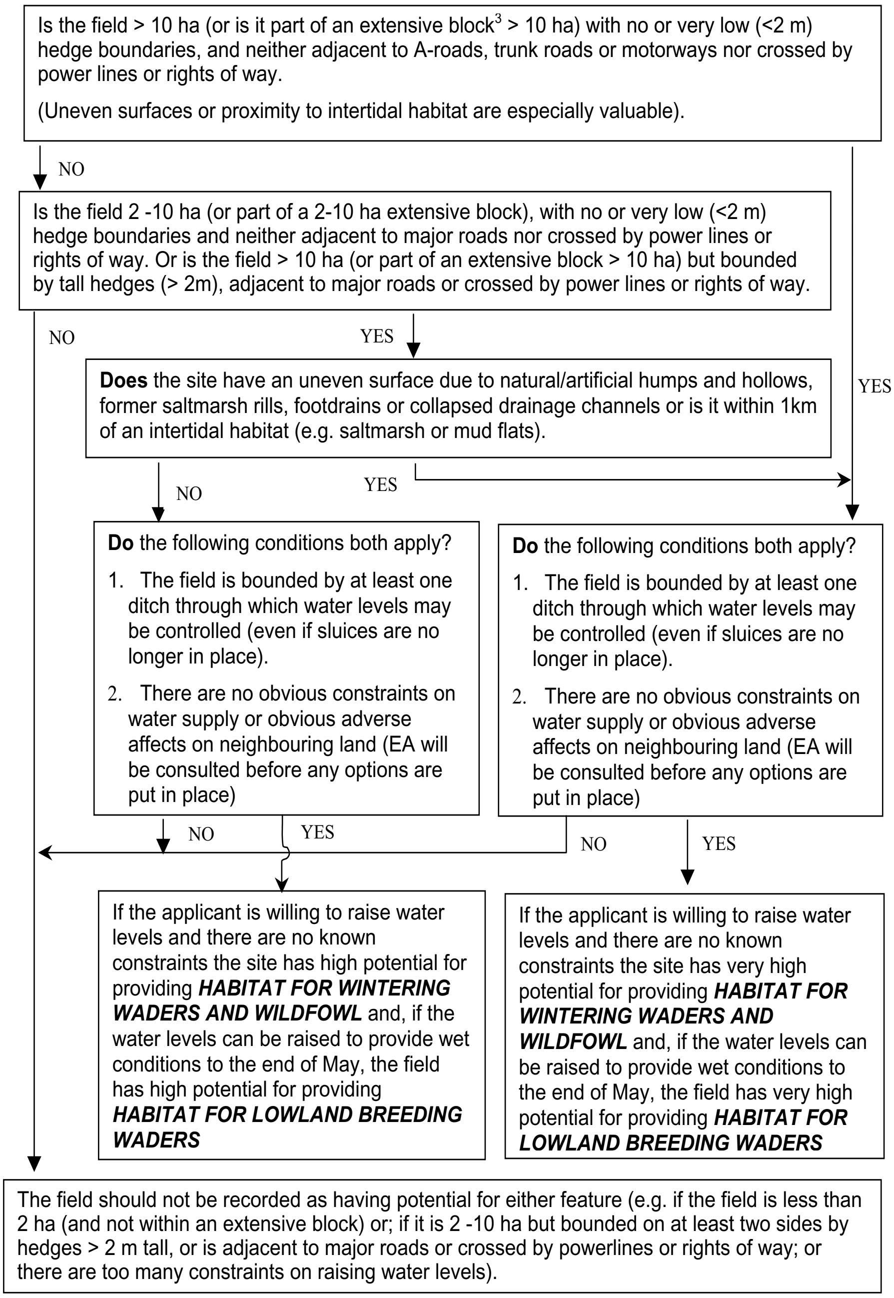

Figure 5. Key to potential biodiversity value: reversion or restoration of existing arable land or grassland to Coastal and Floodplain Grazing Marsh with conditions for wintering waders and wildfowl or for lowland breeding waders

Keys to CFGM with existing value for breeding birds were field tested in coastal situations in Cumbria and Kent and in river systems in Oxfordshire. For CFGM, all major attributes were built into the key to existing value (Figure 4). Only intrinsic attributes were built into the key to potential value (Figure 5). Use of indicator species in the CFMG keys proved equally problematic, and their use in the key was subsequently made optional.

Interpretation

The final stage in the process has been in the production of illustrated guidelines, to help interpret the keys to non-specialists and to explain desired outcomes to farmers. An example is given in Annex 2.

The keys have a sound scientific base and have been field tested by specialist and non-specialist surveyors. Their wider uptake and effectiveness in the new schemes will only become apparent through random field checking in forthcoming years.

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Annex 1. Example targets from the UK Biodiversity Action Plan (JNCC 2005)

Box 1. Action Plan targets for Coastal and Floodplain Grazing Marsh

Coastal and floodplain grazing marsh are pastures or meadows bounded by open ditches through which water levels can be managed. Grazing marshes are seasonally flooded and are particularly important for breeding waders such as snipe *Gallinago gallinago* and curlew *Numenius arquata*. Certain UK grazing marshes also support internationally important populations of wintering wildfowl including Bewick swans *Cygnus bewickii* and white fronted geese *Anser albifrons*.

Plate 1. Elmley Marshes, Kent, SE England (Photo by Steve Peel)

- Maintain the existing habitat extent (300,000ha).
- Maintain the quality of existing habitat (300,000ha).
- Rehabilitate 10,000 ha of grazing marsh habitat which has become too dry, or is intensively managed, by the year 2000.
- Begin creating 2,500 ha of grazing marsh from arable land in targeted areas.

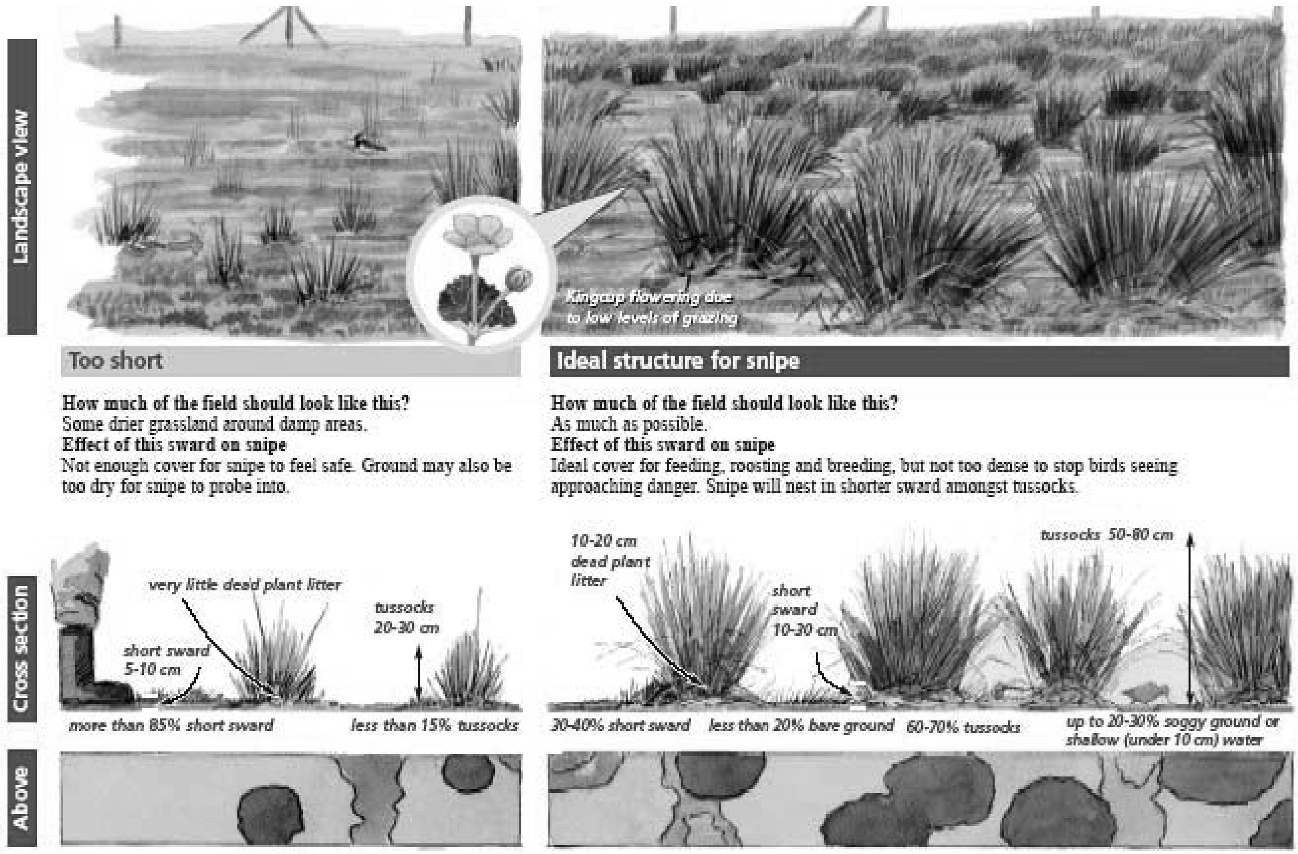
Box 2. Action Plan targets for Lowland Calcareous Grassland

Lowland calcareous grasslands form on shallow lime-rich soils generally overlying limestone rocks, including chalk. They support a rich flora including many rare species such as pasque flower *Pulsatilla vulgaris*. The invertebrate fauna is also diverse and includes scarce species like Adonis blue *Lysandra bellargus* and wart-biter cricket *Decticus verrucivorus*.

- Arrest the depletion of lowland calcareous grassland throughout the UK.
- Within SSSIs, initiate rehabilitation management for all significant stands of lowland calcareous grassland in unfavourable condition by 2005.
- Attempt to re-establish 1000 ha of lowland calcareous grassland of wildlife value at carefully targeted sites by 2010.

Plate 2. Man orchid and calcareous grassland vegetation, Hackhurst Down, SE England (Photo by Mark Stevenson)

Annex 2. Illustrated guide to grassland condition (for breeding snipe *Gallinago gallinago*)



Share of legumes in selected non-forest plant communities in the San valley

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Abstract

This paper presents the results of research on the floristic composition and the share of legumes in semi-natural meadow swards against the background of soil properties. The research material consisted of 14 plant communities identified on the basis of 494 phytosociological relevés. The habitat conditions were estimated on the basis of 199 soil samples. As many as 31 species of legumes were found present in the studied plant communities. They were diverse in respect of their ecological spectrum, from stenobionts present in one or two communities to eurybionts recorded in associations of all classes. The number of species of legumes and their share in meadow sward depended on moisture content and trophic characteristics of the soil.

Keywords: legumes, plant communities, habitat, soil, biodiversity, San River valley

Introduction

Legumes are rated among precious meadow herbs. Their occurrence in plant communities and their presence in herbage intended for fodder are very desirable due to their high digestibility and palatability, as well as high protein and mineral content. Thanks to their symbiosis with nitrogen-fixing bacteria, they enrich the soil with bio-available, and ”free” nitrogen, which is very good not only for economic reasons but also for the environment. In recent years, research has not only focused on cultivated but also on wild species of legumes growing in semi-natural swards, together with investigations into factors which either stimulate or inhibit their occurrence (Szoszkiewicz *et al.,* 1998; Wyłupek and Trąba, 2003). This paper provides information on the affect of soil characteristics on the composition, consistency of occurrence and proportion of legumes in selected plant communities of *Phragmitetea, Molinio-Arrhenatheretea* and *Festuco-Brometea* classes in the San River valley.

Materials and Methods

The base material consisted of 14 plant communities, selected from 40 non-forest areas identified in the foothills regions of the San River valley (south-eastern Poland). Phytocenoses (natural and man-created plant communities) with legumes growing in diverse conditions of moisture content and soil trophism were selected. Among them were 4 of the *Phragmitetea* class, 8 of the *Molinio-Arrhenatheretea* class (4 of the *Molinietalia* and 4 of the *Arrhenatheretalia* order), as well as 2 of the *Festuco-Brometea* class plant communities. In 2002–2004 (May – June) as many as 494 phytosociological relevés were taken using the Braun-Blanquet method and 199 collective samples of soils were taken from a depth of 5–15 cm for chemical analyses. The pH reaction was determined by potentiometric method, humus content – by the Tiurin method, bioavailable forms of P and K – by the Egner-Riehm's method, Mg – by the Schachtschabel method, and Cu, Zn and Mn forms soluble in 1 M HCl by the AAS method. Moisture contents of habitats (F) and nitrogen (N) abundance were determined by Ellenberg's phytoindicative method. The Shannon-Wiener species diversity index was calculated according to Magurran (1996). The floristic table specifies constancy degree (S) and cover coefficient (D) of legumes as determined in the analyzed plant communities (Szafer, 1977).

Results and Discussion

In general the soils had a slightly acidic pH and very low P content, a high concentration of Mg, and medium concentration of N (Table 1). Plant communities of *Phragmiteta* class occurred in moist habitats (F = 7.9 – 9.1). Among them, the *Phragmitetum australis* association occurred in conditions most abundant in P, Mg and N, whereas the *Caricetum vesicariae* association occurred in most moist, poor and acidulous conditions. Among plant communities of the *Molinietalia* order the *Deschampsietum caespitosae* association occurred in most acidic and K-, N-, Mg- and Cu-deficient habitats, whereas *Alopecuretum pratensis* occurred in habitats which were most dry and most abundant in N and K. Phytocenoses of the *Molinietalia* order occupied mainly humid but not moist habitats (F >6). The meadow sward of *Cirsietum rivularis* association was mowed once a year, and that of the *Alopecuretum pratensis* – twice a year. Habitats of plant communities of the *Arrhenatheretalia* order were medium moist (F 4.0–6.0), had slightly acid soil reaction and medium nitrogen abundance (N = 5.5 – 6.0). Among them *Trisetetum flavescentis* occurred in soils most deficient in P, K, Cu and Mn, and *Lolio-Cynosuretum* occurred on those most abundant in Mg, Cu and Mn. Meadows with the *Lolio-Cynosuretum* association were excessively exploited. Meadows with the *Poa pratensis*-*Festuca rubra* plant community were used variably, and those with *Arrhenatheretum elatioris* and *Trisetetum flavescentis* were used for hay growing, as well as cattle grazing in the autumn. Both plant communities of the *Festuco-Brometea* class occurred in dry habitats, at the borders with medium moist habitats that had a neutral pH reaction and were very deficient in phosphorus and nitrogen. Altogether, 31 species of legumes were found in all phytocenoses. They were most numerous in plant communities of the *Arrhenatheretaria* order – 28, and the least numerous in those of the *Phragmitetea* class – 9. It was mainly affected by the degree of habitat moisture and by the biodiversity of the plant communities. Among phytocenoses of the *Phragmitetea* class, only 3 species were identified in the *Caricetum vesicaria* association, whereas their maximum, 7, was identified in *Caricetum gracilis*. In plant communities of the *Molinietalia* order, most (i.e. 15) species of legumes were found in *Alopecuretum pratensis* and the least (i.e. 9) of them in *Cirsietum rivularis*. In plant communities of the *Arrhenatheretalia* order, most (i.e. 27) species of legumes were found in *Arrhenatheretum elatioris* and the least (i.e. 16) of them in *Lolio-Cynosuretum*. However, in *Lolio-Cynosuretum* these plants occupied the largest surface area (30% on average), as confirmed by the research of Grynia *et al.* (1997), as well as that of Wyłupek and Trąba (2003). In plant communities of the *Festuco-Brometea* class the taxa commonly occurring in meadow communities of the *Molionio-Arrhenatheretea* class were identified more rarely and were less numerous, while for example *Medicago falcata, Ononis arvensis, Coronilla varia, Trifolium medium* – the indices of habitats abundant in $CaCO_3$, were more frequent and numerous. The numbers of legume species were greatest in florally richest plant communities, as evidenced by the values of the H′ index (refer to Table 2). The narrowest ecological scale was exhibited by species occurring only in 1–2 plant communities, for instance *Trifolium montanum, Onobrychis viciaefolia, Astragalus cicer* occurred in the *Brachypodium pinnatum* plant community only, and the *Lathyrus niger* species only in the *Arrhenatheretum elatioris* association. In turn, *Lotus uliginosus* grew only in plant communities of the *Phragmitetea* class and in the *Scirpetum sylvatici* assembly of the *Molinietalia* order. On the other hand, a very wide ecological scale was exhibited by *Lathyrus pratensis, Trifolium hybridum, T. pratense, T. repens, Vicia cracca, V. sepium* and *Lotus corniculatus*, which occurred in 11–13 plant communities belonging to three classes. Literature data indicate that these species occur in meadow plant communities of various phytosociological classes, irrespective of climatic conditions, type of soil, moisture and trophism, although respective optimums remain in specific phytocenoses (Grynia *et al.,* 1997; Szoszkiewicz *et al.,* 1998; Wyłupek and Trąba, 2003). This was also the case in the San River valley, e.g. *Trifolium hybridum* and *Lathyrus pratensis*, though they frequently occurred in phytocenoses of the *Phragmiteta* class*,* their optimum conditions were those in plant communities of the *Molinietalia* association*.* In turn, *Trifolium pratense* reached the highest constancy degree and cover coefficient in the assemblies *Trisetetum flavescentis, Lolio-Cynosuretum*, while the *Trifolium repens* reached its highest indices in the *Lolio-Cynosuretum* associations, though they were also present in phytocenoses of the *Phragmiteta* class and *Molinietalia* order. *Lotus corniculatus* grew equally frequently and numerously in plant communities of the *Arrhenatheretalia* and *Festuco-Brometea* order, whereas *Medicago falcata* – in plant communities of the *Festuco-Brometea* class only (refer to Table 2).

Table 1. Habitat conditions of the plant communities in the San River valley (mean sample value)

Communities		*Cv*	*Ca*	*Cg*	*Pa*	*Ss*	*Cr*	*Dc*	*Ap*	*Ae*	*Tf*	*P-F*	*L-C*	*Be*	*Bp*
Humus $g \cdot kg^{-1}$		980	52	36	38	41	86	70	58	39	29	26	40	17	18
pH in KCl		5.3	5.4	6.3	6.5	5.5	5.8	5.0	5.8	5.7	5.3	5.6	5.8	6.9	7.0
P	$mg \cdot kg^{-1}$	27	19	17	80	17	28	64	37	28	13	18	34	15	13
K		28	98	95	88	97	140	50	150	130	61	140	90	160	80
Mg		560	210	250	300	160	320	47	230	220	210	190	340	90	130
Cu		24	10	8	11	9	34	7	17	16	7	16	27	7	17
Zn		27	36	32	27	18	18	19	15	17	14	9	22	8	6
Mn		1110	497	580	520	440	530	308	307	291	118	250	409	200	300
F*		9.1	8.0	7.9	8.3	7.3	7.1	6.6	5.9	5.0	5.2	5.4	5.1	4.8	4.1
N*		4.0	5.1	4.3	6.5	4.7	4.9	4.2	6.0	5.8	5.5	5.5	5.4	4.8	3.8

Explanations: *Cv – Caricetum vesicariae, Ca – Caricetum acutiformis, Cg – Caricetum gracilis, Pa – Phragmitetum australis, Ss – Scirpetum sylvatici, Cr – Cirsietum rivularis, Dc – Deschampsietum caespotosae, Ap – Alopecuretum pratensis, Ae – Arrhenatheretum elatioris, Tf – Trisetetum flavescentis, P-F – Poa pratensis-Festuca rubra community, L-C – Lolio-Cynosuretum, Be – Bromus erectus community, Bp –Brachypodium pinnatum community;* table 1: * Ellenberg's index; table 2: [1] constans degree, [2] cover coefficient

Conclusions

Legume species identified in the studied plant communities were diverse in respect of their ecological spectrum, from stenobionts present in or two plant communities to eurybionts recorded in associations of all classes. The number of legume species and their share in meadow sward depended on soil moisture and on its trophic characteristics.

Table 2. Ecological spektrum of legumes in the surveyed habitats in the San River valley

Communities	Cv	Ca	Cg	Pha	Ss	Cr	Dc	Ap	Ae	Tf	P-F	L-C	Be	Bp
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of relevés	6	11	13	8	44	30	27	29	147	38	68	61	10	12
Total number of species	66	108	111	88	143	151	162	139	242	151	209	154	104	141
H’	2.2	2.3	2.7	2.7	3.0	3.2	2.9	3.0	3.2	3.3	3.5	3.4	3.0	2.8
Lotus uliginosus	I[1]	I	II	–	III	–	–	–	–	–	–	–	–	–
	8[2]	5	12		12									
Lathyrus pratensis	I	II	I	II	II	IV	II	III	II	III	I	I	I	–
	8	55	4	69	224	486	48	221	92	113	52	56	6	
Trifolium hybridum	I	III	III	II	IV	III	II	II	I	I	I	I	–	–
	8	109	185	125	759	327	141	124	3	4	86	27		
Trifolium pratense	–	I	II	–	III	II	II	IV	III	V	IV	V	III	I
		45	15		155	173	46	547	317	508	191	528	19	4
Trifolium repens	–	I	II	I	III	III	II	IV	IV	IV	V	V	I	–
		50	81	6	389	254	267	731	558	1341	912	2130	6	
Vicia sepium	–	I	–	–	I	I	I	II	II	II	I	II	I	I
		9			7	20	9	63	93	54	27	13	6	4
Vicia cracca	–	–	II	I	I	I	III	II	III	IV	IV	III	IV	II
			12	6	6	23	20	16	214	101	126	62	31	54
Lotus corniculatus	–	–	I	–	I	I	II	II	III	III	IV	II	IV	IV
			38		44	39	80	106	254	274	321	230	306	54
Vicia grandiflora	–	–	–	I	–	I	I	I	II	I	II	II	–	I
				6		2	4	8	52	8	16	70		4
Medicago lupulina	–	–	–	–	I	–	I	I	II	I	II	II	–	I
					14		2	2	95	20	149	280		4
Trifolium dubium	–	–	–	–	I	I	I	I	II	III	II	II	–	–
					11	23	67	39	75	301	155	207		
Coronilla varia	–	–	–	–	–	–	I	–	I	II	I	I	II	III
							2		96	55	34	2	12	100
Vicia tetrasperma	–	–	–	–	–	–	I	I	II	I	II	I	–	I
							6	2	14	16	23	8		4
Ononis arvensis	–	–	–	–	–	–	I	–	I	–	I	–	IV	III
							2		8		2		87	25
Trifolium aureum	–	–	–	–	–	–	I	–	I	–	I	–	I	–
							2		2		1		1	–

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Medicago ˣvaria	–	–	–	–	–	–	–	I	I	I	I	–	II	–
								18	14	14	13		12	
Trifolium medium	–	–	–	–	–	–	–	I	I	I	II	–	II	II
								5	33	8	63		12	50
Vicia hirsuta	–	–	–	–	–	–	–	I	I	–	I	I	–	–
								2	4		25	16		
Medicago falcata	–	–	–	–	–	–	–	–	I	I	I	–	V	V
									3	8	25		950	1150
Medicago sativa	–	–	–	–	–	–	–	–	I	I	I	I	–	–
									22	14	5	13		
Melilotus officinalis	–	–	–	–	–	–	–	–	I	–	I	–	I	I
									29		1		62	4
Anthyllis vulneraria									I		I			II
									5		1			25
Trifolium montanum										I				III
										4				200
Onobrychis viciifolia														II
														150
Number of legumes	3	7	6	5	10	9	14	15	27	18	25	16	12	18

Species with I constancy, which one, two or three plant communities: *Astragalus cicer* I,5 Bp; *A. glycyphyllos* I, 13 Ae, I,2 P-F and I,4 Bp; *Lathyrus niger* I,8 Ae; *L. tuberosus* I,9 Ae, I,1 P-F and I,2 L-C; *Melilotus alba* I,3 Ae, I,7 P-F and I,4 Bp; *Trifolium arvense* I,8 Ae and I,1 P-F; *Vicia angustifolia* I,2 Ap, I,1 Ae and I,12 L-C

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Perennial grasses as energy crops in Lithuania

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Abstract

Perennial grasses may be an important source of renewable energy. Studies on the production of different grasses for combustion were started in Lithuania in 1997. Three perennial grasses – reed canary grass (*Phalaris arundinacea*), awnless bromegrass (*Bromus inermis*) and tall fescue (*Festuca arundinacea*) – were grown in pure swards and in mixtures with the legumes sweet clover (*Melilotus officinalis*), perennial lupin (*Lupinus polyphyllus*) and goat's rue (*Galega orientalis*). Field experiments were carried out on a light gleyic loam soil (Cambisol) humus content ca. 2%. The dry matter yield (1998–2003) of the grasses in pure stands ranged from 6.4 to 9.2 t ha^{-1} based on one cut per season. Under favourable weather conditions grass-legume mixtures without nitrogen (N) fertilization were higher yielding than N-fertilized (120 kg N ha^{-1}) grass in pure swards, but the mixtures were lower yielding in years with inadequate rainfall. In all cases mixtures had an important ecological advantage compared with N-fertilized grass swards. The energy potential of perennial grasses was up to 153 Gj ha^{-1}.

Keywords: perennial grasses, biomass, combustion

Introduction

Renewable energy from biomass has the potential to reduce reliance on the imports of fossil fuels. After evaluating 35 potential herbaceous crops in the US, of which 18 were perennial grasses, and 20 in Europe, it was concluded that native perennial rhizomatous grasses, namely switchgrass, miscanthus, reed canary grass and giant reed showed the greatest potential as bioenergy crops (McLaughlin *et al*., 1999; Nilsson and Hansson, 2001; Lewandowski *et al*., 2003). Reed canary grass has a C3 photosynthetic pathway and is native to Europe, displaying the following advantages: it is an indigenous crop, already adapted to the site conditions; it can be harvested once a year during late autumn to early spring and delayed harvest is possible; the biomass has good combustion quality and, compared to hardwood, good fibre quality; it has broad genetic variability (Hadders and Olsson, 1997; Börjesson, 1999; Olsson, 2003; Lewandowski *et al*., 2003). In Lithuania, as in most European countries, it was found that perennial grasses are higher yielding and less demanding in terms of soil compared with annual plants, moreover, they can yield for 7–10 years without reseeding and protect the hilly soils from erosion and maintain soil fertility (Lithuanian Institute of Agronomy, 2000). This advantage of perennial grasses on the hilly and less fertile soils that account for over 0.5 million ha in Lithuania is of special importance since such soils are not suited for intensive agriculture. From research into bioenergy crops it has been suggested that tall-growing grasses are suitable for cultivation for energy purposes, the energy value of their biomass is not lower than that of wheat straw and that the highest biomass of grasses is produced in June and July (Kryzeviciene *et al.*, 2004). The aim of the present study was to test reed canary grass, awnless bromegrass and tall fescue as bioenergy crops, their cultivation feasibility without nitrogen fertilization, i.e. in mixtures with sweet clover, perennial lupin and goat's rue. This was the first time such mixtures were tested in Lithuania.

Materials and Methods

In field experiments perennial grasses were tested in pure-sown stands and in mixtures with legumes. The soil was characterized as Endocalcari – Epihypogleyic Cambisol, light loam. Soil pH varied between 5.2 and 7.0, humus content was 1.5–1.9%, available P_2O_5 150 mg kg^{-1} and K_2O 169 mg kg^{-1}. The trials were set up in 1997 (Experiment 1) and in 2000 (Experiment 2). The net plot size was 10 m^2, arranged in one band with four replications. In Experiment 1 (from 1997 to 1999) we compared swards of awnless brome (*Bromus inermis*) and tall fescue (*Festuca arundinacea*), and in Experiment 2 (from 2000 to 2003) we compared swards of *B. inermis* and reed canary grass (*Phalaris arundinacea*). The stands of grasses were established following the same recommendations as for forage swards establishment. The grasses were sown in July without any cover crop. The seed rates for pure *Ph. arundinacea, F. arundinacea and B.inermis* stands were 15, 15 and 25 kg ha^{-1}, respectively and for the mixtures we added another 10–15 kg ha^{-1} of legume seeds. The pure grass swards were fertilized with nitrogen, as 120 kg N ha^{-1} in two equal applications in spring and after the cut. The mixtures were composed of two-components, i.e. the above-mentioned grasses with the legumes sweet clover (*Melilotus officinalis*), perennial lupin (*Lupinus polyphyllus*) and goat's rue (*Galega orientalis*). The mixtures received no nitrogen fertilization. All swards received 60 kg ha^{-1} of both P_2O_5 and K_2O. The yield values presented are from one cut per season taken on 15–20 July. On the day of cutting the sward height was measured, and the harvested biomass was weighed and sampled for species composition, fibre, ash and dry matter (DM) content determination. DM was determined having dried the sample to 105 °C temperature to a constant weight. The yield data and their analysis were statistically processed using analysis of variance. Energy potential of swards was calculated according to the herbage DM yield and calorific value of biomass fuel. The data on calorific value and other characteristics of grass-biofuel and total energy input for biofuel production were identified in Experiment 2. These data are comprehensively analysed and discussed in Kryzeviciene *et al*. (2004). In 1998, rainfall was favourable for herbage growth, and in 1999 and 2001 conditions were normal. In 2002 and 2003 conditions were adverse due to the lasting droughts (in May–July of 2002 rainfall amounted to 35%, and in 2003 to 77%, of the long-term seasonal mean).

Results and Discussion

The grasses grew intensively until June. Later in the season, the height of swards and biomass yield varied though not significantly. Legumes had a positive impact on the yield of mixtures, and the proportion of legumes in the biomass DM changed annually: the content of *G. orientalis* increased from 10% in the first harvest year to 56% in the third harvest year; that of *L. polyphyllus* from 4.5% to 28%, respectively; whereas *M. officinalis* accounted for up to 25% in the sward in the first harvest year and later decreased to 4%. DM yield data of swards are presented in Table 1. In Experiment 1 the swards grew in favourable weather conditions and during the whole experimental period all mixtures were higher yielding than the N-fertilized pure grasses, average two years' DM yield of mixtures with *M. officinalis* amounted to over 10 t ha^{-1}. *B. inermis* was higher yielding than *F. arundinacea* in all cases. In Experiment 2 we introduced another treatment – a mixture of grasses with *G. orientalis*. In all of the experimental years the productivity of these swards was lower compared with the swards in Experiment 1, the reduction being attributed to moisture deficit. Average DM yields ranged between 4.2 and 7 t ha^{-1}. In 2001 the DM yield of the two grass species in pure stands was similar and ranged from 7.5 to 7.8 t ha^{-1}. Much higher yielding than these grasses were mixtures composed of *Ph. arundinacea – G. orientalis* and *Ph. arundinacea – L. polyphyllus*, 8.4 t ha^{-1}. In the same trials in unfavourable years (2002) pure grasses were markedly more productive than the mixtures. It is likely that the rapid effect of nitrogen fertilizers alleviated the negative effect of drought on grass growth. In 2003, despite the moisture shortage, the DM yield differences of swards differing in composition declined or disappeared; pure *Ph. arundinacea* and its mixtures with *G. orientalis* gave the same DM yield, 7 t ha^{-1}. This result was attributed to the fact that in the mixtures of the third harvest year the share of *G. orientalis* was already high and they were able to supply the sward with biological nitrogen. Mean results from the three harvest years suggest that the swards of *Ph. arundinacea* were higher yielding than *B. inermis* swards, especially in mixtures. Characteristics of biomass are listed in Table 2. The highest fibre content (39%) was identified in the biomass of pure swards. Legumes tended to decrease fibre content in the biomass of mixtures and increase ash content and moisture content of biomass. The highest net calorific value was identified for the mixtures *Ph. arundinacea – L. polyphyllus* (18.47 MJ kg^{-1}) and *B. inermis – M. officinalis* (18.22 MJ kg^{-1}) (Kryzeviciene *et al.,* 2004). The energy obtained was up to 19 times greater than the energy input for biofuel production. The energy potential of perennial grasses was determined by biomass DM yield and net calorific value and it was up to 153 GJ ha^{-1}. The highest potential was from pure *Ph. arundinacea* and its mixtures with *G. orientalis*. Humus content in the swards remained virtually unchanged during the experimental period, except in the mixtures with *G. orientalis* where it tended to increase.

Table 1. Dry matter yield of swards of different species composition, t ha^{-1}

Grass species and their mixtures	DM yield t ha^{-1}						
	Experiment 1 (sown in 1997)			*Experiment 2* (sown in 2000)			
	1998[1]	1999[2]	mean	2001[2]	2002[3]	2003[3]	mean
Festuca arundinacea:							
pure sward	7.5	5.3	6.4				
mixture with *Melilotus officinalis*	13.5	6.8	10.2				
mixture with *Lupinus polyphyllus*	7.5	5.9	6.7				
$LSD_{0.05}$	0.38	0.51	0.32				
Bromus inermis :							
pure sward	10.8	7.5	9.2	7.8	5.5	5.8	6.4
mixture with *Melilotus officinalis*	14.8	9.1	12.0	6.5	3.2	2.8	4.2
mixture with *Lupinus polyphyllus*	10.6	8.4	9.5	7.3	3.2	4.2	4.9
mixture with *Galega orientalis*				6.3	4.1	5.0	5.1
$LSD_{0.05}$	0.43	0.28	0.26	0.38	0.42	0.49	0.25
Phalaris arundinacea:							
pure sward				7.5	6.1	7.0	6.9
mixture with *Melilotus officinalis*				7.8	4.2	3.2	5.1
mixture with *Lupinus polyphyllus*				8.4	5.0	6.4	6.6
mixture with *Galega orientalis*				8.4	5.5	7.0	7.0
$LSD_{0.05}$				0.49	0.26	0.59	0.27

Weather conditions during growing periods (April – October): [1] favourable, [2] normal, [3] unfavourable

Table 2. Characteristics of the total biomass DM, averaged data from 2001 and 2003

Grasses species and their mixtures	Moisture (%)	Ash (%)	Fibre (%)	Calorific value MJ kg^{-1}
Phalaris arundinacea:				
pure sward	48	6.0	38.9	17.79 ± 0.09
mixture with *Melilotus officinalis*	53	6.2	36,8	17.96 ± 0.06
mixture with *Lupinus polyphyllus*	54	6.4	36.5	18.47 ± 0.03
mixture with *Galega orientalis*	54	6.5	35.2	17.78 ± 0.06
$LSD_{0.05}$	4.80	0.87	2.00	
Bromus inermis:				
pure sward	44	4.3	39.0	18.08 ± 0.06
mixture with *Melilotus officinalis*	45	5.0	38.7	18.22 ± 0.03
mixture with *Lupinus polyphyllus*	47	5.6	36.5	–
mixture with *Galega orientalis*	47	5.4	36.5	–
$LSD_{0.05}$	2.22	1.25	3.05	–

Conclusions

Species composition of swards and growing conditions had the same effect on the dry matter yield of perennial grasses when grown on light soils with a humus content of about 2%. In favourable years the DM yield of grass-legume mixtures was better than, or similar to, pure grasses fertilized with N. In all cases *B. inermis* was higher yielding than *F. arundinacea*, and the average DM yield varied from 9.2 to 12 t ha^{-1}. In unfavourable years with insufficient rainfall the swards of *Ph. arundinacea* were higher yielding than *B. inermis* swards, especially so in grass-legume mixtures, and average DM yield varied from 5.1 to 7 t ha^{-1}. The energy potential of *B. inermis* and *Ph. arundinacea* swards differed similarly to that of DM yield and amounted to 153 GJ ha^{-1}. Humus content in the mixtures *Ph. arundinacea – G. orientalis* tended to increase.

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Evaluation of seed mixtures for montane pastures

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Abstract

Areas within the montane belt are widely used as wood pastures in Austria. Due to the severely limited productivity of such sites, seed mixtures used for restoration of pastures in such altitudes should ensure satisfactory yield and forage quality combined with low nutrient demand and should be sustainable.
At Eschwald (1.400 m a.s.l., Styria, Austria), one commercial seed mixture (SM1, containing fast growing grassland varieties that should enable intensive utilisation combined with high yield) and one mixture containing a high percentage of species well adapted to the site conditions (SM2, enabling yields adapted to site conditions) were compared over a period of three years. The experimental site was fertilised each year.
The species were divided into three ecological groups, based on their adaptation to the site. In the last year of observation, SM2 showed better vegetation cover, a higher proportion of site-adapted species with satisfactory forage quality and higher yield compared to SM1, where most species had disappeared after three years. Nevertheless, the remaining vegetation in plots containing SM1 had a higher content of site specific species that were able to colonize the developing gaps.

Keywords: montane pasture, site specific seed mixture, sustainability, recultivation

Introduction

Mountain farming is still a very important branch of agriculture in Austria. At present, more than 833,000 ha of alpine pastures are utilised. Constant maintenance and improvements of the pastures are necessary. The separation of wood and pasture is still an important aim of agricultural policy in Austria. In 1998, more than 400,000 ha were burdened with the right of grazing in woodland (Poetsch *et al*., 1998). During the last few years, several procedures of separation have been started and every year extensive areas have to be reseeded or restored. Also in the montane vegetation stage, infrastructural measures especially for winter tourism require restoration or reseeding. It is the main goal of restoration to create pastures that ensure satisfactory yields and forage quality combined with low nutrient demand and are sustainable
Two research projects have recently been carried out at the Federal Research and Education Centre Raumberg-Gumpenstein (HBLFA) in order to test whether site-adapted vegetation leads to more stable and ecologically site-adapted populations in comparison to commercial seed mixtures containing varieties bred for intensive grassland farming (Krautzer *et al.,* 2002; Graiss, 2004). To answer this question for agriculturally utilised meadows in the montane vegetation belt, plant stands originating from site-adapted and commercial seed mixtures were assessed over a period of three years.

Materials and Methods

The effects of seed mixtures for montane pastures on agricultural utilization and nature conservation were studied over a period of three years at site Eschwald (Table 1).

Table 1. Experimental site, mean air temperature (MAT) during the growing season (June to August, average of 3 years) and soil chemical properties at trial establishment (Graiss, 2004)

Site	Country	Altitude (m); Exposition	MAT	Soil chemical properties				
			°C	pH_{CaCl2}	humus g kg^{-1}	N_{tot} g kg^{-1}	P (CAL) mg kg^{-1}	K (CAL) mg kg^{-1}
Eschwald	Styria, A	1,415; WSW	12.5	3.9	220	8.1	86	150

Trials arranged as two factorial plot designs with plots of 8.5 m², replicated four times, were carried out from 1998 to 2001. Two different seed mixtures (SM1 = common commercial seed mixture according to national stipulations; SM2 = site-adapted seed mixture, containing site-adapted and site-specific grasses, legumes and herbs) were established by hand broadcasting. The plots were fertilised every year with 11,250 kg ha^{-1} mature compost. In addition, a liming treatment (1,900 kg ha^{-1} y^{-1}) was included. In order to measure the ecological value of the different plots, species were classified into three groups. Group 1: site-specific species, growing naturally under site conditions. Group 2: site-adapted species, not site-specific but sustainable under comparable site conditions. Group 3: non-site-adapted species, not occurring naturally under the specific climatic and site conditions. Vegetation cover and botanical composition (as a proportion of cover of each species) were assessed each year in the second week of July. The proportion of each species in each ecological group was summarised (see Table 2). For the seed mixture, the total value of each group is expressed as percentage of weight and the results of the field assessments are expressed as percent of cover.

Table 2. Composition of seed mixtures and classification of all assessed species with a cover exceeding 1%, in each ecological group

Species	SM 1 commercial seed mixture	SM 2 site-adapted seed mixture	Ecolo-gical group	Species not contained in mixtures	Ecolo-gical group
Agrostis capillaris		7.1	2	*Avenella flexuosa*	1
Cynosurus cristatus		4.4	2	*Carex brizoides*	1
Festuca rubra agg.	7.7	29.5	2	*Carex leporina*	1
Lotus corniculatus	4.3		2	*Carex pallescens*	1
Poa pratensis	20.7	16	2	*Carex pilulifera*	1
Trifolium repens	12.9	13.4	2	*Cerastium holosteoides*	3
	45.6	70.4		*Homogyne alpina*	1
Dactylis glomerata	10.3	3.6	3	*Juncus effusus*	3
Festuca pratensis	17.2	11.8	3	*Juncus filiformis*	2
Lolium perenne	16.5	5.3	3	*Luzula multiflora*	1
Phleum pratense	10.3	8.9	3	*Luzula sylvatica*	1
	54.3	29.6		*Nardus stricta*	2
				Poa annua	3
				Rumex acetosella	2
				Trifolium hybridum	3

Results

For the commercial seed mixture (SM1) the content of site adapted species amounted to 45% of total seed weight. In comparison, the content of site-adapted species in SM2 was 25% higher and exceeded 70% (Table 2). Neither seed mixture contained site specific species.
A total vegetation cover exceeding 70% is a main requirement to avoid erosion (Krautzer *et al.,* 2002; Tasser *et. al*., 2003). Both seed mixtures showed satisfactory vegetation cover over the period of assessment. However, at the end of the experiment total cover was 10% higher for SM2 than for SM1 (Fig. 1). A significant decrease in non-site-adapted species was observed for both seed mixtures. For SM1, this group of species could not really establish and they covered less than 5% in 2001. The site-adapted species made up 63% of the vegetation cover in 1999 and maintained this proportion for the remainder of the experimental period. The non-site-adapted species were replaced by site-specific vegetation immigrating from the surrounding areas. For SM2, non-site-adapted species only made up 0.4 % of the vegetation cover in 2001. The site-adapted species, on the other hand, made up over 80 % of the vegetation cover over the whole period. Because of the higher total cover of species appearing from the seed mixture and their high competitiveness, only a small proportion of site-specific species was able to establish.

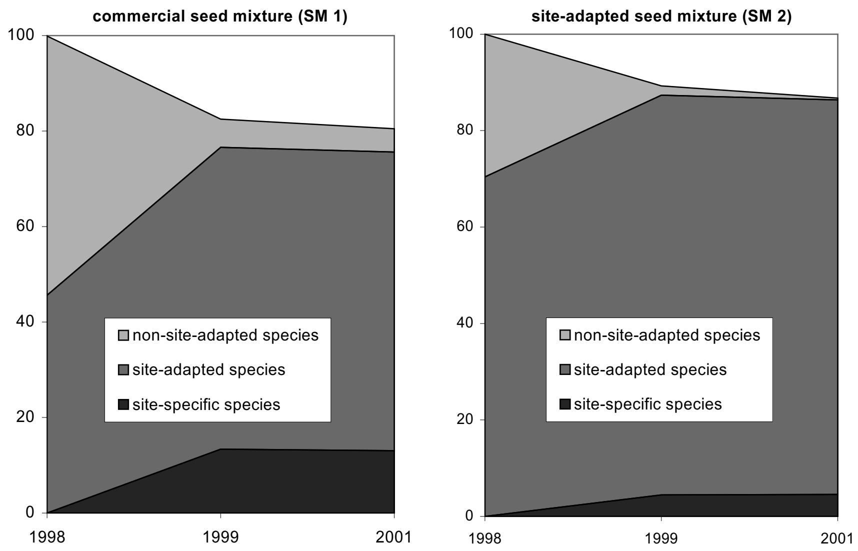

Figure 1. Average percentage of grouped species referring to their ecological value (1998 = % of weight in original seed mixture, 1999 – 2001 = species cover in %) in the treatment without liming

Compared to the non-liming treatment described above, liming generally showed a very positive effect on total vegetation cover (Fig. 2). The liming treatment tended to result in a higher percentage of non-site-adapted species while a lower percentage of site adapted species remained after three years. This demonstrates that also under improved soil conditions, non-site-adapted but agriculturally useful species are not able to persist in spite of the harsh climatic conditions in the montane vegetation belt. In practice, liming of such areas is generally not usual either because it is difficult to apply or it is too expensive. Due to the improved soil conditions, SM1 and SM2 showed high competitiveness against immigrating site specific species.

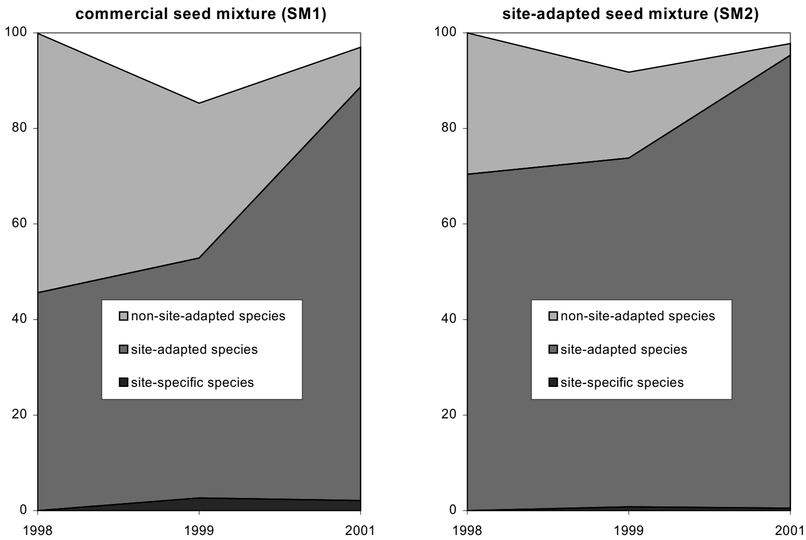

Figure 2. Average percentage of grouped species referring to their ecological value (1998 = % of weight in original seed mixture, 1999 – 2001 = species cover in %) in the treatment with liming

Discussion

In general, productivity and feeding value are important characteristics for the composition of seed mixtures for pastures in the montane vegetation belt. Therefore, both mixtures contained non-site-adapted species, i.e. 55% and 30 % by weight for SM 1 and SM2 respectively. The development of both mixtures clearly showed, that the use of non-site-adapted species was unsuccessful under the extreme climatic and soil conditions (Krautzer *et. al*., 2000). Therefore, on extensively utilised pastures, the use of sustainable, site adapted seed mixtures should be favoured.

Conclusions

Agriculturally utilised pastures in the montane vegetation belt should be reseeded with seed mixtures containing a high proportion of site-adapted species. The use of non-site-adapted species is of no value under extreme climatic and soil conditions.

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Evaluation of seed mixtures for subalpine pastures

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Abstract

Pastures within the sub-alpine and alpine vegetation belt belong to the most sensitive parts of the Alps. Therefore, seed mixtures used for such areas should combine different economic and ecological characteristics such as low demands on nutrients, satisfactory yield and digestibility, a closed sward, persistence and good adaptation to climate and soil.
At the location Hochwurzen (1.830 m a.s.l., Styria, Austria), one commercial seed mixture and one mixture containing site-specific subalpine and alpine species that are also useful for agricultural utilisation, were compared over a period of four years. With regard to the normally limited possibilities to reach and utilise such areas, only a single fertiliser application in the setup year was carried out. The assessed species were divided into 3 ecological groups, based on their adaptation to the site. Summarizing the valuable groups with expected sustainability, site-specific seed mixtures reached more than 80% cover with site-specific and site-adapted species. In comparison, the share of valuable groups from the commercial mixture remained about 50%. Results obtained generally showed an increase of positive ecological effects on plots where site-specific seed mixtures were used. Only the seed mixture containing a high share of site-specific and site-adapted species was able to guarantee a sustainable vegetation and sufficient protection against erosion.

Keywords: site-specific vegetation, subalpine pastures, low-input grassland, persistency of vegetation

Introduction

Permanent changes have taken place in the entire region of the Alps during the course of the last 50 years. Wide areas used for agrarian purposes have been reduced or abandoned. On the other hand, the widespread opening of power stations and intensive road building, torrent and avalanche barriers, as well as extensive infrastructural measures especially for winter tourism occurred. All of the measures described lead to intensive building each year, which then requires the restoration of the disturbed areas. However, as site conditions become more extreme, restoration is increasingly more difficult due to the rapidly worsening conditions. In most cases, a combination of usually cheap restoration procedures and cheap and non-site-adapted seed mixtures are turned to. The resulting ecological and often economic damage is comprehensive: inadequate vegetation cover, soil erosion, increased surface drainage, the high costs of ecologically dubious fertilisation measures and management, and introduction of alien species are some of the resulting effects that follow.
During the last seven years, two research projects were carried out at the Federal Research and Education Centre Raumberg-Gumpenstein (HBLFA) in order to investigate if site-specific and site-adapted vegetation leads to more stable, sustainable and ecologically site-adapted populations in comparison to commercial seed mixtures containing lowland species (Krautzer *et al.,* 2002; Graiss, 2004). To address this question for agriculturally utilised meadows in the subalpine vegetation belt, plant stands occurring from site-specific and commercial seed mixtures were assessed over a period of four years.

Materials and Methods

The effects of seed mixtures for subalpine pastures on agricultural utilization and nature conservation were studied over a period of four years on site Hochwurzen (Table 1).

Table 1. Experimental site, mean air temperature (MAT) during the growing season (July to August, average of 3 years) and soil chemical properties at trial establishment (Peratoner *et al*., 2004)

Site	Country	Altitude (m); Aspect	MAT	Soil chemical properties				
			°C	pH_{CaCl2}	humus g kg^{-1}	N_{tot} g kg^{-1}	P (CAL) mg kg^{-1}	K (CAL) mg kg^{-1}
Hochwurzen	Styria, Austria	1.830; SE	11.3	6.6	40	2.1	13	47

Exact trials arranged as two factorial split-plot designs with plots of 21 m², replicated three times, were carried out from 1999 to 2002. Two different seed mixtures (SM1 = usual commercial seed mixture; SM2 = site-specific seed mixture, containing sub-alpine and alpine grasses, leguminosae and herbs) were established, using the application technique of hydroseeding (15 g m^{-2} mineral fertiliser (15N:15P:15K), 5 g m^{-2} Rekuform®, 15 g m^{-2} synthetic binder, 15 g m^{-2} seeds). In order to measure the ecological value of the different plots, a classification of the assessed species referring to their ecological value was made. Group 1: site-specific species, growing naturally under site conditions. Group 2: site-adapted species, not site-specific but sustainable under comparable site conditions. Group 3: non-site-adapted species, not occurring naturally under the specific climatic and site conditions. Protective vegetation cover and botanical composition (as share of protective cover of each single species) were assessed each year at the stage of flowering of *Festuca nigrescens*, in order to guarantee comparable conditions. The proportions of each species within each ecological group are summarised in Table 2. For the seed mixture, the total value of each group is expressed as percent by weight and the results of the field assessments are expressed as percent of projective cover. Due to the normally limited possibilities of reaching and utilising such areas, only a single fertiliser application in the setup year was carried out.

Table 2. Composition of seed mixtures and classification of all assessed species with a cover exceeding 1%, referring to their ecological group

Mixtures Species	SM 1 commercial seed mixture	SM 2 site-specific seed mixture	Ecological group	Mixtures Species	SM 1 commercial seed mixture	SM 2 site-specific seed mixture	Ecological group
Campanula barbarta		0.22	1	*Festuca ovina*	2.5		3
Festuca nigrescens		35.00	1	*Lolium perenne*	15.7	3.00	3
Phleum alpinum		10.00	1	*Phleum pratense*	19.9		3
Poa alpina		15.00	1	*Trifolium hybridum*	2.4		3
Trifolium nivale		7.00	1	*Vicia sativa*	3.4		3
Crepis aurea		0.50	1		43.9	3.00	
Poa supina		5.00	1	*Achillea millefolium*	0.7	1.00	2
Trifolium badium		5.00	1	*Agrostis capillaris*	4.6	4.00	2
		77.72		*Anthyllis vulneraria*		5.00	2
Species not contained in mixtures				*Festuca rubra*	31		2
Elymus repens			3	*Leontodon hispidus*		1.00	2
Chenopodium album			3	*Lotus corniculatus*	5	3.00	2
Persicaria lapathifolia			3	*Melandrium rubrum*		0.03	2
Rumex obtusifolius			3	*Poa pratensis*	10.6		2
Tussilago farfara			2	*Poa violacea*		5.00	2
				Silene vulgaris		0.25	2
				Triolium repens	4.2		2
					56.1	19.28	

Results

Figure 1 indicates the development of the share of grouped species over the years, compared to their share (in % by weight) in the seed mixtures SM1 and SM2. The percentage of species of the seed mixtures shows the initial situation. SM1 contained no site-specific species but more than 56% of site-adapted species, mainly *Festuca rubra*. The total vegetation cover developed from 73% in 1999 to nearby 80% in 2002. Since 2000, a slow immigration of site-specific species, mainly from neighbour plots, was noted. The share of site-adapted species decreased after the first two years and again reached 56% in 2002. The non-site-adapted species spread out for the first two years, probably because of the effect of fertiliser application in 1999. After 2000, their share decreased below 20%. In total, the share of the valuable groups with expected sustainability reached 59%.
Mixture SM2, contained only 3% of the non-site-adapted *Lolium perenne*, variety “Guru”, as a fast-growing nursery crop. Nearby 78% by weight were allocated to the group of site-specific species and around 20% accounted for the group of site-adapted species. The total vegetation cover increased from 70% in 1999 to 94% in 2002, nearby 15% higher than SM1. The ratio of the different ecological groups did not differ very much between the years of observation. The share of non-site-adapted species increased to 11%, of which 7% was *Lolium perenne* “Guru”, a variety that showed remarkable winter hardiness. In 2002 a share of 72% of site-specific species and 10% of site-adapted species could be assessed. In summary, the share of valuable groups exceeded 82% of vegetation cover.

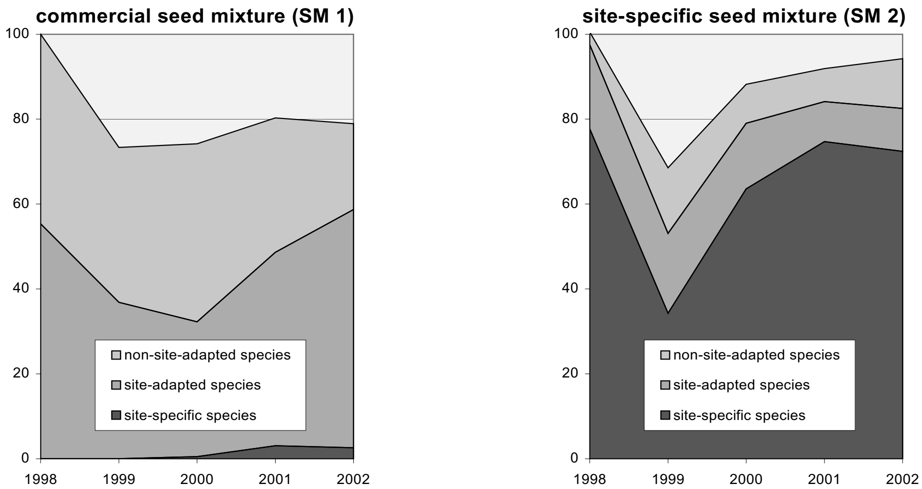

Figure 1. Average share of grouped species referring to their ecological value (1998 = % of weight in original seed mixture, 2000–2002 = species cover in %)

Discussion

The literature reports the use of a range of indicators to describe the ecological value of plant stands, e.g. weighted scores of the ecological indicators of Landolt (1977), indicator values following Ellenberg (1992) or an efficiency index (Parente *et al.*, 2002). In comparison, the present method of a grouping of species according to their ecological value allows a simple comparison of different sites and different seed mixtures.

In Austria, most subalpine and alpine grassland are utilised for agriculture during summer. The excellent suitability of site-specific seed mixtures for agricultural purposes is evident in previous publications (Krautzer *et al*., 2004; Peratoner *et al*., 2004). Nevertheless, a fast and enduring protection against erosion that only can be reached with the help of a dense sward is the first and most important target. In the short term, this can be assured by the use of a high quality application technique (Krautzer *et al.,* 2002). In the long run, a plant stand with sustainable, site-specific vegetation is necessary. Results of several assessments indicate that at altitudes between 1,200–2,400 metres, a minimum vegetation cover of 70–80% is required to avoid erosion (Tasser, 2003). The results obtained show that the share of non-site-adapted species and therefore the cover of plots with SM1 will continue to decrease. In a mid-term evaluation, the cover will fall below the critical value of 70% and problems with erosion can be expected. In practice, commercial seed mixtures, containing a high percentage of species that are not site-adapted to site conditions, would need repeated seeding and fertiliser application in order to achieve and maintain a vegetation cover ensuring sufficient protection against erosion. In a long-term perspective, the lack of sustainable site-specific species will thus result in repeated effort and thus expenditure, especially in the subalpine vegetation stage.

The share of valuable species of SM2 increased up to the last year of observation. A dense sward with cover values above 80 % can also be expected in a long-term view. In practice, restoration and reseeding of degraded areas in high altitudes should be done with the help of site-specific seed mixtures. They are able to stand the harsh climatic conditions of such sites and ensure sustainable vegetation with a sufficient long-term protection against erosion processes.

Conclusions

At altitudes above the subalpine vegetation stage, only seed mixtures containing a high share of site-specific and site-adapted species are able to guarantee a sustainable vegetation and sufficient protection against erosion.

Acknowledgements

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Cutting effects on persistence and sustainability of an alfalfa-tall fescue mixture

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Abstract

In a grass-legume binary mixture, the interactions between two components result in a large variation of grass and legume production. The knowledge of such variation and its underlying mechanisms strongly contributes to establishing effective management schemes. The purpose of the study was to investigate the year by year changes of grass and legume production grown in mixture in relation to their monocultures. The experiment was conducted in Drama, northern Greece. Plants of *Medicago sativa* v. Yliki and *Festuca arundinacea* cv. festorina were cultivated in monoculture and binary plots and three cutting regimes were applied. The above ground dry biomass of each cultivation year was measured in four consecutive years. The performance of plants in the mixture was expressed by their plasticity lines. Results showed that grass grown in mixtures performed better than when grown in a pure stand and its production improved year by year. On the contrary, the production of the leguminous component of the mixture showed no differences in relation to its monoculture. The cutting intensity did not affect the interference effect.

Keywords: alfalfa, tall fescue, mixture, cutting, plastic response

Introduction

In the Mediterranean areas, the use of legumes in mixtures in degraded lands and under variable conditions could be essential to achieve persistent and high quality pasture swards (Porquenddu *et al*., 2004). In a grass- legume mixture, the study of interactions between components proves to be essential for understanding high variations of grass and legume densities (Schwinning and Parsons, 1996). The maintenance of species balance in a mixture is an indication of sustainable quality and quantity of the mixture. The main focus for sustainable mixtures should be the use of appropriate management schemes *per se*. The common practice of cutting is a principal and drastic factor affecting the structure, growth and plant performance by affecting the course of interference (Zannone *et al*., 1986) and therefore the productivity and the quality of the swards (Papanastasis and Papachristos, 2000).
The purpose of the study was to investigate the year by year changes of grass and legume components within a mixture compared with their monocultures and how cutting intensity modifies the balance of the mixture components.

Materials and Methods

The experiment was conducted in the field area of Tobacco Institute of Drama, Northern Greece. Its latitude is 41°09' and altitude 130 m from sea level. The mean annual temperature is 15.2 °C and the total annual precipitation is 589 mm, suggesting a semi-arid mediterranean climate. The soil was of low fertility and productivity and therefore it was not cultivated, for over ten years. The textural class was silt loam with a pH 7.6. The experiment was established in the autumn of 1995. The studied species were *Medicago sativa* (*L*). cv. *Yliki* (*Alfalfa*), bred by the Forage Crops and Pastures Institute at Larisa, Greece and *Festuca arundinacea* cv *festorina* (tall fescue) introduced from U.S.A.

The experimental design consisted of completely randomized field plots (1m × 1 m) of pure and mixed (1:1) stands. The sowing density of pure plots was 4.5 g m^{-2} for *Festuca arundinacea* and 4.0 g m^{-2} for *Medicago sativa,* and in the mixed stand each component was seeded at half the pure stand seeding rate. All plots were irrigated by sprinkler to maintain field capacity. The following levels of cutting intensity were also applied: a) one cutting in the summer, at the stage of full maturity (namely uncut, C0), b) cutting at 7 cm from the soil surface (light cut, C7), and c) cutting at 3 cm from the soil surface (heavy cut, C3). The measurements were repeated for four years (1996–1999). The latter two cutting intensities were applied when the first inflorescences appeared during spring and early summer, the first and fourth year of the measurements. Two more cuttings were applied the second and third year, one in early spring and one in autumn. The cut material was oven-dried at 75 °C for 48 hours and the above ground dry biomass (g m^{-2}) was determined. There were four replications for each cutting treatment.

The nature of interference effects was expressed by the concept of plastic responses and calculated separately for each species by the formula:

$$[n(Y_{ij}/Y_{ii})]-1 \text{ for each species,}$$

where, Y_{ij} and Y_{ii} are the above ground dry biomass (g m^{-2}) of species in mixed and pure plots respectively, n is a multiplication factor relating the population in mixture to the same unit area of monoculture and in our case it equaled 2 (Zannone *et al*., 1986).

Results

The interference effects revealed by plastic responses are illustrated in figure 1 for uncut, in figure 2 for light cut and in figure 3 for heavy cut treatments. The analysis of plastic responses was made on the total years production. Irrespectively of the cutting regime, a strong co-operation effect (*sensu* Zanone *et al*., 1986) established and favoured tall fescue, as its plasticity line always attained positive values through the period of experiment. In addition, fescue performance seemed to be gradually favoured through the years. However, the advantage of grass did not result in a disadvantage to the legume. The plasticity line of alfalfa approximates the *x*-axis, indicating that alfalfa has experienced a persistent neutralistic interference effect. It is remarkable that cutting regime did not have any effect on the plasticity lines of both species; i.e. cutting did not change the mode of interference between the species.

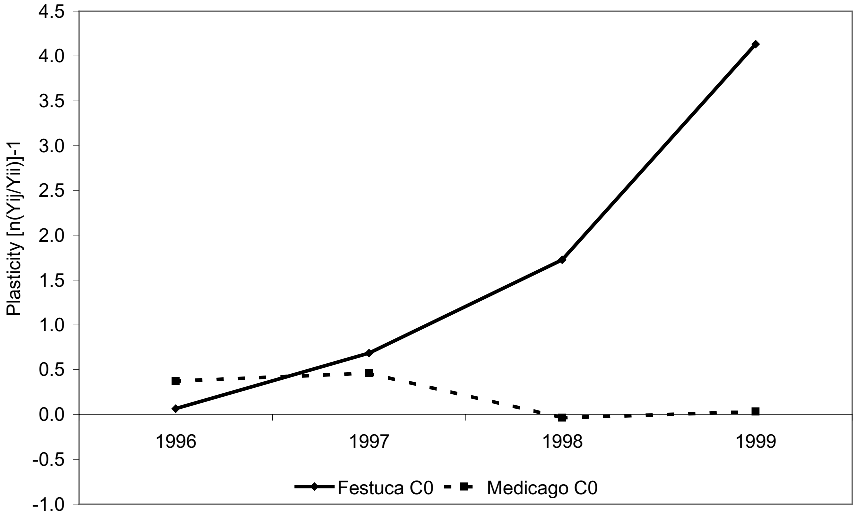

Figure 1. Changes of plasticity line of tall fescue and alfalfa through the years, under the uncut treatment (C0)

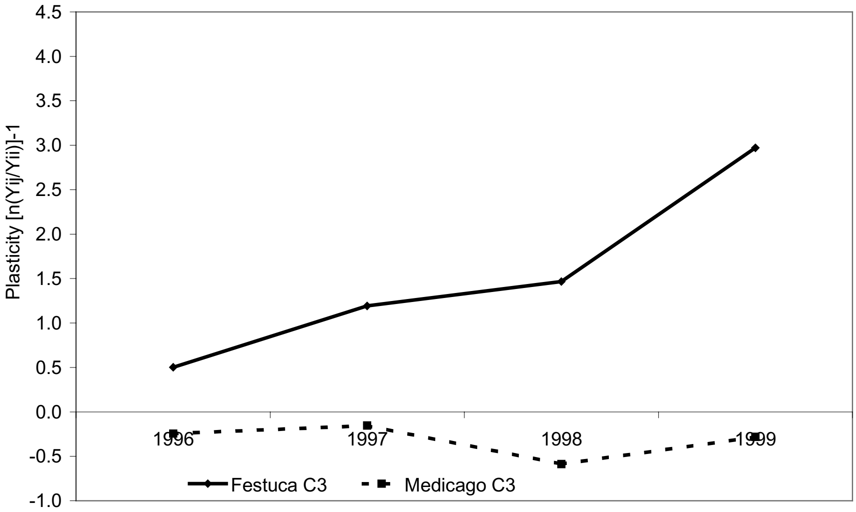

Figure 2. Changes of plasticity line of tall fescue and alfalfa through the years, under the light cut treatment (C7)

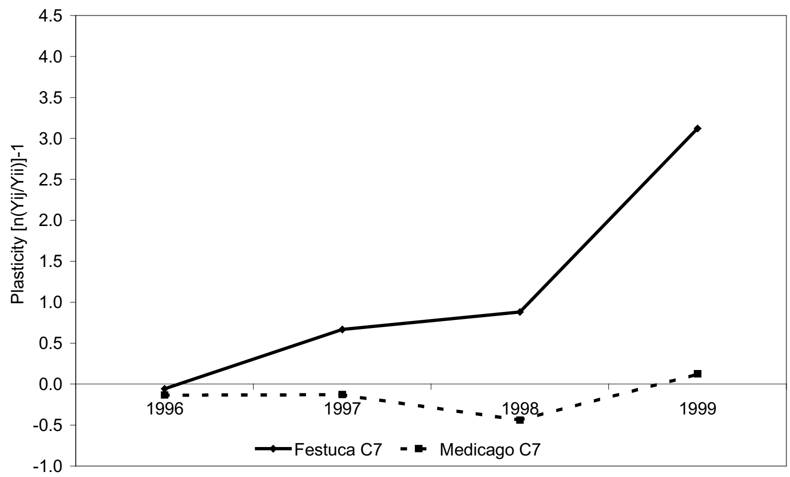

Figure 3. Changes of plasticity line of tall fescue and alfalfa through the years, under the heavy cut treatment (C3)

Discussion

The results showed that under favorable watering conditions tall fescue seems to exploit more effectively the available resources (summarized by the term *space* according to Begon *et al*., 1996) than alfalfa. This was also apparent in studying the first year's seasonal changes of those species grown in the mixture (Lazaridou *et al*., 2002a). Generally, tall fescue is regarded to be aggressive towards alfalfa when they grow in mixtures (Beuselinck *et al.*, 1992; Koc *et al*., 2004. It seems that under favourable conditions tall fescue reaches each development stage earlier than alfalfa. This behavior has already been reported in tall fescue/ alfalfa mixtures, mainly due to the tall fescue's earliness of root formation (soft-seeded plants) and its tuft root system compared to the hard-seeded, woody-rooted alfalfa (Lazaridou *et al*., 2002b). Tall fescue benefits from the ability of alfalfa to introduce nitrogen into the system (Schwinning and Parsons, 1996; Soussana and Machado, 2000). Consequently, under favourable watering conditions tall fescue sustains its competitive advantage over alfalfa but co-existence is guaranteed as no negative interference effect is observed in alfalfa. The latter species seems to avoid competition by sustaining a higher reproductive effort (data not shown); a response that has already been recorded in mixtures of annual clovers (Vrahnakis, 2000). Cutting effects, as reported in a cut by cut analysis in previous papers (Lazaridou *et al*., 2002a; Lazaridou *et al*., 2002b), were not observed in this year by year analysis. Similar differences in the results depended on the method of analysis were also reported by Zannone *et al.* (1986).

Conclusions

Grass grown in mixtures performed better in relation to its pure stand and its production improved year by year. The production of the legume component of the mixture did not show any differences compared with its monoculture. The cutting intensity did not affect the interference effect.

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Initiatives to improve biodiversity in Scotland

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Abstract

The value of sustained biodiversity for the future of both natural and managed habitats and for human wellbeing is increasingly coming into sharper focus as existing and potential threats are recognised. Against a background of a progressive shift of emphasis in farming during the second half of the 20th century from all-out production to increased consideration for the environment, a sequence of initiatives has been developed so that farmers can maintain or enhance the biodiversity of plant and animal species. Global agreements have placed more or less urgent obligations on national governments, which have implemented statutory measures and commissioned local government action plans for specific habitats or species. A range of support schemes is available in Scotland, broadly grouped into: official agri-environmental and national schemes, local Action Plans and non-government initiatives. For the successful implementation of all of these, good cooperation between conservationists and land managers is essential and any support needs to be accompanied by viable commercial farming. Monitoring procedures are desirable to evaluate impacts on species biodiversity and, if necessary, to point to required management changes.

Keywords: action plans, agri-environment, biodiversity, monitoring

Introduction

The importance of biodiversity, the richness and variety of all living things across the world, is progressively coming into sharper focus. All species are interdependent within the global system in which humans exist; biodiversity contributes to a sustainable balance in food production, climate control and genetic potential for the future. With the ever expanding world population and scope of human activities, biodiversity is coming under increasingly serious threats from pollution, global warming, unchecked economic growth, exploitation of natural resources and ozone depletion. The urgent need to protect biodiversity was recognised by world leaders at the 1992 Rio Earth Summit, where a Convention on Biodiversity was signed with pledges from countries of the world to develop and implement plans of action to sustain biodiversity (United Nations, 1992).

Following the Summit meeting at Rio, a Biodiversity Action Plan was set out in the UK in 1994, with the formation of a steering group representing all interests in land use, and a framework set for national action for species and habitats. In 1996 a Scottish Biodiversity Group sought to implement this action in Scotland, ultimately devolving to the administrative regions to formulate Local Biodiversity Action Plans (LBAPs). These aimed to assess the existing local biodiversity, to designate habitats and threatened species in need of conservation as a Local Priority, and then to specify a programme of action needed. Central to the LBAPs was the involvement of local communities and individuals through publicity and cooperative management.

The Action Plans emphasise that 'everyone has a responsibility to maintain the environment for present and future generations' (Barnes, 1998). Farmers, who manage over 80% of the land in Scotland, have a particular role to play, and several agri-environmental support schemes are available. It is important, however that these are accompanied by commercially viable farming (Nosberger and Kessler, 1997). In addition, a series of statutory local, voluntary and commercial initiatives have emerged in Scotland, all of which are intended to improve care of the environment and conservation of wildlife and also to sustain and improve landscape and amenity for the benefit of the public. Some of the main examples of initiatives operating in Scotland are listed below.

Statutory Conservation Areas

a) Internationally important

Special Protection Areas – E C Directive e.g. for wild birds on coastal areas.

Special Areas of Conservation – E C Directive e.g. for bogs and moorlands.

Ramsar Wetland Sites – International Wetland Convention to protect wetlands

b) Nationally important

Sites of Special Scientific Interest (SSSIs) – Sites selected to protect geology or plant and animal assemblages

National Nature Reserve – Areas with plant communities or bird life that are nationally important.

Locally Important Conservation Areas

Sites with wildlife features of significant local interest; usually small and often established using voluntary funds and labour.

Local Nature Reserves;

Local Wildlife Sites – identified by the Scottish Wildlife Trust;

Bird Sanctuaries – designated and managed by the Royal Society for the Protection of Birds (RSPB);

Forestry Sites – designated within Forestry Authority plantations, sometimes as Forestry Parks with facilities to attract the public;

Wetland Trust Sites – wetland sites of particular local interest;

National Trust Sites – designated within estates owned and managed by the National Trust for Scotland.

Agri-environment Schemes

Schemes formulated with government backing for farm land and provision of grant support, to encourage environmentally friendly farming and conservation/enhancement of wildlife habitats on farms.

Environmentally Sensitive Area (ESA) Five or ten year scheme requiring prescribed managements on wildlife habitats e.g. hedgerows, water margins. Available in selected areas with high landscape value.

Countryside Premium Scheme (CPS) Similar to ESA Scheme but available in non ESA areas.

Rural Stewardship Scheme (RSS) The main environmental scheme now available to farmers largely replacing ESA and CPS scheme. RSS applications are ranked according to a points system based on the number and quality of actual or potential wildlife features on a farm. As funds are limited this ensures only the most suitable farm units receive support.

Scottish Forestry Grants Scheme – provides grants to aid new tree planting.

Scottish Forestry Farmland Premium – assists tree planting in small areas on farmland.

Farming and Wildlife Advisory Group (FWAG).

FWAG Farmland Biodiversity.

Scottish Executive Environmental and Rural Affairs Department Organic Aid Scheme.
Merse Management.
Geese Management.

Miscellaneous Schemes

These are operated locally by e.g. the Woodland Trust for tree planting.

RSPB Grassland for Corncrakes Scheme to promote management for attracting corncrakes.

White and Wild Milk to give premium milk prices in return for establishing farm wild life features.

Heather Trust, to promote heather management for grouse.

Some commercial companies provide grants for environmental improvements e.g. Shell, Transco, Sainsburys. Local and National Competitions also give encouragement to farmers e.g. Farmcare run a Silver Lapwing national competition with regional rounds. Some local Grassland Societies run environmental competitions as well as grassland management competitions.

Measures to improve biodiversity on farms

Examples of habitats on farm for which grant aid is available under RSS to improve biodiversity are given below.

Species rich grassland, moorland, wetland, water margins and ponds, field boundaries and hedgerows, woodland and scrub, heather regeneration, bracken eradication.

Discussion

The principal mechanism for conserving or enhancing biodiversity in Scotland is channelled through the combined efforts of conservation organisations with their specialist knowledge of species and habitats, and land managers who are responsible for habitat treatments. The administrative structure of national and local Action Plans provide detailed treatment programmes. RSS and other agri-environment schemes, that were developed largely as a result of public pressure, give a framework within which farmers can contribute. Clearly monitoring is necessary to evaluate the effects on biodiversity of the numerous schemes and baseline data should be recorded from the beginning (Flynn *et al.,* 2002). Local records often indicate that the decline in rare species or habitats has been halted, and some formerly extinct species, e.g. red kite, have been re-introduced. There is limited evidence, often anecdotal, that agri-environmental schemes have given positive benefits (Tilzey, 1997). However the scattered and discontinuous distribution of conserved habitats on farms is a limiting factor to the maintenance of viable populations (McCracken and Tallowin, 2004). Improved biodiversity has been achieved in many schemes but attempts to recreate high conservation value habitats such as broad leaved woodlands or species-rich grasslands have been only partially successful because current management systems cannot precisely mirror past traditional regimes. It is important that individual habitats receive a specific and positive management prescription to sustain biodiversity. For example, on species-rich grassland, grazing or mowing may be delayed until late summer to allow the plants to seed, no nutrients added from manuring or winter feeding of livestock, and no pesticide application (McCracken and Tallowin, 2004).

Conclusions

A range of schemes to improve biodiversity is available in Scotland. The main channels are LBAPs, agri-environmental schemes and non-government initiatives. To be successful any scheme must be integrated with commercially viable farming practices, and quantitative monitoring of biodiversity changes should be a prerequisite. Land managers and nature conservationists must continue to collaborate closely to achieve the objectives of improved biodiversity effectively.

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Functional diversity in low-input grassland farming systems: characterisation, effect and management

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Abstract

High biodiversity in grasslands is widely perceived to have a major role in maintaining or enhancing the amenity and cultural value of landscapes in Europe. In this paper, we focus mainly at community level, evaluating factors that appear to influence biodiversity at farm and landscape levels. In order to establish generic principles we examine the maintenance of biodiversity in terms of maintaining or enhancing functional diversity (FD). We define plant functional types (PFTs), groups of species having the same function and/or the same effect in the grassland ecosystem, species identified on the basis of plant traits. These traits reflect ecological responses to nutrient input and/or defoliation frequency, and they can also have an effect on ecosystem properties. We reviewed the literature, examining the relationship between several leaf and plant traits and principal ecological factors and, in turn, how these traits could influence the feed value of the grassland vegetation for herbivores. FD was determining as the range of relevant PFTs at community, farm and landscape levels. We propose a practical method of assessing agronomic value of semi-natural grasslands based on the determination of dominant PFTs by measuring traits *in situ*, or through using a trait database coupled to species abundance records. We then assess the relevance of the method for semi-natural grasslands subjected to several management practices.

Keywords: biodiversity, grassland, defoliation, fertilisation

Introduction

At the livestock farm scale, specific and functional diversity of the vegetation depends greatly on how farmers manage grasslands and meadows, and how they are spatially arranged in the landscape. Adoption by livestock farmers of management practices that enhance biodiversity depends on subsidies they receive and on their objectives for animal performance, production costs and labour. Biodiversity has a range of functional roles within agroecosystems at a range of scales (Altieri, 2002). However, most studies have been done at just one scale, the plant community (plot level) or landscape level (Freckleton, 2004).

High grassland biodiversity is generally associated with low-input livestock systems that support less than 1 LU per ha (Duru, Hubert, 2003). Today biodiverse grasslands only survive where economic drivers towards intensification can not operate or where there is adequate compensation against intensification via agri environment subsidies (Hodgson *et al.,* 2005). Biodiversity rich areas are often characterized by marked differences in management between fields that reflect topographic and environmental differences. Although grassland biodiversity may provide a diversity of potential utilitarian functions (Swift *et al.,* 2004) at an ecosystem or landscape level such as sequestration of carbon, purification and filtration of surface water, provision of amenity facilities for society, to the livestock farmer the essential function is to feed herbivores (Guérin, Bellon, 1990).

In this paper, we use plant functional traits, to characterize the functional diversity of grasslands at different spatial scales. We hypothesize that this approach could be a bridge linking management practices to the vegetation structure and to their productivity and quality.

We exclude sown grasslands and we consider only ecological factors on which farmers could act upon through management of nutrient inputs and defoliation regime (mowing and/or grazing). These are the most important environmental factors that drive the structure and the composition of plant communities (Grime*,* 1988; Kleyer, 1999).
We define functional diversity (FD) of a grassland community using a combination of plant functional traits which reflect the influence of ecological factors on functional diversity and on the ecosystem properties. We examined a range of plant and/or leaf traits in order to identify ones that were specific to particular ecological factors. Two approaches were used, one based on plant functional types (PFTs) and a database of species having the same strategy for resource acquisition and use, and the second based on plant trait measurement *in situ*. We review the advantages and limitations of a functional-trait based approach to the categorisation of grasslands examining issues relating to the plant plasticity, and the comparison of plant growth forms. We also evaluate the relevance of both approaches to assess grassland functional diversity at farm and landscape scales.

From plant functional traits to functional diversity at plant community level: some methodological aspects

A functional classification of species based on plant traits

It has been recognized that predicting the response of species and neighbour relationships to variations in resources and climatic change requires a functional classification of species (McIntyre, 1999). It could be based on traits directly linked to growth and development functions of plants, or strongly correlated to other variables describing these functions (Weiher *et al.,* 1999). A short list of key plant functional traits has been identified (Diaz, Cabido, 1997), which has led to the development of the concept of plant functional type (PFT). PFTs are defined as non-phylogenetic groupings of species exhibiting common biological traits that enable them to fulfil specific functions in a similar way within an ecosystem (Gitay, Noble, 1997). PFTs are regarded as a concept enabling the identification of general principles for the functioning of organisms which can be used for making predictions, but also as a practical tool to reduce a wide diversity of species to a small number of entities. The basis of PFT rests on an analysis of the traits developed by plants growing in communities. One distinguishes traits of response, which are those whose values change in response to factors applied to the community, and traits of effect that act on the processes of the ecosystem (productivity and nutrient cycling among others) (Lavorel, Garnier, 2002).

Plant traits as indicators of environmental factors (response traits)

Land management acts upon the composition and the dynamics of plant communities through changes in nutrient availability and defoliation regime. Nutrient availability depends on fertilizer supplied, amount and kind (quality) of litter and excreta through grazing. Defoliation regime could have an indirect effect modifying the light incoming at different heights of the canopy, and also direct effects making gaps, or removing vegetative or reproductive plant components (Bullock, Marriott, 2000).
Prediction of community or ecosystem response to changes in land management has driven a search for key traits that take account of: (i) the capacity to exploit resource-rich or -poor environments; (ii) the capacity for competitive dominance; (iii) the response to disturbance (Wilson *et al.,* 1999). Modelling vegetation dynamics for predicting the rate at which the vegetation changes needs extensive studies on plant strategy for regeneration, avoidance, and tolerance, and most often the interaction with the climatic circumstances that are not considered here.

Certain leaf traits can be used to indicate the morphogenetic strategies of species to exploit resource-rich or -poor environments. For example, fast growing species have low tissue density and short organ lifespan (Ryser, 1996). Slow growing species have low area per leaf mass (SLA) and long leaf lifespan (LLS) indicative of slow turnover of plant parts, long nutrient residence times, and slow response to favourable growth conditions (Westoby *et al.,* 2002). Wilson *et al.,* (1999) showed that leaf dry matter content (LDMC) was much less variable than the other leaf traits, being largely independent of leaf thickness and a better predictor of location on the resource capture/use-availability axis (Garnier *et al.,* 2001). High correlation was found between LDMC and the density of tissues, which is the key variable to distinguish the strategies of morphogenetic development of species.

Managing or knowing the response of plants within a community to nutrient availability needs to take into account the capacity of individual species to exploit the resources, but also their capacity for competitive dominance. Ryser and Urbas (2000) showed that a nutrient-conserving strategy with long LLS is of advantage in nutrient rich environments when no external disturbance removes the conserved nutrient.

Analysing the response of plant species within a community to a defoliation regime needs to take account of their individual capacities for competitive dominance. Specific shoot height (SSH) is considered to be the most relevant trait indicating capacity for competitive dominance (Hodgson *et al.,* 1999), because it expresses an ability to capture light (Vesk *et al.,* 2004). However, in cut or grazed grasslands this trait alone can not predict a species' capacity for competitive dominance. Others plant traits are related to meristem position (Bonser *et al.,* 1996), resprouting and branching abilities (Lavorel *et al.,* 1999). The timing of managements such as mowing, if imposed at the same time each year, will eventually lead to selection of phenological traits such as start of flowering and timing of seed set that are adapted to the particular management regime. After abandonment of any fixed agricultural management regime, seed production is no longer time-limited, which appears to explain the increase in late flowering species (Kahmen, Poschlod, 2004).

Plant traits determining effects of plants on vegetation characteristics influencing feed value for domestic herbivores

Porter and Remkes (1990) showed that species with low relative growth rate (RGR), longer LLS, lower SLA and higher leaf tissue density (Reich *et al.,* 1992), also contained proportionally more cell wall material (lignin, hemicelluloses, cellulose) than species with higher RGR. The latter contained proportionally more cytoplasmic elements such as protein and sterols (i.e. compounds in solution) (Ryser, 1996). Species with high RGR have high leaf water content, low leaf specific mass, low proportion of cell wall per unit of leaf area, high proportion of mesophyll protoplast per unit volume and high organic nitrogen concentration. Different proportions of leaf mesophyll (highly digestible tissue) among herbaceous species result in a large range of nutritive values (Van Arendonk, Poorter, 1994). Differences in tissue anatomy and chemical composition have a major influence on the digestibility of plant components (Wilson, 1993). Leaves having long LLS tend to have a high fibre/crude protein ratio, high lignin concentration and low nitrogen and phosphorous concentration (Nelson, Moser, 1994). Long LLS is very important for storing nutrients (Escudero *et al.,* 1992). Low specific leaf area is also often associated with increasing concentrations of secondary compounds and starch (Aerts, Chapin, 2000).

During the reproductive period, herbage growth pattern depends greatly on the rate and duration of stem growth, whereas during vegetative regrowth, it depends mostly on the leaf lifespan (Duru *et al.*, 2002). Over the vegetative period, the herbage bulk density is also highly correlated with leaf plant traits (Duru *et al.,* 2004), species having higher LDMC also have higher bulk density.

From plant traits to functional diversity

The nutrient factor shows considerable overlap between response and effect traits. Leaf traits that are indicators for resources capture and utilization are also predictors for herbage growth rate, herbage nutritive value and leaf toughness. Timing of initiation and of flowering that determines the beginning and the end of stem elongation act upon the herbage growth pattern over the reproductive period. Specific shoot height which depends on defoliation management acts upon sward structure. On the other hand, demographic and regeneration traits, associated with response to disturbance, are known to have little connection with adult traits involved in plant ecophysiology (Lavorel, Garnier, 2002). They would be of little relevance to assess vegetation characteristics.

Functional diversity characterizes the extent of complementarity among species' trait value by estimating the dispersion of species in trait space (Mason *et al.,* 2003). When the number of species is small, they generally present a high level of similarity in their plant features and could be related to the same functional group.

Some key questions for functional diversity assessment

Comparison of leaf traits in a set of species growing in pure stand showed that LDMC values separated the species into three life form classes (grasses, rosette forbs and upright forbs, $P \leq 0.001$) while this is not the case for SLA and LLS. Rosettes and upright forbs are respectively defined as dicotyledonous having, at the vegetative stage, entire wide leaves without stems and not entire leaves with stems or/and large petioles (Cruz *et al*., 2002). This result was confirmed when comparing SLA and LDMC for grass and rosette life forms growing in the same community (Viegas *et al*., 2005): the average values for LDMC were, respectively, 160 and 270 g kg^{-1} for rosette forbs and grasses, whereas the SLA was the same (26 m^2 kg^{-1}) for both plant life form. Consequently, LDMC should not be measured without considering separately plant life forms, unless the study is only on grasses. The choice of grasses is also justified by their high abundance in natural grasslands and their similar morphology (one botanical family) which avoid changes or adaptations in the procedure of trait measurements. Furthermore, when measuring only grass populations, the loss of information is low with respect to the whole community (Ansquer *et al*., 2005).

Evidence that species ranking for plant traits is strongly influenced by environmental conditions was shown in pot studies on *Dactylis glomerata* and *Brachypodium pinnatum* grown in different environmental conditions: 3 nitrogen x 3 phosphorus nutrient levels (Ryser, Lambers, 1995). LDMC varied from 160 to 220 g kg^{-1} for *D. glomerata*, and from 260 to 320 for *B. pinnatum*. For SLA, it was 28 to 42, and from 23 to 28, respectively. Therefore, under these controlled experimental conditions although plant traits appear to be environment dependent, the species ranking was not affected (Cruz *et al.,* 2005; Poozesh *et al*., 2005). Species ranking was also compared at the plant population and plant community levels (Table 1). It is apparent that for these species the plant traits showed great variability reflecting therefore considerable phenotypic plasticity. Nevertheless the species ranking remained consistent.

Table 1. Comparison of average values of LDMC (g kg^{-1}) for some grasses growing in pure stand (Toulouse : 150 m asl, with or no N application) or in plant communities having great differences in P and N herbage nutrient status (Ariège, Central Pyrenees (1°17'E, 42°51'N, 600–900 m a.s.l), data 2001, P. Cruz, unpublished data)

Species	LDMC of species in pure species stands: mean and (SD) for 3 growing seasons		LDMC of species in grassland communities (1 to 4 spring seasons): mean and (SD); n = number of plots	
	N+	N–	different N and P plant status	min and max measured values
Holcus lanatus	208 (24)	219 (20)	235 (26) n = 28	173–280
Lolium perenne	220 (42)	246 (31)	246 (25) n = 18	193–269
Dactylis glomerata	237 (35)	250 (24)	270 (22) n = 29	249–329
Agrostis capillaris	256 (30)	270 (28)	283 (26) n = 11	263–355
Festuca rubra	273 (48)	302 (42)	304 (38) n = 9	272–335

Use of plant trait measurement for plant functional diversity assessment and management

A plant functional approach to grassland community classification could be developed from a database of plant functional types, or directly in the field through measurement of plant traits.

A database, containing a list of relevant response and effect plant traits for a large range of grassland species, needs to be developed to show groups of species that have close similarity in plant trait values. The database would then be used to position different grasslands on an ecological gradient and classify them in terms of their agronomic characteristics. It would, however, be necessary to assess variation in FD within and between plant communities by comparing the abundance of different functional types (Petchey, Gaston, 2002). The agronomic characteristics of the pasture can then be deduced from those of the dominant functional type. This is the case of communities growing in nutrient-rich environments where competition for light lead to elimination of slow growing species. By contrast, under lower competition levels, several functional types can coexist (Lavorel, McIntyre, 1999). An example of database is given in Appendix 1.

Table 2. Comparison of two methods that could be used to characterized the functional diversity within and between grassland plant communities

	Plant functional type	Plant functional trait
Advantages	Opportunity to study correlations between a set of plant traits (leaf, phenological; some of them being hard to measure) Species typology based on several plant traits Linking with ecological factor and vegetation properties inside the database	Takes account of trait plasticity Low botanical knowledge needed
Limitations	Trait plasticity Some botanical knowledge needed Number of species in the database	Only a limited number of plant traits easily measurable at field level Requires knowledge on the relevance of plant traits for a given ecological factor and for the vegetation properties

Plant traits that are easy to measure in the field could be used to assess the position of a plant community on an ecological gradient, and to measure FD. An index proposed by Mason *et al.,* (2003) allows for the inclusion of small functional differences between species, which might be ignored by the database approach. It should be possible to quantify functional diversity and functional richness with this approach. FD index reflects the range of character values present in a given area, so it does not have the same significance for all plant traits. To assess the potential (maximum) FD index in a given area, we used the minimum and the maximum recorded values.

Advantages and limitations to characterizing grassland communities using either the plant functional type method, in which a database on individual species is required, or the plant functional trait approach are summarized in Table 2.

Assessment and management of grassland functional diversity: some examples from natural grasslands used for cutting and grazing

Within plant community

To assess FD within plant community, we used a long-term trial (17 years), conducted on a natural grassland in Rio Grande do Sul (Brazil), where the grazing pressure by cattle was maintained at four levels of intensity (Table 3). The vegetation structure of the most intensively grazed treatment (4% dry matter allowance) was homogeneous. The productivity of the grassland in this treatment was very low, in some extent due to low light interception. Grassland production and animal performance were higher in the 12 and 16% intensity treatments. These lenient grazing treatments allowed the cattle to select preferred forage species, which created structural heterogeneity with tall grass patches dominated by ungrazed or only lightly grazed species and tightly grazed short sward areas containing preferred species. Increasing grazing pressure reduced the FD. FD was higher when analysed using SLA values compared with LDMC values in all the treatments. There was, however, a tendency for LDMC to increase and SLA to decrease at lower grazing pressures.

Table 3. Average SLA ($m^2\ kg^{-1}$) and LDMC ($g\ kg^{-1}$) values for 4 plant communities (data for grasses only which constituted more than 45% of the total herbage mass) that had developed under different grazing intensities, Cruz and Theau (unpublished data)

Grazing intensity *	Number of species	SLA		LDMC		Live weight gain**	
		Mean	FD	mean	FD	kg per animal day^{-11}	kg ha^{-1}
4%	10	16.3	0.12	307	0.03	0.2	80
8%	13	15.7	0.21	313	0.06	0.4	125
12%	10	13.2	0.21	350	0.10	0.5	145
16%	11	13.3	0.18	337	0.09	0.5	110

* in kg of DM per 100kg of live weight per day (grazing pressure adjusted monthly during seventeen years)
** from Nabinger *et al*., 1999

The animal performances per animal or per ha were the lowest for the highest stocking rate treatment that coincide to the lower FD. In contrast, the lenient grazing treatments that allowed a better spread of forage over the year coincide with a higher FD.

Defoliation regime introduces changes of species either directly (via mortality following removal of apices) or indirectly (via change in competitive relations between species), which will result in differences in the dynamics of accumulation of herbage mass during regrowth. In the case of pastures that are exclusively grazed, these dynamics can result in substantial

heterogeneity of the vegetation. Low grazing pressure conditions will favour several types of vegetation structures, each with species belonging to a different functional group.
Considering the minimum and the maximum LDMC and SLA observed at field level in the studied area, we computed the FD for a community having 50% of species of each leaf traits; it give respectively 0.50 and 0.75. It means that results shown in Table 3 express only a small fraction of the maximum diversity, respectively 20 and 28%.

Between plant communities

For these illustrations, we focused on natural grasslands that were cut for hay and grazed most often heavily in spring or in autumn, in such a way that there was only little effect of dietary choices of animals. Consequently, diversity is expected to be greater between plant communities than within.
To illustrate the relationship between management, measured functional diversity and agronomic characteristics, we used grassland communities located high in the central Pyrenees. There were large differences in herbage N and P status and defoliation regimes (Table 4).

Table 4. Leaf plant traits (average value and FD) for some upland grassland communities differing in their defoliation regime and nutrient status (grasses only). Proportion of the different functional types: A, B, C (see Appendix 1)

Defoliation regime C: cut; G grazing (l: lax; s: severe) (defoliation score)	Sward nutrient status		SLA (m^2 kg^{-1})		LDMC (g kg^{-1})		
	N index	P index	average	FD	average	FD	functional types (A, B, C)
C – C – G (1)	82	63	24.4	0.10	245	0.03	41 42 7
	61	100	24.9	0.10	261	0.03	39 45 6
Gs – C– G (2)	81	86	24.7	0.09	250	0.03	56 43 3
	66	70	21.6	0.04	264	0.01	35 65 5
Gl – C – G (3)	70	76	24.2	0.18	260	0.03	28 41 31
	68	49	14.6	0.15	287	0.03	4 3 93
G – G – G (4)	76	69	23.7	0.14	267	0.02	25 13 62
	66	44	18.9	0.16	270	0.03	15 20 75

Measured and computed (see Appendix 1) plant traits were highly correlated, respectively 0.67 ($p<0.01$) with SSH (Specific Shoot Height), 0.65 ($p<0.01$) for LDMC, and 0.82 ($p<0.001$) for SLA. There was also significant correlation between plant traits: SSH vs LDMC: 0.76***, SSH vs SLA: 0.61*, SLA vs LDMC: 0.75***, indicating that a single one could not be a specific response trait

FD is low for LDMC and higher for SLA, and there is a trend to have higher FD for SLA when there was no cut or a lax spring grazing. Considering the minimum and the maximum LDMC and SLA observed at field level in the studied area (respectively 175 and 350 g kg^{-1}, and 12 and 36 m^2 kg^{-1}), we computed the FD for a community having 50% of species of each leaf trait value; it gave respectively 0.34 and 0.63. It means that results shown in Table 5 express only a small fraction of the maximum diversity, respectively 8 and 29%.
We found that the plant trait LDMC was highly correlated with spring forwardness (date at which herbage mass reach 200g m^{-2}), the daily herbage growth rate over the linear phase, and the date at which herbage ceiling yield for reproductive spring growth was reached (correlation coefficients were, respectively: 0.93 ($p<0.001$), –0.82 ($p<0.01$) and –0.82 ($p<0.01$). SLA and flowering date were the plant traits best correlated with the maximum standing herbage (0.84, $p<0.01$) and the date at which it occurred ($r = 0.65$, $p<0.10$).

The relevance of plant functional approach to assess an ecological factor was assessed first using plant trait measurements. Given data from Table 4, we show that LDMC and SLA were both well correlated to the herbage nutrient index ($r^2 = 0.75$; $p<0.001$), and that SSH was the trait which was best correlated with the defoliation regime ($r^2 = 0.71$; $p<0.001$). When using computed plant traits instead of measured ones, coefficients of correlation were significant but at lower levels. There was not a plant trait specific to nutrient availability and defoliation regime. Finally, LDMC assessed both factors according to the following equation LDMC = 332 – 1.3 Npi + 3.79 defoliation, $r^2 = 0.81$ (NPi: sward nutrient index; defoliation: defoliation score).

However, in a sample of 80 meadows and grasslands, we observed that plant functional types based on the LDMC database responded to defoliation regime and nutrient availability (Table 5), which meant that LDMC was not specific to an ecological factor. Furthermore, the proportion of plant functional types established on the LDMC basis depended on both nutrient availability and defoliation regime. There was a trend for a more even distribution of plant functional types in plant communities that had a lower nutrient herbage status, and those that were only grazed. The number of species was greatest when the proportion of the different functional types was more evenly distributed; i.e. when the competition for light was lowest (low nutrient, and/or early defoliation in spring).

Table 5. Functional diversity assessed at grassland community level through the proportion of different functional groups of grasses (A, B, C: see Appendix), and species diversity of 80 grasslands differing in defoliation regime and nutrient herbage status (from Ansquer *et al*., 2004)

Criteria	Defoliation regime: C = cut; G = grazed	Herbage nutrient status		
		low	medium	high
Functional diversity	C C G	28-31-41	52-40- 8	65-28-7
	G C G		48-34-18	
	G G G		25-28-47	
Number of species	C C G	32	21	21
	G C G		28	
	G G G		30	

At farm and landscape levels

Surveys conducted on four commercial farms showed that each of them had grasslands dominated by one of the three PFT. This diversity between grasslands allows farmers to fulfil a set of functions (Guérin, Bellon, 1990). However, the proportion of each vegetation type varied greatly according to farm (Table 6). For example, type C occupied from 6 to 28% of the grassland area.

Farms 1 and 3 with the higher stocking rates had the highest proportion of grasslands in which the type A functional group was dominant (Table 6). However, the proportion of *Chaerophyllum aureum*, an undesirable invasive species growing in nutrient-rich habitat and particularly when there is no spring grazing (Magda *et al*., 2003), was also more abundant on vegetation type A. This species was most abundant in grasslands in the valley bottom, due probably to more favourable soil conditions compared with the slopes.

Table 6. Functional diversity assessed at farm and landscape levels in terms of the proportion of different functional groups of grasses (A, B, C); the computed averages over three years are shown. Values with different superscript letters are significantly different ($p<0.05$)

Level	Percentage of grasslands where the functional groups A, B, C are dominant			Production system characteristics	
	A	B	C	stocking rate (cow ha^{-1})*	proportion of undesirable species
Farms					
1	60 ^{a}	34	6	1.20 ^{a}	0.75^{a}
2	37 ^{b}	39	23	1.05 ^{b}	0.35 ^{b}
3	47 ^{a}	33	19	1.22 ^{a}	0.40 ^{b}
4	43 ^{a}	28	28	0.95 ^{b}	0.27 ^{b}
Landscape					
Valley bottom	57 ^{a}	39	4		0.70 ^{a}
Slope	30 ^{b}	27	40		0.14 ^{b}

At landscape level there was clustering of the landscape units, for example the valley bottoms being mainly occupied by type A, which corresponds to grasslands having the higher nutrient level, and/or being not heavily grazed in spring.

In areas where most of the grasslands were cut for hay at least once per year the plant functional diversity was higher at farm and landscape levels than at community level. Differences in the timing of hay harvest between fields due to topographic and edaphic reasons, for example, probably had a major influence on grassland FD at the farm/landscape level. Greater functional diversity in grasslands at the farm/landscape levels probably also reflected the needs of individual farmers, such as the ability to maximise the duration of the grazing season and thus vary the management regime at the field level between years depending on between year variations in weather.

Conclusion

Management practices implemented to fulfil different functions in livestock feeding systems generate functional diversity in plant communities between fields within a given farm. Furthermore, topographic field characteristics determine the spatial distribution of the management practices within the farmland. Unfavourable field characteristics, such as steep slope, poor drainage or distance from the farm, determine the management practices of paddocks and consequently the vegetation types. As spatial and temporal scales increase (from field to farmland; from a season to a year or years) particularly where there is considerable variability in soil type, slope, elevation, aspect and climatic conditions, these factors drive an increase in vegetation diversity (White *et al*., 2004). In other words, grassland community diversity has a functional role in farmland management, and this role of diversity can only be assessed over the entire managed area at farm level. White *et al.* (2004) argue that a functionally diverse plant community over the entire managed area should be promoted in terms of potential for livestock farming sustainability, as well as for the biodiversity benefits of localized species diversity within grasslands. The farmland area could be a field used in continuous grazing (with high functional diversity) or a set of fields used in rotation grazing or for grazing and hay, leading to high diversity at farm level, but each of them having low functional diversity. The maintenance of a range of grazing intensities at the landscape level can allow the conservation of a wide diversity of herbaceous plants (McIntyre *et al*., 2003).

Plant traits derived from measurements or databases are useful to assess grassland community characteristics, but they are not specific to a single management practice. There is a challenge to use them for growth modelling (Viegas *et al.*, 2005). On the other hand, further researches should be done on linking planned and associated diversity (Altieri, 1999). Indeed, in less favoured areas, one role of grazing animal is maintenance or enhancement of sward structural heterogenity, and thus botanical and faunal diversity, by selective defoliation due to dietary choices, treading, nutrient cycling and propagule dispersal (Rook and Tallowin, 2003).

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Appendix 1. Database used for designation of plant functional types (PFT).
Seed of 17 grass species collected from meadows in the Pyrenees were sown in pure stands at Toulouse and grown with two N application rates. Measurements were taken once for time of flowering and SSH) or three (LDMC, SLA) growing seasons.
We show that LDMC was a reliable plant trait measure because it was well correlated to flowering time, plant digestibility, and herbage growth rate. Four significant groups were determined (from Ansquer *et al*., 2004)

Species	Date of flowering (Julian days)	SSH (cm g-0,33)	LDMC (g kg^{-1})	LDMC classes*	SLA (m^2 kg^{-1})
Lolium perenne	141	44	196	A	28.2
Holcus lanatus	131	41	198	A	32.6
Arrhenatherum elatius	138	43	218	B	32.5
Festuca arundinacea	150	51	222	B	18.7
Anthoxanthum odoratum	96	20	222	B	28
Dactylis glomerata	134	41	225	B	25.2
Poa trivialis	143		238	B	34.2
Trisetum flavescens	158	37	240	C	26.5
Agrostis capillaris	176	31	242	C	31.4
Phleum pratense	175	26	247	C	30.8
Festuca rubra	134	29	249	C	21.8
Avena pubesens	162	41	250	C	20.5
Festuca ovina	150	34	257	D	16.9
Cynosurus cristatus	121		262	D	19
Deschampsia cæspitosa	176	32	266	D	14.2
Briza media	146	37	274	D	18.9
Molinia cærulea	172		302	D	19.9
Brachypodium pinnatum	162	41	313	D	22.3

Agronomic aspects of extensive grassland farming and biodiversity management

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Abstract

Grasslands in Europe make an important contribution to the biodiversity of agricultural landscapes. The species and community diversity of grasslands is a result of a traditional extensive grassland management interacting with a broad range of site conditions. Until the early decades of the last century, grassland sites were hardly ameliorated and the agronomic potential was generally low, depending on the fertility of the soils. From the second half of the last century onwards, the production from grassland was markedly improved by regular fertilisation and liming and by artificial drainage of wet sites. Correspondingly, the stocking rates and the cutting frequency increased. Thus, biodiversity strongly decreased, and unimproved species-rich swards only persisted on a low percentage of the total grassland area. The preservation of the remaining species-rich grassland is a primary goal of nature conservation. The continuation of traditional ways of grassland management that would best preserve biodiversity is often not compatible with the requirements of intensive livestock production. Therefore, this grassland is at risk of being abandoned from agricultural use and there is a need for compensation payments for farmers to maintain grassland management. Apart from the unimproved species-rich grassland, there is an increasing area of now de-intensified species-poor grassland which can be managed to increase biodiversity. Grazing at a low stocking rate seems to have the potential to facilitate the restoration of diverse swards and to support reasonable individual performances of the grazing animals.

Keywords: grassland management, biodiversity, species-rich grassland, agronomic potential, grazing

Introduction

Grassland plays an important role in the land use of Europe. It is a main part of agricultural production systems and it strongly supports the livelihood of farmers. In the EU (EU25) more than 30% of the agriculturally utilised area is covered by grassland (EUROSTAT). There is a large variation between countries from less than 5% of grassland in Finland to more than 75% in Ireland. Site conditions, grassland vegetation, management, and production potential are highly variable. European grasslands make an important contribution to the total biodiversity of the rural landscapes (Nösberger, Rodriguez, 1996). A considerable percentage of plants and animal species mainly occur in open grasslands and are rarely found in other vegetation types. In addition, diverse grasslands are highly valued by society due to their potential for recreation and their attraction for tourism (Schüpbach *et al.,* 2004). Therefore, grasslands have become of primary interest for society, politics and research. About 60% of the farms in Europe that keep cattle are located in disadvantaged regions (Dabbert, Krimly, 2004); this emphasizes the importance of grassland managed for biodiversity and nature conservation as less favoured areas usually have a higher diversity compared to productive areas.

If biodiversity targets are to be integrated into grassland systems, the effect of biodiversity on agronomic performance and profitability of grassland has to be explored. Usually, farmers

perceive the biodiversity targeted management of grassland as a limitation to the potential livestock production. The maintenance and enhancement of biodiversity commonly require a reduction of inputs and result in a loss of herbage yield and quality compared to intensively managed grassland. On the other hand, ecologists claim that preserving and restoring grassland diversity may be beneficial to maintain desirable levels of several ecosystem processes, and may therefore have applications in land management and agriculture (Minns *et al.,* 2001).
The aim of this paper is to investigate the agronomic consequences of nature conservation and biodiversity targeted grassland management. First, the recent situation of grassland farming in Europe is briefly outlined. The historical development of species-rich grassland and the following loss of diversity as a result of intensification of grassland management are described. Secondly, the management of unimproved swards with a high nature conservation value and of mesic now de-intensified formerly improved swards is investigated.

Grassland farming in Europe today – general options for integrating agronomy and biodiversity targets

The utilisation of grassland in Europe has seen considerable changes during the last two decades. Whereas the overall agriculturally used area in Europe (EU25) has not show a consistent trend of change, the grassland area has decreased slightly in most countries (EUROSTAT). A much stronger decrease occurred in the livestock numbers. Cattle numbers, including dairy and beef, were reduced by 10% from 1992 to 2002 in the European Union (EU25, EUROSTAT, ZMP) with a much stronger decline in the new member states (32% in EU10) compared to the older member states (6% in EU15). A similar situation is found for sheep numbers. The reduction of cattle numbers led to a decrease in beef production of 6% for the whole EU, and of 26% for the new member states. The number of dairy cattle showed a stronger decrease with more than 20% for the whole EU (15% and 38% for EU15 and EU10 respectively). Although the number of dairy cows decreased markedly, dairy production in the whole EU countries hardly changed during this period. Again, a difference between old and new member states occurred with a slight increase in dairy production in EU15 and a decrease of 15% in EU10. A similar amount of milk had been produced with fewer dairy cows; the milk yield per cow increased by some 30%, from about 4400 kg per cow and year in 1992 to about 5500 in 2001 (ZMP).
These changes in land use and production figures are related to changes in grassland farming. The eastern and central European countries, formerly belonging the COMECON, changed their agricultural land use when they switched from a state to a market economy. Since 1989 livestock numbers have generally decreased by more than 50% up to 70%. The management intensity of improved grassland used by intensive livestock husbandry was reduced, particularly in less favoured regions. Some of the grasslands were even completely abandoned from agricultural use and are now exposed to successional change. In many central and western European countries, such as in Germany, The Netherlands, Denmark and Sweden, the dairy performance was increased by introducing high digestible forages from arable land (e.g. maize) and concentrates into the rations, mainly at the expense of herbage from grassland. Thus, with a fixed milk quota, the percentage of milk being produced from grass is decreasing and grassland is less and less used for dairy production. If technology of production and animal performances continue to progress at current rates, the grassland area needed for dairy farming and intensive grazing will further decrease in the future, unless the demand for dairy and beef products increases significantly (Feehan *et al.,* 2005).
As dairy production is the most profitable way of grassland utilisation, this development will have a strong impact on the maintenance of grassland in the future. Grassland that was

no more used for dairy production during the last years has then, to some extent, been de-intensified and further grazed by suckler cows and beef cattle. However, the market for beef and consequently the potential of grassland based beef cattle farming is limited in Europe. The situation in eastern European countries has demonstrated that some formerly intensively utilised grasslands may be converted into fallow land directly, when dairy and beef production decrease.

With regard to the maintenance and enhancement of grassland biodiversity, the above outlined situation presumably has the following consequences: For grassland that is no longer needed for intensive dairy cow or beef cattle husbandry, intensive management is unlikely to be continued, for economic reasons. Heavy fertilisation and regular sward renovation will be ceased and stocking rates will be low. This management seems to be in accordance with management measures that are generally recommended to enhance biodiversity. However, unimproved species-rich grassland will be increasingly at risk of being abandoned from any agricultural use. Indeed, in the first place, extensive grazing systems will rely on de-intensified grassland which has a history of agricultural improvement and which is therefore superior to unimproved grassland in terms of herbage yield and quality.

For the farmed land as a whole and for grassland in particular, there is an increasing social awareness of the multifunctional character of farming (Jeangros, Thomet, 2004; Lehmann, Hediger, 2004). Grassland provides multiple benefits to farmers and society and among these benefits, biodiversity receives special attention. Agri-environment schemes have been established to accomplish non-market performances of grassland farming. It is estimated that at least 20% of the agriculturally used area in the EU is managed under an agri-environment scheme (Rounsevell *et al.,* 2005); in Switzerland, ca. 100.000 ha (ca. 13% of the total Swiss grassland area, alpine pastures excluded) of meadows and pastures are managed according to ecological compensation area schemes (Walter *et al.,* 2004). Presumably, the importance of agri-environment schemes for the continuation of farming on de-intensified and on unimproved species-rich grasslands will increase in the future (Rounsevell *et al*., 2005) and will therefore be essential to maintain and enhance biodiversity.

Historical background of grassland management and grassland biodiversity

The origin of grassland, its vegetation and plant species composition are closely related to human activities and farming practices that have developed since the Neolithic Age. In the temperate regions of Europe, the distribution of natural grassland was limited to sites where natural forests fail to grow, such as sites above the timberline in mountainous regions, very wet or dry sites in the lowlands, or marshlands close to the sea (Ellenberg, 1996). New studies on the history of grasslands suggest that, apart from these sites, grassland could also develop on fertile sites as a result of megaherbivore grazing (Vera, 2000). Grassland dominated open landscapes could have been created in fluvial plains before man controlled the vegetation through deforestation and introduction of crop and animal husbandry. There is evidence that many of the species-rich grassland communities date back to the bronze and iron ages, when regular pasture management and grazing started to establish (Prins, 1998). Since the Middle Ages, when the human population increased, forests on less fertile sites had also been cleared and replaced by grassland and arable land (Korneck *et al.,* 1998). The large diversity of plant species and communities that is found on semi-natural, unimproved grasslands today, has its origin in the Middle Ages and in the early Modern Era (Speier, 1996; Prins, 1998). It is the result of a broad range of site conditions and traditional extensive management systems (Nösberger, Rodriguez, 1996). Soils were not improved until the first half of the 20th century, the agronomic potential was rather low and grass production was dependent on the natural fertility of sites. Traditional grassland utilisation systems were characterised by a generally low level of nutrient return to the swards and, on grazed grassland, by little adaptation of the stocking rates to the actually available herbage. Communal grazing was a common practice. Swards were underutilised in times of herbage surplus and overgrazed when grass growth was limited. In addition, in the traditionally man-made landscape, sheep, cattle and other livestock were important vectors for plant propagules (Poschlod *et al.,* 1998).

At the beginning of the 20th century, diverse, unimproved semi-natural grasslands covered a large percentage of the agriculturally utilised area throughout Europe. Starting from this time, grasslands were agriculturally improved and the management intensified. On acid soils with a low fertility, the pH values of the soils and the soil nutrient contents were raised by liming and regular fertilisation. On wet soils, artificial drainage was introduced to remove surplus water. This process was accompanied and followed by an increased use of fertiliser nitrogen and higher stocking rates and defoliation frequency. Thus, grasslands with a high species and community diversity were replaced by productive pastures and meadows. The result was a dramatic decrease in biodiversity as the swards of improved grasslands were dominated by few productive forage species with a high competitive strength and less productive species were eliminated. Traditionally managed grasslands lost their function as a feed resource for livestock (Willems, 2001) and were reduced to a low percentage of the agriculturally utilised area (Fuller, 1987; Green, 1990; Poschlod, Schumacher, 1998). The remaining semi-natural grasslands are now highly valued by nature conservationists and, in many countries, their maintenance has received priority in nature conservation activities and in agri-environment schemes (Söderstrom *et al.,* 2001; Dipner, Madel-Kubik, 2004; Jeangros, Thomet, 2004).

Maintaining species-rich grasslands by agricultural management

The maintenance of unimproved semi-natural grasslands requires that grassland management is not intensified (Schellberg *et al.,* 1999), i.e. soils are not ameliorated, no or little fertilisation is applied, and stocking rates are low. However, a regular defoliation of the swards is necessary. It has been frequently suggested that the best way of maintaining semi-natural grasslands would be the maintenance of traditional management measures (Bakker, 1994; Spatz, 1994; Poschlod, Schumacher, 1998; Prins, 1998; Fischer, Wipf, 2002; Muller, 2002). Consequently, management prescriptions laid down in many agri-environment schemes are based on historical ways of agricultural management, such as late cutting, low stocking rates, or reduced fertiliser use. This demonstrates the general problem of integrating semi-natural grasslands into production systems of modern grassland farming. Traditional grassland management systems had been given up during the last century because they no longer met the requirements, of the improved livestock production systems in terms of herbage yield and quality and thus were no longer profitable. Therefore, farmers who continue to manage their grasslands in a traditional extensive way act, in many situations, against economic interests unless they receive subsidies to compensate production losses. The amount of payments necessary to maintain a traditional grassland management depends on the gross margin that can be obtained from agricultural products. The more efficiently a semi-natural grassland is integrated into the production process of the grassland farm, the higher is the economic return by the sale of agricultural products. Thus, the need for subsidies to maintain the nature conservation value of these grasslands would be lower and a larger area could be reached with agri-environment schemes within the limitation of public budgets.

Abandonment of semi-natural grasslands from agricultural use is a major risk for grassland diversity. Many investigations have shown that almost independently of the vegetation type, cessation of grassland management leads to successional change and to a loss of plant species diversity. At a local scale, vegetation succession facilitates the invasion of shrubs, the dominance of tall growing species from later successional stages and the competitive exclusion of species typical for managed grasslands (Krahulec *et al.,* 2001; Moog *et al.,* 2002; Tasser, Tappeiner, 2002; Pykala, 2003; Gaisler *et al.,* 2004; Hejcman *et al.,* 2004; Kahmen, Poschlod, 2004). At the regional scale, succession increases the similarity of different grassland communities and thereby reduces the total species diversity (Dullinger *et al.,* 2003).

Major constraints for a continued agricultural management of semi-natural grasslands are the low herbage yield and quality. In a review on the agronomic potential of semi-natural lowland hay-meadows, Tallowin, Jefferson (1999) showed that the herbage growth rate and harvestable yield of species-rich grasslands were at least 50% lower compared to intensively managed meadows. Similar results were obtained from upland and mountainous grasslands (Peeters, Janssens, 1998; Schmid, Jeangros, 1990). The herbage yield of meadows is an important aspect of profitability. As herbage conservation through silage or hay-making is expensive, a minimum herbage yield per cut should be attained; Spatz (1994) suggested 3 tonnes dry matter per ha. This level is frequently missed by marginal grasslands on acid sandy soils or limestone. The herbage quality is even more important for the potential use of herbage from species-rich grasslands. When the primary growth of a species-rich hay-meadow and that of an agriculturally improved grassland are cut at the same time, the digestibility may be the same (Schellberg *et al*., 1999) or slightly lower on species-rich swards (Tallowin, Jefferson, 1999), obviously depending on the botanical composition. Such comparison is, however, hardly relevant for the farming practice as unimproved swards are less frequently defoliated. Hence, if the late cut primary growth of diverse swards is compared with early cut herbage from improved swards, a large difference between systems is found. This is particularly relevant for many agri-environment schemes where a late first cut is prescribed. Late cut hay from species-rich swards rarely exceeds an organic matter digestibility of 60% (Daccord, 1990; Stoll *et al.,* 2001). Hay or silage of such a low quality cannot be used in intensive livestock systems, i.e. for dairy cows or fattening bulls. It may, however, be fed to dry suckler cows or growing heifers (Spatz, 1994; Stoll *et al.,* 2001).

Grazing is an interesting alternative to cutting in order to maintain species-rich grasslands. Grazing is cheap compared to cutting and forage conservation, it requires less labour input, and the individual performance of the animals is usually higher with grazing compared to barn feeding of conserved late cut herbage. Although some of the traditionally diverse grasslands have developed through long-term hay-cutting and diversity could be best maintained through the continuation of cutting (Spatz, 1994; Fischer, Wipf, 2002; Stammel *et al.,* 2003), there is some evidence that plant species diversity can also be maintained by extensive grazing (Schlapfer *et al.,* 1998; Stammel *et al.,* 2003; Troxler, Chassot, 2004). Plant communities of formerly species-rich grasslands that have been abandoned from agricultural use can be restored by extensive grazing (Pykala, 2003; Hellström *et al.,* 2005). Such grazing creates a mosaic of short and tall grass patches (Bakker *et al.,* 1983). It was shown that in tall grass patches plant species typical for hay-meadows were able to flower and to set seed which is necessary for the persistence of the species in the sward (Correll *et al.,* 2003). In addition, grazing can maintain and increase community diversity at the landscape or regional level (Dullinger *et al.,* 2003). The re-introduction of communal grazing and the establishment of payment schemes that would allow support of the joint utilisation of nature conservation grassland by a group of farmers could be a promising tool for the future management of species-rich grasslands.

Various investigations with grazing sheep and cattle on species-rich, low productive grasslands have shown that the animal performance per unit area is generally low, depending on the fertility of the sites (Jans, Troxler, 1990). However, it also appeared that the individual animal performance is not necessarily lower as compared to intensive grassland, even if the average herbage quality is lower (Troxler, Chassot, 2004). Obviously, grazers can maintain a good individual performance through selective grazing when the herbage on offer exceeds the demand (Pavlu *et al.,* 2001). This is characteristic for extensive grazing.

Management of de-intensified grassland to enhance biodiversity

Since the early nineties of the last century, an increasing percentage of grassland has been abandoned from intensive agricultural use. Management has either been changed to support less intensive livestock production such as suckler cow or sheep farming or the grasslands have no longer been utilised at all. This is particularly obvious in less favoured areas in central and eastern Europe. Due to a history of agricultural improvement, the biodiversity and therewith the nature conservation value of these grasslands are relatively low. However, many investigations have been performed to study the possibilities to increase biodiversity through extensive management. With regard to the profitability of farming on de-intensified grassland the production costs have to be low. Measures to improve the productivity of the swards like fertilisation, herbicide application, or reseeding etc. are usually not employed and area rents are generally low. Grazing rather than cutting and forage conservation is the promising utilisation option. In addition, the individual performance of the livestock gains in importance as compared to the performance per unit area. Thus, the management becomes similar to the situation before the agricultural improvement of the sites during the last century. The conditions for a restoration of species diversity are promising in this respect. This was the starting point for various attempts to develop management systems that meet both agronomic and biodiversity targets. A new challenge in the changing agri-environment is therefore to develop management systems that meet both agronomic and biodiversity targets and that are based on the idea that relatively large grassland areas are to be managed with relatively little stock (Rook *et al.,* 2004b).

Various experiments during the last decade have shown that de-intensification of grassland management does not immediately reverse the process of species loss that occurred during the agricultural improvement of the sites. Species number increases if at all slowly (Jeangros, Bertola, 1997; Bakker, Berendse, 1999; Dyckmans *et al.,* 1999; Jeangros, Thomet, 2004; Marriott *et al.,* 2004). Major constraints to the restoration of plant diversity are a high residual fertility of the soils and a continuing high nutrient availability. On mineral soils, phosphorus availability is obviously a key factor (Janssens *et al.,* 1998; Bakker, Berendse, 1999; Koch, Masé, 2001). Herbage production remains on a relatively high level and the dominating forage species prevent the invasion of lost species and the re-establishment of a diverse vegetation. An important prerequisite for the restoration of diverse swards is the decrease in herbage production (Oomes, 1990; Berendse *et al.,* 1992). Unless drastic techniques of nutrient depletion, such as deturfing of the swards, are employed, the reduction of available phosphorus in the soils and the decrease of herbage production is not readily achieved. Therefore, it has been suggested that new techniques should be explored which support the enhancement of species diversity despite a moderate or high nutrient availability (Critchley *et al.,* 2002).

Similarly important is the availability of propagules of plant species that are not present in the current vegetation (Bakker, Berendse, 1999; van Diggelen, Marrs, 2003). Experiments during recent years have shown that the restoration of diverse grasslands was often not successful even if the productivity of the existing swards had decreased. This was due to a lack of appropriate propagules, either from the soil seed bank or from neighbouring vegetation (Bakker *et al.,* 1996; Bekker *et al.,* 1997; Muller *et al.,* 1998; Coulson *et al.,* 2001). In order to overcome this limitation, the addition of propagules had been suggested (Bakker, Berendse, 1999) and investigated in field experiments (e.g. Hopkins *et al.,* 1999; Jones, Hayes, 1999; Kowarsch *et al.,* 2001; Hofmann, Isselstein, 2004). Propagule additions proved to be successful as long as regeneration niches (Grubb, 1977) were sufficiently provided in the sward (Walker *et al.,* 2004). This is primarily dependent on the botanical composition and the sward structure which in turn are controlled by grassland management. Appropriate grazing systems and cutting dates have to be implemented to provide microsite conditions that facilitate germination and establishment of introduced seeds (Smith *et al.,* 2000; Marriott *et al.,* 2004). Recent research on seedling recruitment in lowland grassland suggests that seedling emergence and seedling survival have different requirements on the microsite conditions. Germination and emergence were enhanced in leniently defoliated swards with a low tiller density or where the sward was partly disturbed by mechanical treatment. Obviously, this provided space for germination and emergence. In contrast to emergence of seeds, their survival was improved by frequent defoliation following emergence. This was due to a reduced competition by the existing vegetation (Hofmann, Isselstein, 2004). A great temporal and spatial heterogeneity of the sward structure with patches of short and tall grasses generally occurs with extensive grazing when the herbage on offer exceeds the demand of the grazing livestock (Correll *et al.,* 2003; Kohler *et al.,* 2004). This is a result of selective grazing due to dietary choices of the grazing animals, of treading, and of the heterogeneous return of nutrients to the swards (Rook *et al.,* 2004a). In addition, grazing has a particular advantage over cutting with regard to biodiversity management: the dispersal of plant species propagules is favoured by grazing livestock (Poschlod *et al.,* 1998). To investigate the potential benefits of extensive grazing for the enhancement of biodiversity, an experiment has been set up in five countries throughout Europe. Biodiversity targeted grassland management with low stocking rates is compared with livestock-production orientated management with moderate stocking rates (Rook *et al.,* 2004b). Preliminary results confirmed other findings that the plant species number does not change rapidly in relation to the grazing treatment (Scimone *et al.,* 2004). However, abundance and diversity of butterflies responded more clearly with higher numbers at the low stocking compared to the higher stocking. The reason is obviously the differences in average sward heights (WallisdeVries *et al.,* 2005).

In agronomic terms, grazing seems to have a clear advantage over cutting in many situations. Late cut hay or silage from de-intensified grassland have frequently been demonstrated to have a poor quality and not to be a suitable forage for livestock with increased energy requirements (e.g. Dyckmans *et al.,* 1999; Isselstein *et al.,* 2001). On extensive pasture, the livestock may achieve an individual performance that is close to intensive systems. However, various authors have shown that the performance per unit area of extensive grazing may decrease to 50 to 70% compared to a moderate or intensive grazing (Hofmann *et al.,* 2001; Fothergill *et al.,* 2001; Pavlu *et al.,* 2001; Barthram *et al.,* 2002; Isselstein *et al.,* 2004). This is an important result for the prospects of integrating extensive grazing into economically viable livestock systems. Assuming the area costs are low, it can be concluded that the individual performance of the livestock is becoming more important and that by this the economic position of extensive grazing compared to intensive grazing is strengthened.

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Biodiversity of grasslands and livestock systems in Europe. Redefining the political issues

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Abstract

Permanent grasslands and rough grazing, which represent the principal source of floristic biodiversity, cover a quarter of European territory and more than half of the agricultural area in many countries. These areas contribute to numerous environmental functions whose floristic richness is only the expression of long adaptation to the diversity of local environments and practices. Paradoxically, this great diversity of grasslands and herbivore farming systems which use them, harms their legibility and is a handicap with regard to support measures from which they ought to benefit since they are producing non-market public goods: preservation of biodiversity, water and air quality, landscapes, etc. … A regrouping of European regions into a few major livestock farming zones presenting common characteristics for the use of soils and the types of grasslands makes it possible to put figures on the present-day importance of grassland and pastoral regions. This zoning also makes it possible to identify the areas of weakness in relation to the CAP, which has been globally unfavourable to them for 40 years, in spite of the strengthening of the second pillar. Important changes in public financial supports would be necessary to modify the erosion of biodiversity in these regions and these livestock farming systems, whose multi-functionality is becoming more and more recognised, but which still do not receive adequate remuneration.

Keywords: biodiversity of grasslands, grasslands and CAP, management of landscapes, livestock farming zones, farming models

Introduction

During the last half century, the biodiversity of grassland was ignored by agronomists and economists, even considered as a handicap for efficient production. Similarly, the diversity of herbivore farming systems was perceived as an obstacle to modernisation and competitiveness compared to pig or crop models. It is only since the early 1990s, in the dynamic of the Rio conference, that these diversities have been recognised more as guarantees of the ability of local agrarian systems to adapt to an economic and social context that is increasingly unpredictable. But this recognition still remains too academic or at least has not enough foothold in agronomists' programmes and in policies.

But grasslands contribute to many environmental functions and are therefore far from being marginal at the European scale. It is even quite central in relation to the new expectations of society. The contribution of grasslands to an "European farming model" that we develop here, is composed of a synthesis between approaches which consider environments and practices that are eminently variable at local level along with stakes that concern Europe as a whole. We will rely on a very synthetic representation of livestock regions for EU 15, showing problems of overall management but which can nevertheless be interpreted at local level. This zoning proposal, which can be enlarged later to the new members, will contribute to a political analysis, emphasising the stakes of maintaining biodiversity via the maintenance of livestock systems and methods that make good use of the whole territory.

Biodiversities of grasslands and livestock farming systems are linked

Permanent grassland and rough grazing areas still largely predominate in the European landscape**.** In 2000, permanent grassland covered one third of the agricultural area (AA) of the EU 15, i.e. 45 m. ha, 15m. ha of which were classified as poor pasture (Vidal, 2001). In addition to that, there are about 10 m. ha of collective grassland outside the AA: high summer pastures and more or less wooded range lands, in particular in mountain or Mediterranean areas.

All of the temporary and legume grasslands less than 5 years old represented 8.5 million ha and forage maize about 3.5 million. So permanent grassland has resisted relatively well to half a century of forage intensification, either because of a lack of any alternative (except forestry), or because livestock farmers have found real advantages in it. These advantages include its low cost and its adaptation to all soils and climate environments, especially the most difficult. This is translated into a growing diversity of flora, especially when it is associated with favourable practices e.g. low fertilisation and its use at the right times, as shown by Table 1 (Thiébaud *et al.*, 2001). It is also apparent that biodiversity is positively correlated with other environmental indicators such as quality and prevention of erosion. It is also necessary to consider the quality of landscapes which are on the whole evolving in the same direction as biodiversity, as well as the typicity and nutritional specificities of animal products coming from these grasslands (Coulon and Priolo, 2002)

Table 1. Interest of the different forage covers and associated practices as regards biodiversity, water quality and erosion (according to Thiébaud *et al.* 2001)

Types of covers and practices	Biological interest		Risk regarding:	
	Number of species	Heritage value	Water quality	Erosion
1. Annual forages / unfavourable practices (maize, excess slurry, herbicides, no inter-crops…)	Low	Low	High	High
2. Annual forages / optimised practices (maize + inter- crops …)	Low	Low	Moderate	Moderate to high
3. Temporary grasslands / unfavourable practices (excessive grazing, turning land over …)	Low	Low	Moderate to high	
4. Temporary grasslands / favourable practices (moderate fertilisation and stocking rate, hay making and grazing …)	Low to medium	Low to medium	Low	Low
5. Long term or permanent grasslands / unfavourable practices (intensive grazing with high level of fertilisation)	Medium	Medium	Moderate	Low
6. Permanent grasslands / favourable practices (low fertilisation and stocking rate, hay making and grazing …)	High	High	Low to very low	Very low
7. Covers with serious ecological constraints / very favourable practices (wet grasslands, rough pasture, dry summer grassland, no fertilisation…)	Variable	Very high	Very low	Very low

On the other hand, from the user animal viewpoint, biodiversity has reduced. For dairy cattle, which represent half of the herbivore LU of the EU of 15, the North American Holstein represents more than 70% of European dairy cows and even 90% in certain countries, despite its genetic potential being seemingly less compatible with grazing. The situation is slightly less critical for beef cattle and sheep breeds, but here too, the larger part of the herd is made up of a few breeds with rapid growth at the expense of many hardier local breeds. But it is the farming system that needs to be preserved and not just one of the parts, grasslands or animals. This preservation of the diversity of livestock farming systems requires their environmental, heritage, social and cultural multi-functionality to be recognised and translated into real financial support for their non commercial public goods contribution. Some regions have understood the importance of these aids for tourist activities and for the whole local economy, in particular when it concerns symbolic farming practices with high summer pastures and pastoral systems of a high ecological value. We should not forget either the more ordinary grassland systems which are still the most numerous but reducing fast, notably in dairy production (Perrot *et al.*, 2004).

A simplified representation of the diversity of livestock farming regions of Europe

To make a "European farming model" credible, it will have to be differentiated from the world market by the establishment of a territorial and social base that is motivating for the citizen and the consumer, at local and regional level. An inter-regional or pan-European dimension will also have to be added, forgetting frontiers, to provide more legibility at European level. So regroupings will have to be made founded on clearly defined criteria of aggregation even if they will have to be capable of evolution in the future.

Given the strong link of herbivore farming to the soil, this zoning gives priority to the soil and climate environment and the land use, firstly, at the level of the major biogeographic zones, then inside these, considering the use of forage areas, which make it possible to characterise regions and herbivore farming systems in relation to the use of the territory (Table 2). A detailed presentation of the criteria and thresholds selected for the typology and zoning have recently been published (Pflimlin *et al.*, 2005).

The three zones with strong soil and climatic constraints (mountain, Mediterranean and grassland) which have the richest grasslands in terms of biodiversity, represent more than half of the AA of the EU 15, 76% of land under permanent grassland, 60% of herbivore farmers, 40% of dairy cows, 64% of suckler cows and 90% of ewes and goats. So they are not marginal areas either for the economy or for land management.

A good superposition can also be observed between the regions with a high percentage of permanent grassland and the less favoured areas (Pflimlin *et al.*, 2005) with two exceptions, the countries of the Arctic zone and the New Länder in Germany.

Consequently, the very great majority of regions grouped in the 3 zones with high constraints of soil and climate have hardly any other choice than to farm with herbivores, as grassland is the only useable resource apart from forestry. Livestock farming also represents one of the pillars of the economy and of local employment, with strong links for the development of tourism (Pflimlin and Todorov, 2003). These three major zones where permanent grassland and herbivore farming play a major role benefit from far fewer aids than the most productive areas, as these aids have historically been attributed to the volume of production and to support prices and markets.

Table 2. Principal technical and environmental characteristics of livestock farming zones

Zones and groups of regions	% AA of Europe	Permanent grassland % AA	Types of dominant livestock farming	Level of inputs / ha	Specific quality of products (PDO[1], mountains …)	Contributions / externalities			
						Environment			Local employ-ment
						Water	Biodiversity	Landscape	
Nordic Zone	4	0	Dairy cows	Medium	/	(+)	(+)	(+)	+
Mediterranean Zone Dry plateaux Irrigated plains and valleys	31	30 + rough grazing low	Suckler cattle and sheep	Very low to nil	High (Esp. It)	++	++++	++	+
			Dairy cows Fattening young steers	High	Cheeses (It)	--	-	-	++
Wet mountain zones	8	75	Milk / cheese cattle	Low	High	++	+++	++++	++
			Suckler cows	Very low	Medium	++	+++	++++	(+)
Grassland zones	16	72	Dairy cattle (Ir. UK)	Medium to high	Rare	+/-	+	++	++
			Sheep and cattle meat	Low to medium	Rare	++	++	++	+
Grass land zones + maize	3	52	Dairy and beef cattle	Medium to high	Rare	-	+	+	++
Zones of forage crops	5	25	Dairy and beef cattle Pigs	High	Rare	---	+/-	+/-	++
Zones of crops + livestock farms	20	23	Crops and milk	Medium to high	Rare	--	+/-	+/-	+
Zones of crops	12	7	Marginal livestock farming	High	/	---	-	-	-

Data sources: Eurostat FSS 2000. Adapted by the French Livestock Institute 2005; +, ++, +++: positive externalities; -, --, ---: negative externalities

[1] PDO – Protected Designation of Origin

A different CAP to preserve the diversity of livestock farming systems and territories

Since it was created more than 40 years ago, the CAP has contributed to the marginalisation of grassland in European agriculture by placing the priority on the development, then the control of basic product (commodities) markets, such as cereals, milk and beef. By "supporting" a price reduction compatible with the modernisation of agriculture, the heart of the "European farming model" was clearly the "high productive holding" capable of eventually adapting to a world market that is increasingly impossible to avoid.

In this system, taking into account holdings that can be qualified as "less productive", comes within a logic of compensation (cf. the compensatory allowances for natural handicaps) or support (support measures of the CAP of 1992) which was to become the second pillar 10 years later. From this point of view, the reform of 2003, in spite of the significant changes it introduces – decoupling in particular – prolongs the great logics of the past: the most productive holdings still receive the most aid and the structural adaptation to lowered prices remains the main option. Similarly, the pursuit of lower cereal prices is translated by a distortion of competition that is unfavourable to grass-fed milk or meat production, and therefore unfavourable to grasslands.

Grasslands are central to the societal challenges of European agriculture. They do not consume fossil fuels and they store carbon. They are beneficial for the environment, for the quality of water in particular and for the protection of soils against erosion. They are symbolic for biodiversity and landscapes. They also contribute to the maintenance of local employment in less favoured areas and minimise economic risks by limiting inputs and investments. All this favours a change in policy which prioritises the preservation of the diversity of livestock farming systems. This new farming model calls for vigorous reform in the political intervention method at the following levels:

- At European level, the internal market has to be favoured by adjusting our milk and meat productions to our internal market. This is already the case for beef and sheep meat production where there are even fears of a growing deficit in the future. For dairy production, the surplus has been reduced to 10% and this policy of reduction in supply should be continued via the maintenance of milk quotas, and their link with the soil or at least with the regions. What is more, European animal productions are subject to a very strict regulatory framework which ought to serve as a protection against non-guaranteed imports from the world market. Finally, does anyone need reminding that animal productions repeatedly undergo health or sanitary crises (BSE, foot and mouth disease, swine fever, avian influenza…) that deeply disturb the world market, and which cannot therefore guarantee our supplies? Consequently, market supports must be looked at again in a totally different way, concentrating on a quantitative control of productions, adapting supply to demand (*via* quotas) and on an environmental and territorial coupling, guaranteeing a balanced contribution from each agrarian zone to the European market.
- At regional and local levels: in the present budgetary framework, the second pillar runs a high risk of obtaining only a few additional means, as part of this money has already been used to respond to environmental conditionality, in particular for storing liquid manure, in the majority of EU countries. The Compensatory Allowances for Natural Handicaps are generally low compared with CAP premiums and very variable from one country to another, in particular in the Mediterranean countries where grasslands that are the richest in biodiversity, but also the most fragile (fires and land abandonment), are to be found. On the other hand, taking charge of the different aspects

of the environment, better integration into the functioning of holdings, or favouring the installation of young farmers on grassland systems could be elements of a more ambitious territorial policy, considering grasslands at the heart of the projects. This point would call for an opening up of agricultural development to environmental and territorial players in the definition of the objectives and steering of measures.

Conclusions

These proposals are an invitation to go beyond the present opposition between "the old" and the "new" CAP of 2003, both of them unsatisfactory as to the place they give to grasslands. The new obligation to maintain surfaces in grass runs a real risk of being felt more as a conservative, old fashioned approach rather than as a real measure of support to grasslands. The biodiversity of grasslands risks regressing even more quickly because of the liberalisation of the market bringing more restructuring and concentration of productions rather than of virtuous diversification. In the sector of herbivore farming, there is a danger not only of an accelerating fall in the number of farmers and grazing animals, but also of a very unfavourable spatial distribution.

So a counter-proposal must be put forward to avoid a particularly catastrophic scenario: the end of community regulations and the rule of "international competition"; a scenario in which the grasslands and farming systems of high heritage value would occupy only a very marginal place. This project may appear Utopian, just after the last CAP reform! On the contrary, it seems to us to be particularly beneficial for the future, as shown by researches in ecology that are rediscovering a multitude of functions and benefits associated with diversity of flora. On condition that it is better integrated and used by multifunctional and sustainable livestock farming systems, spread over the whole territory and in particular in what are currently considered as the less favoured areas.

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Effects of livestock breed and stocking rate on sustainable grazing systems: butterfly diversity and abundance*

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Abstract

Finding an optimal balance between livestock production and the impact of grazing on animal biodiversity is an important issue in the development of sustainable grazing systems. Butterflies are suitable indicators of grazing impact. Here, we consider the results of similarly designed grazing experiments, carried out over three years in the United Kingdom, France, Germany and Italy. All sites involved a comparison of three treatments, replicated threefold in a randomized block design: 1) a moderate stocking rate with a commercial breed, 2) a low stocking rate with a commercial breed and 3) a low stocking rate with a traditional breed. Butterfly species richness and abundance were assessed by bi-weekly transect counts.

Although countries differed in species composition and butterfly numbers, the effect of the various treatments showed a consistent pattern across countries. Species richness and abundance of butterflies were enhanced by the low stocking rate compared to the moderate stocking rate, but no clear difference between breeds emerged. Both butterfly species preferring short grasslands and those preferring tall grasslands benefited from the lower stocking rate. This project showed that butterfly diversity on grasslands increased within three years by reducing stocking rates.

Keywords: biodiversity, butterflies, grazing, stocking rate, livestock breed

Introduction

Grazing herbivores have the potential to impose a dramatic influence on the structure and composition of plant and animal communities. Butterflies appear to be suitable indicators of grazing impact (Bailey *et al.*, 1998). Unfortunately, in determining grazing impact, research mostly focuses on the comparison of grazed and ungrazed areas, whereas a comparison of different stocking rates would be more meaningful. Moreover, differences between livestock species and breeds have rarely been considered (Rook *et al.*, 2004a).

This paper reports results from an EU Framework 5 project (QLK5-2001-00130 FORBIOBEN) that is based on an integrated experimental programme at several sites across western Europe, examining the effects of management intensity (stocking rate) and breed of grazing animal on natural and semi-natural grassland systems. Main treatment effects on biodiversity are only expected for species that strongly respond to changes in the structure of the vegetation. Breed effects, if any, are expected to develop more slowly. Results on animal biodiversity over the first year already indicated substantial effects of stocking rate on butterfly abundance and species richness (WallisDeVries *et al.*, 2004). Here, we present the results for butterflies over the entire, three-year experimental period.

Materials and Methods

Treatment lay-out has been described by Rook *et al.* (2004b; see also the project website http://www.iger.bbsrc.ac.uk/Forbioben/index.html). The same experimental set-up was used in 4 countries: Devon lowland in the United Kingdom, Solling Uplands in Germany, Auvergne uplands, Pordenone foothills in Italy; a fifth site was located in Galician uplands in Spain, but this site is not considered here, as it had a different experimental set-up. Cattle were used in the British, German and French sites, and sheep were used in the Italian site. Three treatments were investigated in each country: moderate stocking rate with a commercial breed (MC), low stocking rate with a commercial breed (LC) and low stocking rate with a traditional breed (LT). Each treatment was replicated threefold according to a randomized block design in paddocks of 1–6 ha in size. At each site and in each paddock butterfly species and numbers were recorded in 10 bi-weekly counts between April and October from 2002 till 2004, along three transects of 50 m in length and 5 m width.

Data analysis focused on treatment effects on individual abundance and species diversity. Diversity was assessed as the number of species (species richness) and as Pielou's specific evenness, a measure of the distribution of individuals over the different species. Results within plots were pooled over transects for each year prior to analysis. Log-transformation was applied to abundance data. Besides treatments, the ANOVA included a fixed factor country, a random block factor nested within countries, a year factor, and three two-way interactions between countries, treatments and years; the contribution of the three-way interaction was explored but proved insignificant and was therefore omitted from the final model.

Results

In total, 6183 butterflies from 66 species were observed, including, in France, 7 individuals of *Maculinea arion*, a species listed in Annex IV of the Habitats Directive. The most species occurred at the Italian site (46), followed by France (34) and the rather species-poor sites in Germany (23) and the United Kingdom (17).

Table 1. Overall effects of grazing treatments on butterfly abundance and species diversity averaged over 4 different countries (different superscripts indicate significant differences between treatments at $P < 0.05$ or at $0.05 < P < 0.10$ between brackets, Tukey's HSD). For abbreviations see text

Treatment	Abundance of individuals	Species richness	Pielou's specific evenness
LT	46.8^{a}	8.6^{a}	$0.69^{(a)}$
LC	41.7^{ab}	8.1^{a}	$0.69^{(a)}$
MC	30.9^{b}	6.5^{b}	$0.75^{(b)}$
P	0.0073	0.0055	0.0451

Butterfly abundance and species richness were significantly different between treatments (Table 1), with higher values at low than at moderate stocking rate. The positive effect of reducing stocking rate on abundance was apparent for species characteristic of tall vegetation ($P < 0.01$) as well as for species from short grasslands ($P < 0.01$; present in France and Italy only). Although, abundance and species richness were slightly higher on average under low grazing with traditional breeds than under low grazing with commercial breeds, this difference was never significant. The main effect was clearly due to the difference in stocking rate. The treatment effects did not change significantly after the first year (Figure 1). Two-way interactions in the model were generally not significant, with the exception of country x year interactions, showing different effects of certain years in the various countries. Treatment effects were thus consistent across countries, despite a wide variation in community structure and composition between countries.

Pielou's specific evenness was also significantly different between treatments, but only marginally (Table 1). Evenness was highest at moderate stocking rate, indicating a similar abundance of individuals across the smaller number of species. In contrast, individual abundance was less evenly distributed over the larger number of species at low stocking rates.

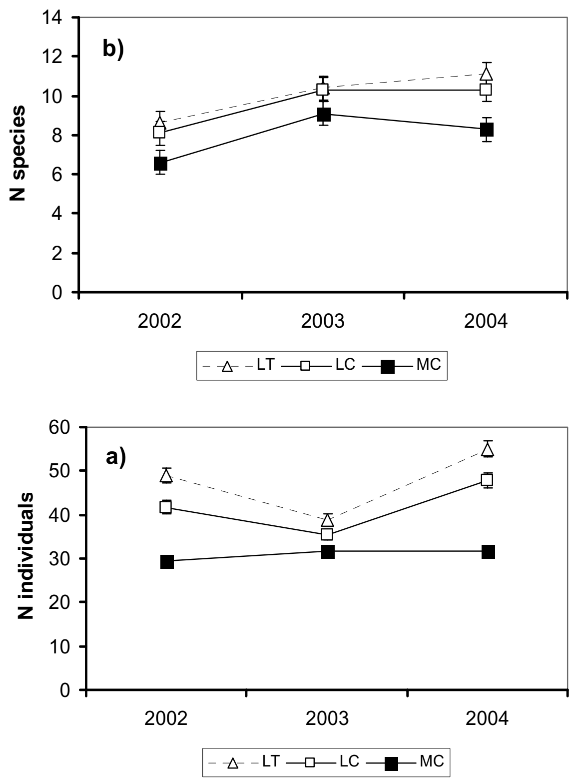

Figure 1. Development of butterfly abundance (a) and species richness (b) under three different grazing treatments (data represent paddock totals from 3 transects averaged over 4 countries, ± s.e.). For abbreviations see text

Discussion

The grazing treatments in the four different countries revealed a consistent effect of stocking rate on butterflies. Low grazing intensity increased butterfly numbers and species richness, resulting in an uneven abundance of individuals for a greater number of species. Interestingly, the positive impact of low grazing intensity was not only apparent for species from tall vegetation, but also for those of short vegetation, despite a greater availability of short vegetation under moderate grazing. Further study may indicate whether this effect can be explained by a lesser disturbance, increased nectar availability or a greater heterogeneity in vegetation structure. It is nevertheless evident that some level of grazing (or mowing) is ultimately required to maintain especially the species dependent on short vegetation.

Breed effects were not significant. Although there was some variation between the two low stocking treatments with respect to butterfly abundance, this was small compared to the difference with moderate stocking and not significant. This variation was not apparent in species richness or in Pielou's evenness.

The treatment effects did not increase over the three years of the experiment. As pointed out by WallisDeVries *et al.* (2004), this indicates that grazing may already have a great impact on the short term, through the alteration of vegetation structure. The absence of further change may partly be due to the spring and summer drought in 2003, when grazing had to be stopped for part of the season. Also, the small size of the paddocks (1–6 ha) may have masked some effects due to the movement of butterflies between fields. However, three years is still a very short period to evaluate the temporal effect of grazing.

Conclusions

The earlier reported short-term positive effect of low stocking rates on butterfly abundance and species richness has been sustained over three years. This effect probably reflects the impact of grazing on vegetation structure and it has been markedly consistent across countries. The two main messages from these results are that the effects of breeds are negligible or, at most, modest and that lenient grazing is preferable from the viewpoint of butterfly diversity. A continuation and a scaling up of the experiment is necessary, however, to be able to evaluate the effects of grazing intensity over a longer period and at the farm scale relevant to sustainable land-use practices.

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Economically sustainable Swedish beef production by large-scale ranching and extensive pasture-mosaics

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Abstract

There is major risk that decoupling of EU income support for beef cattle will result in reduced beef production and a shortage of livestock for preservation of biodiversity in Swedish semi-natural pastures. Small, inefficient herds, high costs of grazing small, scattered pastures and expensive indoor wintering of beef cattle are important factors. However, decoupling of income support also for grain production and a conceivable abolition of the strict demand for replanting after clear cutting may create economic possibilities to re-establish large pasture-mosaics consisting of the present semi-natural pastures and arable land, and former pastures, which were afforested during the last century. Canadian experience and Swedish cost estimates suggest that large-scale beef production with outdoor wintering and grazing in such large pastures is economically sustainable even after decoupling. The risk of extinction of grassland species due to habitat isolation is lower in such mosaics than in small-scale pastures.

Keywords: Beef, economic sustainability, pasture-mosaics, biodiversity.

Introduction

In the 1920s, there were more than one million ha of semi-natural pasture in Sweden together with large areas of grazed forests. Now there are less than half a million ha of, mostly small and fragmented, semi-natural pastures and forest grazing has almost disappeared (Statistics Sweden 1930 and 2003). Most of the former pastures and grazed forests have become high-density spruce forests.

Now there is a national goal to continue grazing on all remaining semi-natural pastures. Environmental allowances and income support per head of beef cattle and sheep have contributed to continued and in some cases increased grazing. However, despite allowances and income support, grazing the remaining semi-natural pastures has generally been unprofitable because of small-scale livestock production and expensive housing for wintering the livestock (Swedish University of Agricultural Sciences, 2004).

The remaining pastures are managed to a large extent by farmers who accept low compensation for their labour and capital. Interviews with a sample of farmers managing especially biologically valuable semi-natural pastures indicate that there is a major risk that about one third of these pastures will not be grazed by 2010. These areas will lose much of their biodiversity. The risk of ceased grazing is especially high in forest-dominated regions with small, scattered pastures, declining milk production and small beef herds (Kumm, 2003).

Increasing number of suckler cows is critically important for the future management of pastures due to the continuing decrease in dairy cows and, thus, calves from the dairy herd. In order to reach future goals for biodiversity and an open, variable landscape, there must be a 70% increase in the number of suckler cows by 2021 (Swedish Environmental Protection Agency, 1997). Now there is a major risk that the decoupling of EU income support, starting 2005, will result in a reduced number of suckler cows and increased shortage of livestock for preservation of biodiversity.

Canadian experience

Economically sustainable Swedish beef production and, thus, grazing-based nature management, require one or more of the following alternatives: Sharply increased willingness to pay more for Swedish beef, greatly increased environmental allowances, farmers willing to accept negligible remuneration for their labour, or drastically reduced cost of production (Swedish Environmental Protection Agency, 1997). In this paper the last alternative is investigated by reporting Canadian experience and analysing to what extent this experience is applicable to Sweden.

Peace River Region (PRR) in British Columbia has similar natural conditions to Central Swedish Flatlands (CSF) but no environmental allowances or income support. The dominating land use on farms in PRR is grasslands for extensive beef production. In contrast, grain and forest dominate land use on farms in CSF.

Table 1. Hectares of different land use and number of suckler cows per 100 ha of land on farms in Central Swedish Flatlands (CSF) and Peace River Region (PRR) in 2001

	CSF	PRR
Semi-natural pastures	5	34
Seeded pasture and ley	11	26
Annual crops and fallow	35	20
Forest and other land	49	20
Suckler cows	2	8

Sources: Statistic Sweden, 2002; Province of British Columbia, 2002

Important explanations for the large share of grassland and many beef cattle in PRR are that there is no income support for grain production and thus a low opportunity cost of land, large herds, and cheap outdoor wintering of cattle. Since settlement started in PRR in the beginning of the 20th century, huge areas of forest have been cleared for beef production and this is still going on (Kumm, 2005).

Swedish traditions

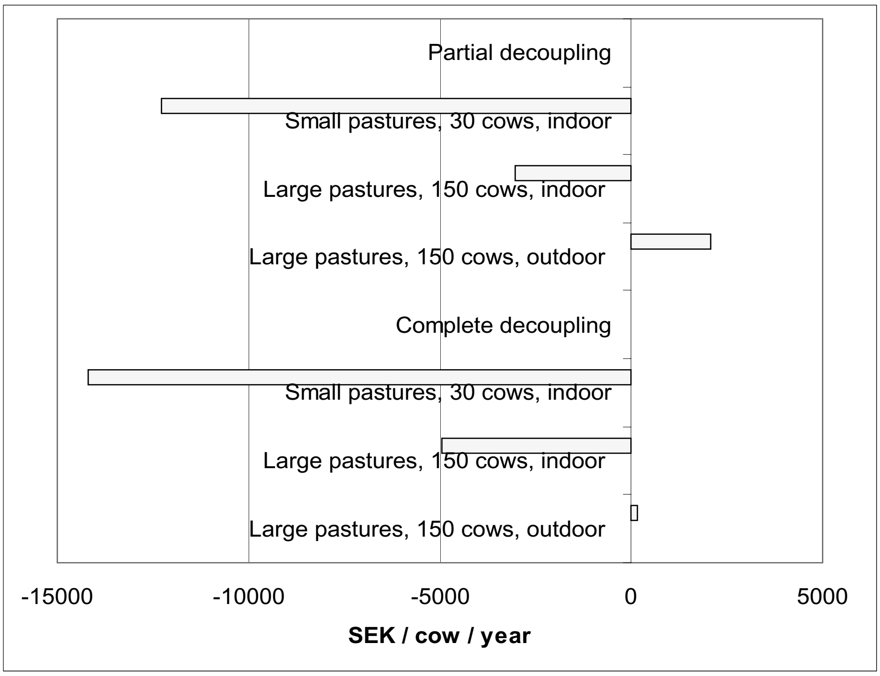
In contrast to North America, suckler cow based beef production in Sweden has developed substantially only during the last few decades within a tradition of small-scale dairy production including indoor wintering of cattle. High price of agricultural products and income support have made high cost production economically possible and opportunity cost of arable land high (Kumm, 2005).

Until 2004, there has been high income support for grain production. From 2005 the support is decoupled from production. This decreases the contribution to land of grains and other annual crops, and thus opportunity cost of land, to zero on large areas of arable land (Swedish University of Agricultural Sciences, 2004; 2005). Continued grain production is especially doubtful on small fields with irregular shapes where the cost of labour and machinery for tilling and harvesting is particularly high. Many such fields are surrounded by semi-natural pastures or forest. Traditionally, they have been afforested.

The Swedish forest industry developed early and its long-term timber provision has had, and still has, high priority. Swedish forestry legislation strictly requires reforestation after clear felling despite the fact that the net present value of reforestation will be negligible or even negative on normal site productivity classes at interest rates commonly found in other industries, if the real price for standing timber does not increase during the rotation (Kumm, 2004).

Swedish cost estimates

Figure 1 shows income less total long-term costs in suckler cow based beef production at present (2005), partial income support decoupling, and complete decoupling of all income support. The opportunity cost of all land is assumed to be zero and the environmental allowance for semi-natural pasture is assumed to be obtained for the whole grazed area. Long-term costs include e.g. hourly farm-worker wage, bank rate of interest including risk premium, and depreciation of buildings and machinery.



Sources: Calculations based on Johnsson & Kumm (2004). Yardage cost for outdoor wintering is supposed to be 2 SEK per day and head of cattle (Keay, 1998).

Figure 1. Income less total long-term costs per suckler cow including her offspring (0.20 replacement heifer, 0.47 steer slaughtered at 2 years, and 0.27 heifer calf slaughtered at 0,5 year) at partial and complete decoupling of income support. Small pastures are 200*100 m and large 800*600 m. Indoor wintering in deep pack barn and outdoor wintering in feedlot. SEK per cow and year. (1 SEK= 0.11 €)

Discussion

Cost estimates suggest that Swedish beef production and grazing-dependent nature management can become economically sustainable by making cheap outdoor wintering of cattle and re-creation of extensive pasture-mosaics possible. Experience from a Canadian region with similar natural conditions as Sweden, but different history, suggests that the main obstacle to economically sustainable Swedish beef production is not unfavourable natural conditions, such as short grazing season, but history and traditions including agricultural and forestry policy and application of parts of the animal welfare legislation.

Extensive pasture-mosaics also have conservation advantages. They are more like the 19th century pre-industrial landscape than the present landscape dominated by dense spruce forests, large rectangular arable fields and small scattered semi-natural pastures. The 20th century reduction of semi-natural grasslands resulted in broken connectivity between grasslands. This transition has increased the risk for local extinction of grassland species due to area-dependent reduction of population sizes and decreased rate of colonization due to habitat isolation Kumm (2004).

The suggested pasture-mosaics will embrace only a very small part of Sweden's total forest area and is not a return to the traditional uncontrolled grazing of most forests that caused severe damage up until the early 20^{th} century.

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Impact of grazing regime on legume-based swards for low-input farming

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Abstract

Organic grassland farming and sustainable agricultural systems need swards able to produce more or less stable yield within seasons and over several years. Different swards composed of selected components from *Trifolium repens* L., *Medicago sativa* L., *Lolium perenne* L. and *Poa pratensis* L. were investigated during 1999–2004 on a loamy *Cambisol* under low-input farming. All swards were grazed using two more and less intensive regimes. The species composition of the sward and grazing frequency had a significant effect on sward yield and quality. The yield of legumes in mixed swards accounted for nearly half of the total sward yield, and in the swards with lucerne even more than half. Legume yield declined annually in both grazing frequencies but to a greater extent under frequent grazing. Lucerne/grass and white clover/lucerne/grass swards showed the highest stability during each grazing season over four years under both grazing frequencies. Dry matter yield was more stable under the less frequent grazing treatment, but more equal distribution of yield during the grazing season was observed in the frequent grazing management. The positive impact of five years less frequent grazing on lucerne-based swards was significant in the 6th year with identical grazing in all treatments.

Keywords: grazing frequency, lucerne, white clover, sward yield, quality, legume, swards

Introduction

The productivity of many types of grasslands has increased during the last decades, however, it has simultaneously resulted in a negative effect on biodiversity and environmental aspects. Forage legumes have been suggested as important components of low input, sustainable systems for livestock production (Jarvis *et al.*, 1996) and are the basis of organic agriculture as environmentally benign (Younie, 2000). Otherwise, legumes can also have negative aspects on the farming systems, such as N loss to the environment (Elgersma, 1998; Younie, 2000).
The grazing regime will affect species differentially through a variety of mechanisms such as direct damage by biomass removal, ability of plants to avoid or tolerate this, alteration of competitive interactions and many others factors (Tonkunas and Kadziulis, 1977; Bullock and Marriott, 2000). Grazing frequency is also one of the important elements which should be optimal simultaneously for the interception of light, harvesting efficiency and selection ability of the animals (ʻt Mannetje, 2000). It affects the persistence of species, productivity and quality of swards, and therefore the best sward composition, increasing biodiversity and avoidance of negative environmental aspects are still relevant objectives in grassland management. White clover is a common component in grazed grasslands. Lucerne is primarily used for cutting, but this productive, high-quality perennial legume could possibly also be a good basis for grazing mixtures.
The objectives of our research were to assess the ability of legume-based swards to produce more or less stable yield over several years without application of nitrogen fertilizers, and to determine the effects of frequent and less frequent grazing on their productivity, persistence and quality. A key objective was to assess the performance of lucerne compared with white clover/grass and grass swards.

Materials and Methods

During 1998–2004 a bi-factorial field trial of pasture utilization was carried out on a loamy *Endocalcari-Epihypogleyic Cambisol* near Dotnuva, Lithuania (55°24'N, average annual rainfall 555 mm, average annual temperature 6° C, average length of growing season 194 days). The pastures were re-established in the spring of 1998 with an oat/vetch cover crop for green forage. The treatments of the A factor involved different swards consisting of white clover (*Trifolium repens* L.), lucerne (*Medicago sativa* L.), perennial ryegrass (*Lolium perenne* L.), and meadow grass (*Poa pratensis* L.) Lithuanian varieties. The treatments of the B factor involved frequent (F) and less frequent (LF) grazing with 6 and 5 grazings per season, respectively. In 2004 the swards in all treatments were grazed 4 times. The grazing season started at the beginning of May and lasted until the middle of October. Swards were grazed with dairy cows. Before grazing the dry matter (DM) yield was estimated in four replicates. Crude protein (CP) was calculated according to the nitrogen concentration (determined by Kjeldhal method), and multiplying it by 6.25. The yield data were statistically processed using analysis of variance.

Results

The different swards and grazing frequencies substantially differed in DM yield in different years (Table 1). The highest yields of 6.50 and 7.55 t DM ha^{-1} were obtained for both lucerne/grass sward grazing frequencies in the first year, where the less frequent grazing had significantly higher DM yield. The other swards were lower in DM yield and differed significantly with the exception of grass sward fertilized N_{240} under less frequent grazing. DM yield decreased from the first to the fourth year under both grazing frequencies, however, the yield of all swards in less frequent grazing declined more slowly than in frequent grazing. Lucerne/grass and white clover/lucerne/grass swards produced more stable yields over all four years under both grazing frequencies, and over five years under less frequent grazing. The comparison between lucerne/grass swards and clover/lucerne/grass swards showed higher DM yields for lucerne/grass swards, the yields of which started to increase from the fifth year, and in the sixth year were nearly the same as in the first year of sward use.

Legumes accounted for almost half of the total DM yield of swards in the first year in both grazing frequencies, while in lucerne-based swards even more than half (Table 2). In subsequent years the yield obtained from legumes was lower in both grazing frequencies and decreased more under frequent grazing. The use of lucerne resulted in a great increase in the sward productivity, and the use of less frequent grazing gave the best results in this experiment. Even under frequent grazing lucerne produced a higher yield than white clover/lucerne in the fourth and fifth years.

The yield of metabolizable energy varied nearly in the same way as DM yield, depending on the grazing frequency and the sward composition (Table 3). The highest efficiency was obtained in lucerne-based swards. All swards produced protein-rich forage. The crude protein concentration varied between 173-233 g DM kg^{-1} under frequent grazing and between 152–207 g DM kg^{-1} under less frequent grazing regime.

Table 1. Total annual DM yield of different swards under frequent (F) and less frequent (LF) grazing

Swards	Dry matter t ha^{-1}											
	1999		2000		2001		2002		2003		2004[a]	
	F	LF	F	LF	F	LF	F	LF	F	LF	F[a]	LF[a]
Trifolium repens/ Lolium perenne	5.61	6.12	3.47	5.49	3.05	5.02	1.42	2.58	1.98	2.69	5.53	5.26
T. repens/L. perenne/ Poa pratensis	5.62	6.56	3.39	5.36	3.21	5.16	1.08	2.47	1.64	2.20	5.22	4.73
Medicago sativa/ L. perenne/ P. pratensis	6.50	7.55	6.32	8.87	4.44	7.19	2.30	3.04	3.97	5.59	7.21	8.63
T. repens/M. sativa/ L. perenne	5.96	6.96	4.91	8.11	3.99	6.56	1.62	3.02	3.14	4.76	6.66	7.04
L. perenne/N_0	2.62	3.23	2.68	4.45	3.14	4.73	0.89	3.12	1.77	2.31	4.86	4.38
L. perenne/N_{240}	5.74	7.54	4.39	7.10	3.18	4.51	1.53	3.04	4.04	4.20	7.64	7.72
$LSD_{.05}$ (A / B factor)	0.303/0.124		0.300/0.122		0.243/0.099		0.320/0.130		0.257/0.105		0.327/0.133	

[a] In the year 2004 4 grazings were used for both treatments of B factor.

Table 2. Share of legumes in the total annual DM yield of swards

Swards	Grazing frequency[a]	DM t ha^{-1}						
		1999	2000	2001	2002	2003	mean	2004[a]
Trifolium repens/	F	2.96	0.71	1.27	0.36	0.27	1.11	3.01
Lolium perenne	LF	2.99	0.84	1.76	0.57	0.19	1.27	2.40
T. repens/ L. perenne/	F	3.11	0.66	1.47	0.29	0.29	1.16	2.70
Poa pratensis	LF	3.48	1.10	2.13	0.74	0.19	1.53	2.00
Medicago sativa/	F	4.46	4.56	2.28	1.31	2.69	3.06	4.86
L. perenne/P. prat.	LF	5.25	5.92	4.69	1.58	4.04	4.30	6.56
T. repens/M. sativa/	F	3.64	2.26	2.03	0.82	1.74	2.10	4.56
L. perenne	LF	4.04	2.71	3.58	1.63	3.04	3.00	4.32
L. perenne/N_0	F	0.22	0.63	0.93	0.08	0.17	0.41	2.39
	LF	0.14	0.53	1.34	0.14	0.09	0.45	2.22
L. perenne/N_{240}	F	0.07	0.04	0.23	0.13	0.14	0.12	0.65
	LF	0.04	0.03	0.13	0.18	0.10	0.10	0.31
	LF	2.40	1.08	1.,87	0.50	0.17	1.20	2.21
$LSD_{.05}$ A factor / B factor		0.151/ 0.062	0.108/ 0.044	0.106/ 0.043	0.115/ 0.047	0.144/ 0.059	0.103/ 0.023	0,169/ 0,069

[a] In the year 2004 4 grazings were used for both treatments of B factor.

Table 3. Yield of metabolizable energy over five years of pasture use

Swards	Grazing frequency[a]	GJ ha^{-1}					
		1999	2000	2001	2002	2003	mean
Trifolium repens/	F	60.73	36.41	35.20	15.75	18.16	33.25
Lolium perenne	LF	63.98	54.89	53.67	27.00	24.86	44.88
T. repens/*L. perenne*/	F	61.04	35.93	35.86	11.59	16.57	32.20
Poa pratensis	LF	69.45	53.70	55.31	26.15	20.56	45.03
Medicago sativa/	F	73.18	71.99	50.08	24.76	31.89	50.38
L. perenne/	LF	83.79	96.28	77.71	31.20	43.25	66.45
P. pratensis	F	65.22	52.87	45.10	17.56	25.76	41.30
T. repens/M. sativa/ L. perenne	LF	74.60	84.32	71.75	32.32	36.23	59.84
L. perenne/N_0	F	24.92	27.53	34.47	8.98	18.57	22.89
	LF	30.27	43.43	49.55	31.12	23.05	35.48
L. perenne/N_{240}	F	59.56	48.03	37.62	17.38	41.11	40.74
	LF	77.17	72.14	50.34	33.82	42.55	55.20
$LSD_{.05}$ A factor / B factor		4.409/ 1.688	3.151/ 1.286	2.651/ 1.082	3.366/ 1.374	2.299/ 0.939	1.456/ 0.581

Discussion

The sward composition and grazing frequency had a significant effect on DM yield and quality. High and stable yields in 3–4 grazings season^{-1} regime have been obtained in Dotnuva in lucerne variety trials (Gutauskas and Petraityte, 2002). Previous research revealed a marked reduction in lucerne under more intensive utilisation (Putvinskis, 1992). In the current experiment, lucerne persisted well in the white clover/lucerne/grass swards in all years even under frequent grazing, and white clover did not have any influence on DM yield of those swards as had been expected. Lucerne-based swards significantly outyielded the grass sward receiving nitrogen. The presented results are in line with the findings of Elsaesser (2004) suggesting that the use of legumes resulted in a great increase in productivity relative to grass alone because of the much higher N flux, but there exist significant differences between white clover and lucerne. The DM of legumes varied between sward type and grazing frequency. A higher legume yield was observed for the swards of lucerne/grass and white clover/lucerne/grass. The content of white clover decreased more rapidly than the content of lucerne. The less frequent grazing treatment had a negative effect on white clover, but a positive effect on lucerne content in the swards. We expected that white clover would substitute for the declining share of lucerne in the white clover/lucerne/grass sward by the third year of use. This assumption did not prove to be valid, as white clover competed poorly in that sward. In the fourth, very dry year lucerne competed well compared with white clover even under frequent grazing. Some researchers have remarked that complex forage mixtures were more productive than simple grass-legume mixtures during drought and also reduced weed ingress. Increasing plant species diversity in pastures may be a simple way to increase forage productivity, stability, and reduced weed competition (Laidna, 2003; Sanderson *et al.*, 2004; Taube, 2004).

Conclusions

The lucerne-based swards were more productive than grass swards, with and without nitrogen application, and white clover/grass swards. Higher DM yields of lucerne-based swards were obtained under less frequent grazing. The research data revealed the advantage of lucerne in swards under both grazing frequencies compared with grass or white clover/grass swards. Lucerne/grass or lucerne/white clover/grass swards on suitable soils provide a good basis for low-input pastures.

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Useful species as quality factors of meadow vegetation on Stara Planina Mountain

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Abstract

Meadows and pastures are significant natural source of animal feed and recently their importance is increasing because of the growing trend in the World regarding production of safe food. Therefore, the quality of the biomass obtained from grasslands with high quality plant species, and the possibilities for increasing their proportion in natural grasslands is extremely important. Investigations were carried out on Stara Planina Mountain of 700–800 m a.s.l. Two main plant associations wereas identified: the *Agrostietum vulgaris* with a total of 47 plant species and *Festucetum vallesiacae* with 77 plant species. High quality plant species present in these grasslands were classified into three categories: high quality grasses, high quality leguminous plants and useful or conditionally useful plant species belonging to other plant families. The association *Agrostietum vulgaris* had 11 useful grasses or 23.4%, 15 useful leguminous plants or 32% and 3 or 6.4% of useful and conditionally useful plants. The association *Festucetum vallesiacae* had 11 high quality grass species or 14.28%, 20 species of high quality leguminous plants or 26% and other useful and conditionally useful plants 11 or 14.28%.

Keywords: meadows, plant association, high quality plant species

Introduction

General characteristics of grasslands in Serbia are insufficient production and unsatisfactory quality. On areas that are not improved, weeds make over half of the plant production. Natural grasslands and pastures of Serbia occupy approximately 30% of agricultural surface. The majority of natural grasslands is located in hilly-mountainous region, and very few in low land region. Livestock production greatly depends on the level of production on grasslands. Stara Planina Mountain, according to geographical, climatic orrographic and other characteristics, represents typical Serbian hilly-mountainous region with livestock production as predominant economical branch. However, on grasslands and pastures, over longer period of time, tendency of abandoning of agricultural areas is evident, the number of livestock is decreasing and people are leaving their villages. Therefore, agriculture in hilly-mountainous region has almost ceased to exist. In order to revitalize these regions it is necessary to systematically investigate meadows and pastures as prerequisite for introduction of new systems of management and market determination in livestock. As stated by Klapp (1986), from the thirdies of the previous century until today, only species from the family of grasses (P*oaceae*) and legumes (F*abaceae*) were considered as useful and desired, and other plants were considered worthless and harmful. Basic criteria for evaluation if certain plant on meadow is weed or not – if livestock consume it or not, what is its nutritive value and digestibility, whether it is poisonous and in what degree, also if it's morphological structure makes it adequate for consumption by domestic animals. In investigations by Tomić *et al*. (2003) on 12 locations on Stara Planina Mountain it was established that share of leguminous plants varied from 0–50%. Objective of these investigations was to determine categories of quality plant species present on grasslands on Stara Planina Mountain on 700–800 m above sea level in determined dominant associations from three locations *Agrostietum vulgareae* with total of 47 plant species and four locations of association *Festucetum vallesiaceae* with 77 plant species. These species were divided in sub-categories: quality grasses, quality legumes and useful and conditionally useful plant species.

Materials and Methods

At the end of June the yield of grassland on Stara Planina Mountain was determined, 650–850 m above sea level, on seven locations four samples from each location. From area of 1 m^2 in two repetitions samples were taken in order to determine the floristic composition of associations. Global evaluation/estimation of the quality of meadow-pasture associations, in other words evaluation of their importance to livestock production, is based on analysis of the presence of useful plant species which are sub-categories: quality grasses, quality legumes and useful and conditionally useful plant species, according to Kojić (1990, 2001).

Results

In our investigations, floristic composition of plant association *Agrostietum vulgaris* from three locations and *Festucetum vallesiaceae* from four locations was determined. Obtained results on share and number of plant species categories are presented in Table 1.

Table 1. Average number and percentage of quality plant categories in ass. *Agrostietum vulgaris* and *Festucetum vallesiaceae*

Association	*Agrostietum vulgaris*		*Festucetum vallesiaceae*	
Presence of species	Number	%DM	Number	%DM
Quality grasses	11	23.4	11	14.7
Quality legumes	15	31.9	20	26.7
Useful and conditionally useful species	3	6.4	10	13.3
Bad and worthless species	17	36.17	26	34.7
Harmful and slightly poisonous species	1	2.13	8	10.6
Very poisonous species	–	–	–	–

Table 2 presents a synthesis review of plant species of investigated categories in both associations. In both associations almost the same species of useful perennial grasses were present: *Arrhenatherum elatius, Festuca arundinaceae, Lolium perenne, Agrostis vulgaris, Cynosurus cristatus, Agropyron repens Trisetum flavescens, Poa bulbosa.*

Table 2. Review of plant species according to categories in plant associations *Agrostietum vulgaris* and *Festucetum vallesiacae* according to Kojić, 1990; Kojić, 2001

	Association	
Category	*Agrostietum vulgaris*	*Festucetum vallesiaceae*
Useful grasses	*Arrhenatherum elatius*	*Arrhenatherum elatius*
	Dactylis glomerata	*Lolium perenne*
	Festuca arundinaceae	*Festuca vallesiaca*
	Lolium perenne	*Festuca arundinaceae*
	Festuca rubra	*Poa violaceae*
	Agrostis vulgaris	*Agrostis vulgaris*
	Poa pratensis	*Bromus erectus*
	Cynosurus cristatus	*Cynosurus cristatus*
	Agropyron repens	*Agropyron repans*
	Poa bulbosa	*Poa bulbosa*
	Trisetum flavescens	*Trisetum flavescens*
Useful legumes	*Trifolium incarnatum*	*Medicago lupulina*
	Lathyrus hirsutus	*Trifolium repens*
	Vicia angustifolia	*Lotus corniculatus*
	Medicago lupulina	*Vicia sativa*
	Trifolium campestre	*Trifolium campestre*
	Lotus corniculatus	*Trifolium montanum*
	Trifolium repens	*Anthyllis vulneraria*
	Lathyrus pratensis	*Onobrychis viciifolia*
	Trifolium alpestre	*Vicia angustifolia*
	Trifolium montanum	*Anthyllis vallesiaca*
	Anthyllis vulneraria	*Trifolium alpestre*
	Vicia tetrasperma	*Vicia cracca*
	Trifolium ochlereucon	*Trifolium incarnatum*
	Vicia grandiflora	*Trifolium panonicum*
	Lathyrus nissolia	*Vicia hirsuta*
		Lathyrus nissolia
		Vicia grandiflora
		Vicia tetrasperma
		Trifolium resupinatum
		Trifolium ochroleucon
Useful and conditionally useful species	*Achillea millefolium*	*Achillea millefolium*
	Crepis biennis	*Sanguisorba minor*
	Fragaria vesca	*Plantago lanceolata*
		Fragaria vesca
		Convolvulus sepium
		Filipendula vulgaris
		Hypochoeris maculata
		Crepis biennis
		Hypochoeris radicata
		Scabiosa columbaria

Discussion

Association *Agrostietum vulgaris* is widely present in hilly-mountainous region of Serbia on the territory where *Chrysopogonetum* is present. Components of the association present in fact transitional phase (which can last several decades) towards permanent phytocenosis with *Chrysopogon*, and sometimes even beyond this zone to altitudes over 600–700 m above sea level (which is top limit for *Chrysopogonetum*), Kojić *et al*. (2004). Meadow of this type has in average 47 plant species. 11 plant species belong to the group of quality grasses, 15 to group of quality legumes and 3 other quality species. Seventeen species were bad and worthless and 1 plant species was harmful. The association F*estucetum vallesiacae* is typicaly representative of the alliance *Festucion valesiacae*. It has a xerothermic character and it occurs mainly on relatively shallow soils of smonitsa type. In our investigations, on average from 4 locations, 77 species were noted, 11 useful species, 20 useful legumes and 10 conditionally useful species. All of the species mentioned are at the same time species preferred by livestock, with good nutritive value, especially in the period of the beginning of grazing in spring, if livestock is grazing all the time. Presence of useful legume species in these associations improves the overall quality of forage mass regardless of the way in which livestock is consuming it. The fifteen legume species of ass. *Agrostietum vulgaris* and the 20 species of ass. *Festucetum vallesiacae* represent most from this family that can be found in hilly-mountainous region of our country. Among those of highest quality are species of genus *Trifolium, Medicago, Vicia* and *Lotus.* These results are similar to those obtained by Tomić *et al.* (2003), where the presence of the mentioned species was 0–42.4%, with share of crude proteins of 4.81–13.57%. In the investigations of Lazarević *et al*. (2003), 56 species were identified in the floristic composition of the ass. Festucetum vallesiacae, weeds were dominating, and in regard to weight share species from the family Poaceae (48.6%), with dominant presence of species *Festuca vallesiaca,* whereas the species from the family *Fabaceae* participated with 8.9%, and species from other families (conditionally "weeds") 42.5%. The same authors obtained results when grassland was improved using PK fertilizer – share of grasses decreased to 35.6%, and share of leguminous plants increased to 16.6% and share of other species to 47.8%. Increase of nitrogen fertilizer increases in all 3 cases grasses to the detriment of legumes.

Conclusion

Meadow and grassland associations on Stara Planina Mountain in the hilly-mountainous region 650–800 m above sea level were investigated from the aspect of useful grasses, legumes and other useful species in order to determine their presence and adequate improvement measures. The dominant association are the *Agrostietum vulgaris* and the *Festucetum vallesiacae* with relatively modest number of plant species – 47 and 77. Regardless of the high presence of leguminous species, improvement measures are necessary. In subsequent year, fertilization with optimal dose of NPK is recommended in order to decrease undesirable species and favour the useful species from families Poaceae or *Fabaceae,* and improves the quality of forage base for nutrition of small ruminants (sheep and goats).

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Effect of different doses of the compost “Dano” on germination and growth of two grasses

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Abstract

The aim of this paper is to estimate the influence of different doses of the compost “Dano” on the germination, yield and utilization level of N, P, K from the compost by the fertilised plants. In autumn 1990 different doses of the compost “Dano”, i.e. 0, 10, 20, 30 tons of organic matter per hectare, were applied to the meadow. In the same year the influence of compost “Dano” on the energy and germination rate of grass seeds (*Lolium multiflorum* and *Festuca pratensis*) was investigated under laboratory conditions.

Keywords: municipal waste compost, energy and germination, compost doses, and utilization of N, P, K from compost

Introduction

The organic manuring of grassland in Poland is used less frequently than mineral fertilisation. The compost from waste materials can play a great role in plant fertilisation. Municipal wastes may form an important part in the balance of organic manuring (Gollardo – Lara and Nogales, 1987) right after composting.
In Poland such a compost is mostly produced by the “Dano” method (Lekan and Kacperek, 1990; Winiarska, 1991).
The aim of this work is to estimate the influence of different doses of compost “Dano” on the germination, yield, and utilization level of N, P, K from the compost by fertilised plants.

Materials and Methods

The investigated compost “Dano” had the following characteristics: 432.2 g kg^{-1} of organic matter, 13.5 g N g^{-1}; 4.5 g P g^{-1}; 4.4 g K g^{-1}; 31.5 g Ca kg^{-1}; and 2846 Zn mg kg^{-1}; 318 mg Mn kg^{-1}; 580 mg Cu kg^{-1}, 4.9 mg Cd kg^{-1}; 460 mg Pb kg^{-1}; 148 mg Cr kg^{-1}.
In the autumn 1990 different doses of compost “Dano” (0, 10, 20, 30 tons organic matter per hectare – o.m. ha^{-1}) were applied to the meadow.
In all the vegetation seasons the mineral fertilisation (120 kg N, 27 kg P, and 100 kg K per hectare) was applied in all combinations.
In 1990 the influence of compost “Dano” on the energy and ability of grass seeds germination (*Lolium multiflorum* and *Festuca pratensis*) was investigated in laboratory conditions. This experiment was carried out on Petri dishes (Wojciechowicz and Dorywalski, 1964) in four replicates, with the following doses of the compost:
1. mineral soil – control
2. soil + 3.46 g o.m. as 10 t of o.m. ha^{-1}
3. soil + 10.38 g o.m. as 30 t of o.m. ha^{-1}
4. soil + 20.76 g o.m. as 60 t of o.m. ha^{-1}

In all the dishes 100 seeds of each grass were sown. Germination was carried out in daylight under controlled moisture. The energy and ability of seeds germination was estimated by PN 79/ 565950. The results were subjected to ANOVA and the differences between the doses of compost "Dano" were tested by the LSD test.

Results and Disscusion

The influence of different doses of compost "Dano" on the energy and germination rate of seeds was determined (Table 1). A higher germination energy observed for seeds of *Lolium multiflorum* in comparison with those of *Festuca pratensis*. The germination energy increased for seeds of both grasses with increasing rates of compost application. However, for *Festuca pratensis* a statistically significant decrease of this characteristic was observed at the highest compost dose (60 t o.m. ha^{-1}).

Table 1. Effect of compost "Dano" dose on energy and capacity germination (%) of grasses

Dose of compost in t o.m. ha^{-1}	Lolium multiflorum	Festuca pratensis
	Germination energy	
0	70.50a	54.75ab
10	72.50ab	55.00ab
30	77.25b	59.50a
60	84.75b	46.00b
	Germination capacity	
0	85.00a	76.50a
10	87.00a	78.25a
30	90.25a	75.75a
60	84.25a	75.25a

a, b, c – values designated unidentical letters have significantly different at p = 0,05.

As far as the germination ability of *Lolium multiflorum* seeds is concerned, it was observed that there were differences in the reaction of *Festuca pratensis* seeds to a successive increase in the compost dose. With the increasing compost dose, the germination ability systematically decreased.

In relation to the different compost doses, the yield of the permanent meadow significant differences thus there was no effect occurred (Table 2). With increasing rates of compost use from 10 to 30 t o.m. ha^{-1} an increase in the fodder yield was observed in 1991. In all the successive years no such pattern occurred. During the investigated period the yield level was high and ranged from 6.92 to 8.37 t of d.m. ha^{-1}.

Table. 2 Mean dry matter yields of fodder from meadow fertilised by different doses of compost in t ha^{-1}

Compost doses in t. o.m. ha^{-1}	Year			
	1991	1992	1993	x
0	7.07	6.35	7.33	6.92
10	8.55	7.45	8.06	8.02
20	8.95	7.49	8.08	8.17
30	9.25	7.52	8.33	8.37
$LSD_{0,05}$	0.53	1.23	1.05	0.52

The compost doses caused an increase in macroelements utilization by the meadow sward (Table 3), which resulted in a higher yields.

Table 3. Utilization of N, P, K by meadow sward from different compost “Dano” doses (mean from 1991–1993)

Compost doses in t. o.m. ha^{-1}	Element					
	N		P		K	
	A	B	A	B	A	B
0	388a	–	48a	–	452a	–
10	486ab	31.5	63ab	14.3	549ab	94.8
20	520ab	21.1	61ab	6.5	586b	65.6
30	580b	20.5	65b	5.6	623b	55.8

A – content in the yield (in kg ha^{-1}), B – utilization from compost “Dano” (in %)

Conclusions

1. Compost “Dano” is rich in organic matter, macroelements and some microelements.
2. Increased doses of compost “Dano” caused an increase in the energy and seed germination for *Lolium multiflorum*, however for *Festuca pratensis* seeds higher compost doses decreased their germination ability and energy.
3. Increased compost doses increased the dry matter yield of the permanent meadow only in one year and, simultaneously increased the utilization of chemical components introduced to soil.

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Herbivore-driven spatial vegetation heterogeneity: consequences for forage quality, production and biodiversity in wet grasslands

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Abstract

In wet natural grasslands, spatial heterogeneity of vegetation appeared related both to abiotic factors and to herbivores' foraging behaviour. An in-situ experimental design showed that the spatial patterns of plant community differ depending of the species of herbivore (horses vs cattle). In term of plant richness, the optimal management is achieved by mixed grazing as horses and cattle show some complementary uses of the resources.

The agronomic consequences of the existence of patches have been examined by investigating the biomass production as well as the qualitative value of the vegetation (C/N). The intensity of forage use by herbivore has also been calculated on the field. Some patches contrasted in their agronomic characteristics while others showed similarities despite difference in their floristic composition. The relationships between the forage qualitative and quantitative value and the species composition are discussed. Overall, the agronomic value of these grasslands appears to have been underestimated and is largely compatible with their biodiversity value. Spatial heterogeneity in grazing and thereafter plant community spatial heterogeneity appears determining for the compatibility between agronomic and biodiversity values.

Keywords: wet grasslands, grazing, spatial heterogeneity, biodiversity, productivity, forage quality

Introduction

Plant community heterogeneity has been abundantly described and, in pasture, can occur at the landscape scale, when a variety of plant communities are found in the same unit of management (WallisDeVries *et al*., 1998) and also at a within-community scale. At the community scale, heterogeneity can be provided by subtle variations of abiotic conditions (predominantly edaphic), but also by the local variation of biotic factors, related to plant interactions and also plant-animal interactions.

In this paper, we have investigated the heterogeneity pattern of grazing for two common macro-herbivores (cattle and horses) in a heterogeneous wet grassland comprising three plant communities along a topographical gradient. Extensive grazing is a common mode of management for conservation targets and there is increasing interest in the benefits of multi-species grazing. Cattle and horses differ in their feeding and dung deposition behaviour. We have examined what kind of plant type and plant diversity patterns develop from these two grazing behaviours, alone and in combination. The agronomic consequences of the existence of patches have been examined by investigating the biomass production as well as the qualitative value of the vegetation (C/N ratio).

Materials and Methods

The dataset was collected in an experimental setting established in 1995 on a commonly grazed land (250 ha) situated in the Marais Poitevin (120 000 ha), a large wetland situated

on the Atlantic coast of France. The studied wet grassland is a former salt-marsh, embanked during the 10th century and used for centuries for grazing with horses and cattle. The grazing season generally last from the end of April to December at the latest. A remnant topographical gradient (up to 50 cm) from ancient salt-marshes distinguished three levels: low-lying depressions flooded 3 to 5 months per year; gentle slopes flooded 2 to 3 weeks a year, where clay-rich soils have remained saline; and flats that are never flooded (Amiaud *et al*., 1998).
The experimental design included two plots grazed with 2 cattle ha^{-1}, two plots with 2 horses per 2 ha, and two plots with mixed grazing with 2 cattle and 2 horses per 2-ha enclosure (1 bovid and 1 horse ha^{-1}). One plot has been left ungrazed by macro-herbivores since 1995.
Plant measurements were made every year in June and July. Relative species covers were recorded in 25 cm square quadrats, with 30 replicates sampled at random at each topographic level in every plot. The above-ground biomass was measured from April to June 2004 as the sum of production over the period for six patches temporary excluded from defoliation, with four replicates per patch. Carbon and nitrogen analyses were run on the plant biomass collected in the first week of May and at the end of June 2004 from six patches temporarily excluded from defoliation. A CHN elemental analyser was used for this purpose.

Results and Discussion

Without herbivores, vegetation showed a pre-existing heterogeneity as a particular plant community was developed at each topographical level. In depressions that remain flooded for longer, the community was hygrophilous (H thereafter). On upper flats, the vegetation was mesophilous (M thereafter). On slopes, the meso-hygrophilous vegetation (MH thereafter) included mainly sub-halophyte species as the soil remains saline (Amiaud *et al.*, 1998).
Beyond the between-community contrast in vegetation, herbivores generated heterogeneity within communities. Loucougaray et al. (2004) showed clear herbivore feeding preference between communities, which discriminated between various plant patches within each community. Mixed grazing led to the same number of patches as with horses alone (Table 1). Some patches were present in every studied grazing regime or, at the other extreme, were characteristic of only one of them (Table 1). Without grazing (i.e. enclosure left ungrazed for 7 years), there was no within-community heterogeneity and less contrast between the three communities. Patches could be ranked along a grazing intensity gradient and distinguished from one another on the basis of their species composition and relative abundance together with their height which lead to substantial contrasted life cycle patterns.
Species diversity varied between patches (Table 1) and the lowest plant diversity was recorded in two contrasting situations: (a) in latrine areas poorly grazed by horses alone, where *Elymus repens* dominated on flats and *Agrostis stolonifera* in wet depressions; and (b) on flats dominated by *Lolium perenne* as a result of heavy grazing by cattle (in both single and mixed grazing treatments). Low diversity associated with strong dominance by perennial species has been reported in grasslands under ungrazed conditions. In term of plant richness, the optimal management is achieved by mixed grazing as horses and cattle show some complementary uses of the resources. For example, in the mixed treatment, cattle grazing on latrine areas lowered the dominance of *E. repens* and *A. stolonifera*, and the diversity was higher than with horses alone due to compensatory effects between the two herbivores (*sensu* Ritchie and Olff, 1999).

Table 1. Heterogeneity and species richness for each community and at the enclosure scale, associated with the various grazing regimes

	Patches	Ungrazed	Cattle	Horses	Mixed grazing
	proportion of the community occupied by the patch (%)				
Mesophilous (flats)	Tall M	100%,	84%	89%	90%
	Short M		16%	11,00%	10%
	species richness M	5.0	15.5	21.5	20.0
Meso-hygrophilous (slopes)	Mh1	100%	42%		
	Mh2		34%	61%	48%
	Mh3		24%		
	Mh4			31%	26%
	Mh5			7%	24%
	Mh6			3%	<5%
	species richness MH	18.0	15.0	26.0	22.0
Hygrophilous (depressions)	H1	100%		with dung, 31%	with dung, 10%
	H2		100%	57%	82%
	H3			12%	8%
	species richness H	8.0	12.5	28.5	30.5
3 communities	Nb patches	3	6	9	9
	species richness	23.0	28.5	43.5	42.5

Table 2. Nitrogen content (in % dry weight) and digestibility values for the various patches in the three plant communities. The number of replicates varies between 4 to 9 except four patches for which chemical analysis were run for only one sample

	Patches	% Nitrogen (SE)	Digestibility (%)
Mesophilous (flats)	Tall M	2.11 (0.06)	42.65 (0.23)
	Short M	2.31 (0.20)	49.17 (0.67)
	Tall M + faeces	1.03 (0.08)	30.89 (0.75)
Meso-hygrophilous (slopes)	Mh1	2.17 (0.04)	45.12 (0.50)
	Mh2	2.21 (0.12)	39.51 (0.42)
	Mh3	2.23 (0.25)	52.62 (1.73)
	Mh4	1.90 (n = 1)	48.25 (n = 1)
Hygrophilous (depressions)	Tall H	1.01 (n = 1)	38.37 (n = 1)
	Tall H +faeces	1.80 (0.06)	32.86 (1.00)
	H1	2.61 (n = 1)	72.61 (n = 1)
	H2	2.26 (n = 1)	55.92 (n = 1)
	H3	1.59 (0.08)	41.06 (0.50)

The agronomic value of the various plant patches could be approached by the biomass available together with its quality. Standing crop biomass, decreased with increasing grazing intensity, and varied enormously amongst patches: from 594 to 1310 g dry matter (DM) m^{-2} in the M community and from 185 to 794 g DM m^{-2} in the MH. Those values are all in the range reported for wet grasslands (Milchunas and Lauenroth, 1993). Aboveground primary production showed less variation amongst patches for M while substantial differences showed up between patches from the MH community. This was probably due to the greater variability of plant forms profiles in the MH compared to the M community, particularly a change to annual grasses and dicots with increasing grazing intensity. When considering the quality of the vegetation at the scale of the patches (Table 2), higher nitrogen contents together with higher digestibility rates characterized heavily grazed patches in all three communities. Fleurance *et al*. (2001) also found higher crude protein contents for the shorter vegetation, irrespective of the community.

Conclusion

Grazing-related heterogeneity in a low-input grassland appears to sustain an interesting level of both floristic diversity, forage production and quality. Our conclusion is that such spatial heterogeneity contributes to the agronomic and ecological value and sustainability of such grasslands, with compatible objectives and management for agronomic and ecological perspectives. Those results perfectly fit within the 'multifunctional grasslands' framework.

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Differences in the phenologic development of forage grasses on mineral and organic soil

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Abstract

The soil type impact on the heading stage commencement and its duration was evaluated on thirty-four varieties of the six following grass species: nine varieties of *Dactylis glomerata* (L.), four of *Festuca pratensis* (Huds.), four of *Festuca rubra* (L.), six of *Lolium perenne* (L.), seven of *Phleum pretense* (L.) and four of *Poa pratensis* (L.). The investigations were conducted in a natural meadow habitat on the organic and mineral soil under the same weather conditions. Over the vegetative period a ground water level ranged from 173 to 232 cm on the mineral soil and 23–86 cm on the organic one. The evaluated varieties entered the heading stage on the organic soil later as compared to mineral. The differences in this stage commencement was greatest between the *Lolium perenne* varieties on mineral soil and between *Dactylis glomerata* varieties on organic, whereas the smallest between *Dactylis glomerata* and *Poa pratensis* varieties on mineral soil. Among the varieties of the species examined there were distinguished some less soil factor-sensitive ones and those showing a long period from the heading start to flowering commencement.

Keywords: grass varieties, heading stage, mineral and organic soils

Introduction

In Poland over 70% of grassland forage is harvested by hay whose nutritional value depends to a great measure on the grass developmental stage at cut. The results of the Polish and foreign studies showed that the optimal harvest date of the first cut is the heading stage. As the harvest date is delayed the forage nutritional value declines due to total protein content decrease and structural carbohydrates and lignins increase in meadow plants (Kozłowski and Swędrzyński, 2001; Vanhatalo *et al*., 1992; Ignjatovic *et al*., 2004). This fact in turn affects fodder digestibility and herbivore performance. The earliness of varieties should be regarded while composing the mixtures for grassland use as that can extend the first cut harvest at the optimal time and facilitate the organization of good quality feed production.

The dates of each developmental stage start and the duration are characteristic for a species and variety, yet the weather conditions and a temperature in particular, enhance or inhibit any stage appearance (Rutkowska *et al*., 1997; Łyszczarz and Dembek, 2003). To make a practical use of the different earliness of varieties composing a mixture, phenological differentiation between species and varieties should be checked at various soil conditions. Actually, 35% grassland in Poland and 45% in the Lublin region is located on the organic soil. In spring the organic soils are colder than mineral because they get warm far slower due to high water content. Therefore, the work was designed to recognize a soil type impact on the commencement date and heading duration of the domestic grass varieties.

Materials and Methods

The studies were made in the years 1998–2000 on the experimental plots set up in 1997 according to a randomized complete block design in natural meadow habitat on the mineral and adjoining organic soils. The investigations covered thirty-four domestic varieties of the following six grass species: nine varieties of *Dactylis glomerata* (Amera, Areda, Arma, Bara, Bepro, Berta, Dika, Nera, Rada), four of *Festuca pratensis* (Cykada, Mewa, Skawa, Skra), four of *Festuca rubra* (Atra, Brudzyńska, Kos, Reda), six of *Lolium perenne* (Anna, Argona, Arka, Maja, Naki, Solen), seven of *Phleum pretense* (Bartovia, Emma, Foka, Kaba, Karta, Obra, Skala) and four of *Poa pratensis* (Beata, Duna, Eska 46, Skiz). During the experimental years over the vegetative period a ground water level ranged from 176 to 232 cm on the mineral soil, whereas on organic from 23 to 86 cm. Annually both soils were supplied with 100 kg P_2O_5 and 80 kg K_2O ha^{-1}. Nitrogen was applied at amount 90 kg N on mineral soil and 45 kg N ha^{-1} on organic. The stands of pure varieties were sown onto plots (2.6 m^2) according to the sowing standards recommended for each species. The heading was considered to start with the first appearance of the tip of a grass inflorescence at the mouth of the sheath of the flag-leaf (10% of the stems are eared), whereas the flowering stage commences with the anthers appearance outside the inflorescence. The evaluation was performed every third day from 15th May to 25th June.

Results and Discussion

The investigations proved that under the same weather conditions all the varieties evaluated (except Solen *Lolium perenne* and Karta *Phleum pratense*) started their heading earlier on the mineral soil than on organic which was thawing and getting warm slower in spring. However, a response of each species and variety to a soil type was differentiated (Table 1).

Dactylis glomerata, subject to a variety, commenced heading 14–22 days later on the organic soil compared to mineral. On the mineral soil, the heading dates of varieties varied, apart from Amera variety that entered the stage 6 days before the other varieties did. The differences in heading dates between the varieties on the organic soil were 8–9 days. The earliest heading was reported for Amera, Areda, Bepro, Berta and Dika varieties, while the latest for Arma and Nera. The variety order concerning the heading occurrence was in accordance with that given by Łyszczarz and Dembek (2003), except for Areda. On both soils a number of days counted from the heading start to the flowering commencement were close, except for Bara and Arma.

The *Festuca pratensis* varieties began their heading on similar dates, yet on the organic soil this stage started 4–6 days later and lasted two or three times longer compared to mineral. The Cykada and Mewa varieties appeared more sensitive to the slow warming up process of the organic soil than the others. Alike, the *Festuca rubra* varieties turned out to be slightly differentiated regarding their heading dates. On the organic soil all the varieties entered this stage later and it lasted over two fold longer than on mineral.

The *Lolium perenne* varieties showed varied heading date start, more noticeable on the mineral soil than organic. On both soils Anna entered the heading stage the earliest and this stage persisted for a shorter time compared to the other varieties. This variety is numbered among the earliest of *L. perenne* in Poland (Rutkowska *et al*., 1997). Solen variety distinguished itself by low sensitivity to the soil conditions and long duration of the stage on both soil types.

The *Phleum pratense* varieties exhibited low susceptibility to the soil conditions and reached the heading stage at similar date (difference of 2–4 days) on both soils. All the varieties of *Ph. pratense* had long heading stages in both habitats.

Table 1. Dates of the beginning of the heading stage (earliness indices according to Gillet*) and the number of days from the beginning of the heading stage to the flowering commencement, for the studied grass varieties (average values 1998–2000)

Species and varieties	Beginning of the heading stage*		Days, from the beginning of heading stage to flowering commencement	
	Mineral soil	Organic soil	Mineral soil	Organic soil
Dactylis glomerata				
Amera	5-2-a	5-6-a	6	5
Areda	5-3-a	5-6-a	6	4
Bepro	5-3-a	5-6-a	7	6
Berta	5-3-a	5-6-a	7	6
Dika	5-3-a	5-6-a	6	4
Bara	5-3-a	5-6-b	8	12
Rada	5-3-a	6-1-a	7	8
Nera	5-3-a	6-1-b	5	6
Arma	5-3-a	6-1-b	10	6
Festuca pratensis				
Cykada	5-3-b	5-5-a	5	14
Skawa	5-4-a	5-4-b	5	10
Skra	5-4-a	5-4-b	4	13
Mewa	5-4-b	5-5-b	6	15
Festuca rubra				
Atra	5-3-b	5-6-a	6	15
Brudzyńska	5-3-b	5-6-a	6	15
Kos	5-4-a	5-6-a	6	15
Reda	5-4-a	5-6-b	6	15
Lolium perenne				
Anna	5-3-a	5-3-b	4	6
Naki	5-4-b	5-6-b	12	8
Maja	5-5-b	5-6-b	8	13
Argona	5-6-a	5-6-b	7	15
Arka	5-6-a	5-6-b	7	12
Solen	5-6-a	5-6-a	10	15
Phleum pratense				
Obra	5-6-a	5-6-b	12	15
Skala	5-6-a	5-6-b	13	12
Emma	5-6-a	5-6-b	12	16
Foka	5-6-a	6-1-a	13	15
Kaba	5-6-a	6-1-a	12	16
Bartovia	5-6-b	6-1-a	10	16
Karta	5-6-b	5-6-b	11	17
Poa pratensis				
Beata	5-3-b	5-4-a	4	5
Duna	5-3-b	5-5-a	4	4
Skiz	5-3-b	5-5-a	3	4
Eska 46	5-3-b	5-5-a	2	4

* Earliness indices according to Gillet (1980): the first digit – month, the second digit – Pentada, a – beginning of the Pentada, b – the end of the Pentada

The *Poa pratensis* varieties showed little differences in respect of heading stage start and its duration. Their response to the soil conditions was similar. All the varieties commenced the heading on the organic soil later compared to mineral (Beata variety by 4 days and the other by 7 days).

Conclusions

This study showed that the soil type plays a vital role in the development rate of the grasses in spring. Different heading dates of the studied grass varieties on the mineral and organic soil (except Solen *Lolium perenne* and Karta *Phleum pratense*) prove a necessity of the variety earliness evaluation at various soil conditions.
The differences in the heading commencement was greatest between the *Lolium perenne* varieties on mineral soil and between *Dactylis glomerata* varieties on organic, whereas the smallest between *Dactylis glomerata* and *Poa pratensis* varieties on mineral soil.
A long period between the heading start and flowering commencement was recorded for all the varieties of *Phleum pratense* on both soils, for all the varieties of *Festuca pratensis*, *F. rubra*, *Lolium perenne* (except Anna and Naki) and Bara (*Dactylis glomerata*) on organic soil only, for Arma (*D. glomerata*), Naki and Solen (*L. perenne*) on mineral soil exclusively.
The results obtained indicate the importance of obtaining heading date information on each grass species so that this characteristic could be made use of composing the mixtures appropriate for the different first cut date.

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Livestock pressure and aspect effect on temperate mountain grassland plant species

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Abstract

The aim of this work was to determine the influence of aspect (North, South and Southwest) and livestock pressure (sheep, cattle and horses) (in relation to animal movement: Hut, Extensive, and Nap zones and Water points) on the grassland herbaceous communities in the mountain grasslands in the Basque Country (northern Spain). Three grasslands differing in aspect were selected, four zones in relation to livestock grazing pressure within them. At each zone 3 sites were selected and 10 random quadrants (0.5 × 0.5 m) were used to determine plant composition and cover.

Forty plant species were present overall and the most common were *Agrostis capillaris*, *Festuca rubra* and *Trifolium repens* with more than 20% of total cover each. The cover of the observed species changed among grazing pressures showing clearly structural differences. *A. capillaris* and *T. repens* presence was favoured by grazing pressure. The most intense livestock pressure (water points) reduced significantly species richness (13.8 $\pm$ 1.10), directly related to the dominance of some species tolerant to high grazing pressure, namely gramineae as *A. capillaris* and *F. rubra*. The lowest grazing pressure and the highest spatial heterogeneity zones (with slopes and apparent rocks), i.e. Nap zones, supported the highest species richness (23.2 $\pm$ 1.30). The intermediate species richness was found at the intermediate grazing pressure site, i.e. extensive zones (17.9 $\pm$ 1.10). Thus, grazing pressure creates a mosaic of vegetation structures that function in the landscape maintaining a high diverse area.

Keywords: extensive pastures, herbivorous pressure, species richness

Introduction

Mountain pasture systems are maintained by the combination of physical and environmental factors and human activity leading to high complexity ecosystems (Watkinson and Ormerod, 2001). Herbivores are major determinants of structure and organisation of plant communities (Milchunas and Lauenroth, 1993; Bai *et al.*, 2001; Amezaga *et al.,* 2004) and topographic conditions also affect pasture diversity and can have an important influence on its structure (Watkinson and Ormerod, 2001; Amezaga *et al.,* 2004). Besides, water is a particularly important element, with livestock activity concentration at water points (Hunt, 2001).

Extensive mountain pasture systems in the Basque Country (Northern Spain) are grazed by livestock (sheep, cattle and horses) from May to October. Animal pressure promotes the maintenance of grasslands in replacement of beech forests. However, the selective activity of herbivores in these grasslands is leading to an unbalanced use of the pastures leading to the degradation of the sites.

The present study was conducted to determine the effect of grazing intensity and aspect on plant community structure.

Materials and Methods

This study was carried out in the Natural Park of Aralar (Basque Country, northern Spain), declared in 1994 with the aim to manage the natural resources and maintain the human activities, especially sheep herding. This activity is characterised by the sheep movement from valleys to mountain pastures in spring, thus, restraining the recolonisation of beech forest and favouring the maintenance of rangelands. The park is located in a mountain range where mean temperature and precipitation are 11ºC and 1800 mm, respectively. Nowadays, 3500 ha are used as grassland, mainly on limestone soils. Traditionally, these communal grasslands have been grazed only by sheep (Latxa breed), but nowadays the multispecific exploitation is common. During the last decade, due to less exigent management and European aids for extensification, the number of beef cattle has suffered a noticeable increase. The actual numbers are: 17757 sheep (92%), 811 cattle (4.2%), and 653 horses (3.8%).

The study design covered all the different pasture zones of the park in relation to aspect and also to livestock movement, especially sheep. Three aspects were selected (North, South, Southwest) (100 ha each one) and each one was divided into 4 zones in relation to animal movement, i.e. time spent in each zone (Hut zone, Extensive, Nap zone and Water points) each of at least 2 ha. The Water point is where the grazing pressure is greatest and where there is a joint effect of sheep and cattle, followed by the Hut point where shepherds milk the sheep and keep them overnight, Extensive zone where animals graze but not so intensively, and finally the Nap zone where the herds rest. In general, the Nap zones are the highest points of the grasslands where there is a light wind as in summer the other zones can become very hot.

In each zone, after calculating the minimum area sampling, 3 samplings (10 randomly thrown quadrants of 0.5x 0.5 m) were carried out to study the vegetation structure. In each quadrant, plant species present and their cover were calculated.

The change of cover of the most common, nutritive and high palatability plant species (*A. capillaris, F. rubra* and *T. repens*) and species 'richness' (numbers of species per site) were analysed by means of an analysis of variance (ANOVA). The two by two comparisons were analysed by means of the Fisher´s Test.

Results

Forty plant species were recorded in this study. The same plant species were dominant in the whole study area, namely *A. capillaris, F. rubra* and *T. repens*, however, they showed differences in cover in relation to aspect and animal movement, i.e. grazing pressure. Other species present typical of these pastures were *Carex caryophillea, Cerastium fontanum, Danthonia decumbens, Galium saxatile, Hieracium pilosella, Lotus corniculatus, Lolium perenne, Bellis perennis, Ranuncuclus acris, Potentilla erecta,* and *Thymus praecox.*

The ANOVA carried out to see the effect of aspect and animal movement on the cover of the dominant species showed that the cover of *A. capillaris* was affected by the interaction of both factors. The *A. capillaris* cover was smallest in the Nap zone and the highest in the Hut zoe and the South aspect (Table 1).

The cover of *F. rubra* was not affected by aspect but it was affected by animal movement ($p=0.0032$). Thus, the highest values were observed in the Extensive zone and Water point, and the lowest in the Hut and Nap zones (Table 2).

Table 1. Mean percentage cover of *A. capillaris* (± SE) in relation to aspect and animal movement

Zone	North	South	Southwest
Hut zone	24.4±3.0 Ba	44.6±7.3 Aa	19.5±6.9 Ba
Water point	29.8±3.4 Aa	30.1±8.0 Aa	13.9±1.6 Aa
Extensive zone	24.6±6.6 Aa	14.4±2.1 Ab	13.6±1.3 Aa
Nap zone	3.4±2.9 Ab	2.8±1.0 Ab	7.5±4.3 Aa

Capital letters show significant differences between aspects within a zone (p<0.05).
Lower case letters show significant differences between zones within an aspect (p<0.05).

Table 2. Mean percentage cover of Festuca rubra (+ SE) in relation to aspect and animal movement

Zone	North	South	Southwest	Mean cover
Hut zone	15.0±7.5	6.9±4.9	22.9±2.4	14.9±3.5 b
Water point	15.5±8.5	32.8±6.6	28.0±2.1	25.4±4.1 a
Extensive zone	23.3±4.6	32.8±3.6	30.4±0.6	26.3±2.2 a
Nap zone	18.5±2.4	16.6±4.3	15.0±1.9	16.7±1.6 b

Letters show significant differences between zones (p<0.05).

T. repens cover was significantly affected by aspect (p = 0.0061) and animal movement (p = 0.0001), but not by the interaction of both. The highest cover values were observed in the Hut and Water point zones, and the north aspect (Table 3).

Table 3. Mean percentage cover of *Trifolium repens* (± SE) in relation to aspect and animal movement (not the interaction)

Zone	North	South	Southwest	Mean cover
Hut zone	21.9±4.4	13.0±1.9	14.3±4.2	16.4±2.30 a
Water point	21.0±5.8	12.6±4.7	8.8±1.3	14.1±2.80 a
Extensive zone	11.2±2.4	6.9±0.9	7.3±1.3	8.5±1.10 b
Nap zone	6.5±3.0	2.0±0.9	2.2±0.4	3.6±1.20 b
Mean cover	15.2±2.60 A	8.6±1.80 B	8.2±2.10 B	

Capital letters show significant differences between aspects (p<0.05).
Lower case letters show significant differences between zones (p<0.05).

Plant species richness was only affected by animal movement, i.e. grazing pressure, (p<0.0001). Richness was highest in the Nap zone (23.3 ± 1.3) and lowest in the Hut zone (16.6 ± 1.40) and Water point (13.8 ± 1.1) (Table 4).

Table 4. Plant species richness mean values (± SE) in relation to aspect and animal movement

Zone	North	South	Southwest	Mean cover
Hut zone	16±4	17±1	20±2	16.6±1.4 bc
Water point	13±1	16±2	16±3	13.8±1.1 c
Extensive zone	19±2	21±1	17±2	17.9±1.1 b
Nap zone	24±1	23±2	29±2	23.2±1.3 a

Letters show significant differences between zones (p<0.05).

Discussion

Grazing pressure was the main factor affecting plant community structure, either by itself or in interactiion with aspect, in compliance with other relevant works (NcNaughton, 1985; Bai *et al.*, 2001, Amezaga *et al.*, 2004). The cover of *A. capillaris* and *T. repens* was favoured by grazing pressure while the cover change of *F. rubra* was somewhat controversial as the highest cover was found in the lower and higher pressure zones. This species has been reported to react to grazing pressure in different ways depending on soil characteristics, namely P and pH (Amezaga *et al.,* 2004). Aspect affected species cover in different ways: milder weather in the South favoured the presence of *A. capillaris* while *T. repens* was favoured by cooler temperatures of the North aspect. These results agree with those of Amezaga *et al.* (2004) in similar mountain pastures. There is an increasing recognition that the effects of herbivores on plant diversity depend not only on the type and density of herbivores, but also on the nature of the environment, particularly soil moisture and fertility (Tobler *et al.,* 2003).

In disagreement with other works where grazing intensity did not affect species richness (McNaughton, 1985; Bai *et al.*, 2001), plant species richness was reduced by means of grazing pressure in the higher grazing intensity zones, namely the Water point and Hut zone. The accumulated long-term impact of water-centred grazing can alter plant composition (Landsberg *et al.*, 2003; Hunt, 2001). Palatable perennial plants decline in density or are eliminated and replaced by unpalatable and/or short-lives species as distance from water decreases due to the higher grazing pressure (Andrew, Lange, 1986). However, this is not the case in the studied grasslands as the most palatable species *A. capillaris*, *F. rubra* and *T. repens* are dominant at the observed Water points, but the species richness is lower.

The mountain pasture structure is affected mainly by grazing pressure, however, aspect leading to weather and seasonal changes also show an effect (Watkinson, Ormerod, 2001; Amezaga *et al.*, 2004). Nevertheless, the heterogeneity in grazing pressure due to animal movement creates a mosaic of vegetation structures that function in the landscape maintaining a highly diverse area. However, there is a need to control grazing, specially at the Water point, as there is a significant reduction in species richness that later may also lead to a reduction in the pasture nutritional value due to the overgrazing and appearance of bare soil. Pastures include species with low tolerance of grazing, which, if not controlled, may lead to their disappearance, i.e. reduction of plant biodiversity.

Conclusions

- The main plant species present in the mountain grasslands of the NP of Aralar were *A. capillaris, F. rubra,* and *T. repens.*
- Grazing pressure had a dominant effect on plant species cover, having a positive effect on *A. capillaris* and *T. repens*. These species cover was also affected by aspect, however, in a different way: the cover of *A. capillaris* was highest in the South aspect while the cover of *T. repens* was highest in the North, i.e. at the coldest and most humid site.
- *F. rubra* was only affected by grazing pressure but its response to it varied in relation to other factors, i.e. soil fertility.
- In general, the grazing pressure had a positive effect in some parts of the park, promoting the presence of high nutrition species for herbivores while reducing species richness. There must be tight control of grazing intensity, especially at the Water points, as there is a risk of over-grazing.

Acknowledgements

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Effects of N, P and K fertilisation on *Brachypodium rupestre* ssp. *caespitosum* in a mountain meadow

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Abstract

As a consequence of the abandonment or the introduction of extensive management practices, meadows and pastures of the Italian side of the Alps are often overrun by *Brachypodium rupestre* ssp. *caespitosum*. In order to deepen the knowledge of the reaction of this grass to the most important fertilizers, the per cent cover of this plant on the plots of a N, P and K fertilisation trial were evaluated during years 2003 and 2004. The experimental design of the trial, that was set up in 1977, is a randomised complete block, with 4 replicates. Based on the results it was observed that *Brachypodium rupestre* ssp. *caespitosum* was absent in those treatments in which all 3 elements or at least P and K were used. Moreover, this species was not noticed or was just hardly present where only N or P was distributed, and the same results were measured when these 2 elements were both present in the treatment. On one hand, in the control (N0P0K0) its presence increased not significantly; on the other hand, it became significantly higher in those treatments with only K fertilisation, independently from the presence and level of N.

Keywords: *Brachypodium rupestre* ssp. *caespitosum*, fertilisation, mountain meadow

Introduction

Brachypodium rupestre ssp. *caespitosum* (subsequently referred to as *Brachypodium*) nowadays represents a species of strong interest for the environmental management of the permanent grasslands. In fact, the spreading of this low quality grass, which can create close lawns or isolated tufts in the more sloping and stony sides, is increasing in the marginal areas as a consequence of the abandonment of agricultural practices or the introduction of more extensive management regimes. In many calcareous grasslands of Western Europe, indeed, cover values of 90% of this species, 10–15 years after the abandonment, have been observed; these changes, that often precede the spreading of shrubs and trees, resulted in a strong deterioration of the forage quality and, at the same time, in a dramatic reduction of specific biodiversity (Bobbink and Willems, 1987; Willems, 2001; Da Ronch *et al*., 2002). Undoubtedly, in order to prevent these problems, permanent grasslands need specific management measures; anyway, it is necessary to protect them also from improper fertilizers uses (Wells, 1974; Willems, 1985). The primary aim of this work was to deepen some aspects of the behaviour of this species in the mountain meadows of the Venetian Alps, in view of a better definition of the management and reduction measures to be adopted; precisely, inside a fertilisation trial with N, P and K, nearly 30 years old, the variations of the cover values of *Brachypodium* in the different treatments have been considered and analysed.

Materials and Methods

The trial, that was set up in 1977, it's situated in a permanent meadow in the locality of Candaten (Sedico-Belluno, NE of Italy), inside the Dolomiti Bellunesi National Park. This area is placed on the bottom of a valley (420 m a.s.l.), is characterized by an annual average temperature of 10.6 °C and a mean annual rainfall of 1535 mm, distributed following a sub-equinoctial course. Soil has a medium-sandy texture, subalkaline reaction, and was originated from limestone-dolomitic alluvium. In 1977, the floristic composition of the meadow could be ascribed to the Arrhenatherum elatioris association, and to the salvietosum pratensis sub-association (Oberdorfer, 1983); no presence of Brachypodium was recorded then. The experimental design was a randomised complete block with 4 replicates. Plot size was 24.0 m^2 (4.0 × 6.0 m) of which the central 18.0 m^2 (3.0 × 6.0 m) were used as test area. Twenty-seven different treatments, obtained from the factorial combination of 3 levels of nitrogenous (0, 96 and 192 kg of N ha^{-1} $year^{-1}$, marked with N0, N1, N2), phosphatic (0, 54 and 108 kg of P_2O_5 ha^{-1} $year^{-1}$, marked with P0, P1 and P2) and potassic (0, 108 and 216 kg of K_2O ha^{-1} $year^{-1}$, marked with K0, K1, K2) fertilisation have been distributed every year. In each plot 3 cuts have been realized yearly; the first cut in the second 10 days of June, and the others about 50–55 days after the previous one. This work is referred to the results obtained from the botanical surveys performed in each plot in 2 different moments, just before the first cut of 2003 and 2004. In the botanical surveys the Braun-Blanquet approach was used, even if modified, since the cover index assigned to each species has been replaced by the per cent cover. All the survey results were further subjected to the analysis of variance.

Results and Discussion

On the average of the 2 years, only the main effects of P and K affected significantly the presence of *Brachypodium* (Figure 1, left). In the first case, it was highlighted that after almost 30 years since the trial was established, *Brachypodium* was present only in those treatments in which P was not applied, whereas the presence of phosphorus, regardless of its rate, prevented the growth of the species. In the second case, instead, it was observed that as the K input in the treatment was higher, also the cover level of *Brachypodium* increased.

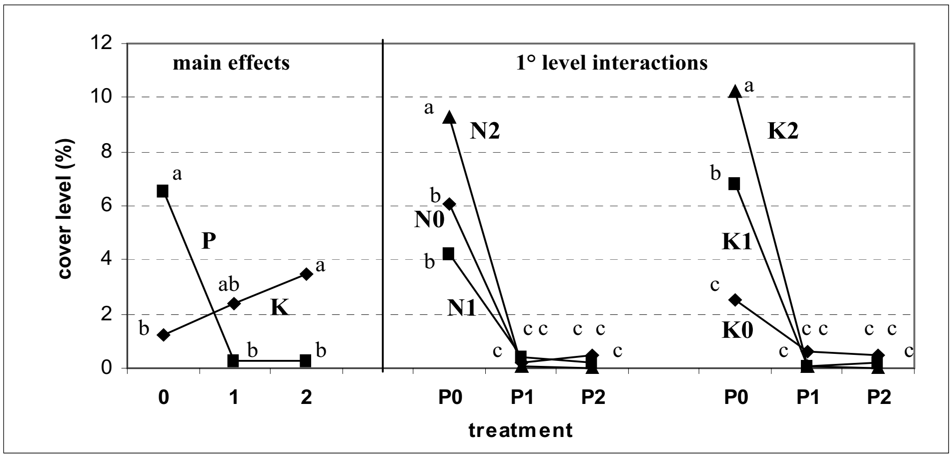

Figure 1. Effects of N, P and K fertilisation on the presence of *Brachypodium*: main effects (left) and first level interactions (right) (all significant at P<0.01). For each effect and interaction, values that have no letters in common are significantly different at P<0.05 Duncan's test

In fact, passing from K0 to K1 and K2, the cover percentage of *Brachypodium* changed from 1.21 to 2.38 and finally to 3.47, but with a significant difference only between levels zero and 2. On the average of the two years, anyway, also N×P and P×K interactions were significant (Figure 1, right). The N×P interaction underlined, first of all, that when P was used, the presence of *Brachypodium*, in relation to the 3 levels of N, was nearly not detected, and without significant differences; on the contrary, when P was not applied in the treatment, the values for N0, N1 and N2 were significantly higher. Moreover, if compared to the control (N0), nitrogen produced a significant increase in the growth of *Brachypodium*, but only if 192 kg of N ha^{-1} $year^{-1}$ were distributed. The P×K interaction, similarly, pointed out that while in the presence of P *Brachypodium* did not profit by the use of K, as P was absent the cover values increased from 2.38, (that was not different from the previous values) to 6.38 and 10.2, respectively for K1 and K2, that were significantly different between them. These results are, probably, the consequence of 3 different situations that occurred in the treatments. On one hand, when all 3 elements were present in the treatment, the canopy was characterized by a high component of tall size species (Figure 2), with the highest average cover values for some grasses such as *Arrhenatherum elatius*, *Bromus hordeaceus*, *Dactylis glomerata* and *Trisetum flavescens*. Regarding small size plants, only *Anthoxanthum odoratum* and some species characterized by a high nutrients demand, like *Cerastium fontanum*, *Galium album* and *Myosotis arvensis* were observed. In this situation, *Brachypodium* could not attain the necessary levels of light radiation (PAR) and its diffusion was completely hampered.

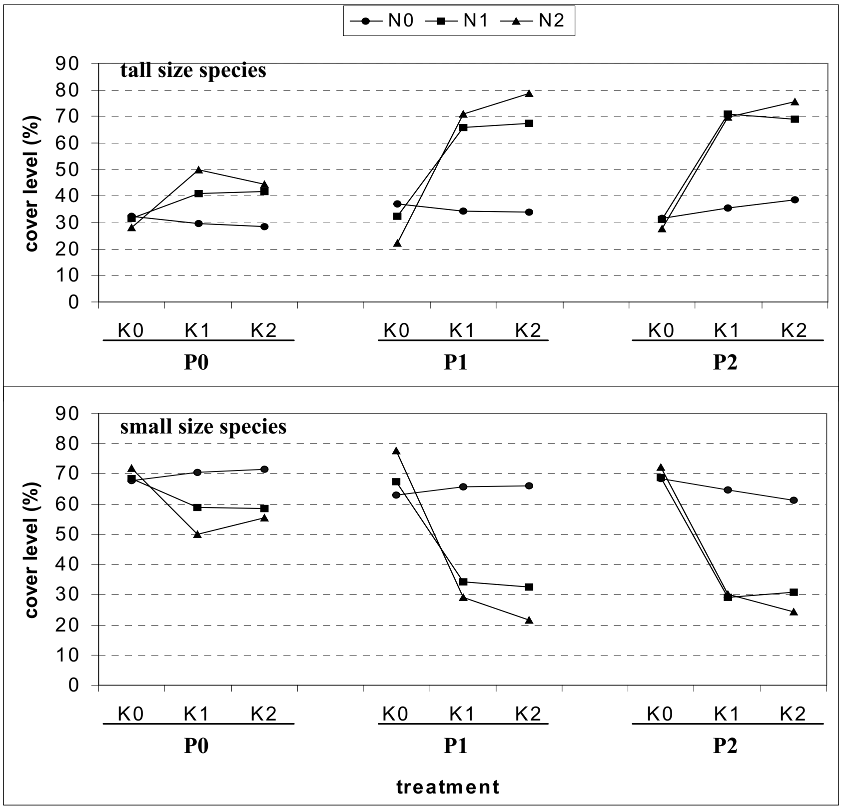

Figure 2. Cover values considering the tall and small size plants (species names are quoted in the text) in the different treatments: average of the annual values in the period 1977–2000

On the other hand, in the case of only K or KN fertilisation, the botanical composition of the sward highlighted a high proportion of small size plants such as *Carex caryophyllea*, *Carex montana*, *Anthoxanthum odoratum* and *Leontodon hispidus*, and an increased amount of *Brachypodium* was encountered. Also *Leucanthemum vulgare*, *Salvia pratensis* and *Lotus corniculatus* increased their cover levels. On the contrary, many tall size grasses with high forage value, such as *Arrhenatherum elatius*, *Poa pratensis* and *Trisetum flavescens* were reduced in a significant way; only *Dactlylis glomerata* was not negatively affected. Moreover, when both the elements (N and K) were present, for each level of K the higher expanding behaviour of *Brachypodium* was observed for the N2 rate (7.8 for N2K1 and 16.2 for N2K2, respectively). However, the capability of this plant of becoming highly competitive in conditions of limiting P and with N extra supply in comparison with other species was already measured in other situations (Bobbink and Willems, 1987; Bobbink *et al*., 1988; Willems, 2001) and probably depends on a better uptake efficiency of the soil nutrients. Finally, in the case of only P-treated plots, or even if this element was associated to N or K, in spite of the wide presence of small size plants characterizing the phytocoenosis, particularly with *Anthoxanthum odoratum* and *Cerastium fontanum*, *Brachypodium* was not able to spread, and its growth was completely restricted. In these treatments also *Avenula pubescens*, *Lolium perenne* and *Poa trivialis* increased, in comparison with the control. Therefore, it is likely that in this case was the distribution of P to prevent the spreading of *Brachypodium*, pointing out the tendency of this species of being better able to grow at low P input in comparison with other chalk grassland species, as it was already reported in other study cases (Bobbink *et al*., 1988).

Conclusions

According to the present work, the adoption and even the regime of fertilisation represent an important means that can strongly influence the presence and the spreading of *Brachypodium*; thus, a particular attention has to be paid during this practice in the management of the alpine grasslands. It resulted that a NPK, well-balanced fertilization did no foster the presence of *Brachypodium*, limiting, indeed, its spreading; this kind of fertilisation, moreover, produced an increase in the proportion of several grasses with high forage value. In the same way, also fertilisation with low levels of N, with N and P or P and K limited the presence of this species. On the opposite, fertilisation with only K and especially with N and K, producing a significant increase of *Brachypodium* and a reduction of many fodder species should be avoided; in this case an addition of P, even in a small amount is suggested.

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Floristic diversity of flooded meadows

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Abstract

River valleys, due to their variable morphological structure and sites conditions over small scales, especially those associated with humidity, create conditions conducive to the development of different floristic communities. The purpose of long-term investigations, which were carried out in river valleys of Western Poland, was to ascertain the phyto-sociological diversity, floristic species richness (number of species), floristic diversity (Shannon-Wiener index) and the degree of synanthropisation (proportion of native and alien species) of flooded meadows and relate this to particular environmental factors primarily humidity and utilisation intensity (number of cuts). On the basis of approximately 2000 phyto-sociological surveys (Braun-Blanquet method), the majority of the meadow communities were classified as Phragmitetea and Molinio-Arrhenatheretea. Their diversity depended, primarily, on the duration of flooding and site trophic properties. Decreasing site humidity in the case of meadow communities of the Molinio-Arrhenatheretea class, favoured the development of transition communities that reduce the species richness and diversity. However, there was an inverse response in plant communities from the Phragmitetea class with irregular flooding and restricted intensive agricultural utilisation decreasing the floristic diversity.

Keywords: meadow swards after suspension of utilization, floristic diversity, utilisation intensity

Introduction

River valleys, due to their variable morphological structure and sites conditions over small, especially those associated with humidity, create conditions conducive to the scales development of different floristic communities (Borysiak, 1994; Kryszak and Grynia, 2001). Although extensive utilisation that might be imposed by site conditions guaranteed a relative ecological balance the river management and regulation resulted in disturbances of the hydrological cycle and changes in the water balance (Grynia and Kryszak 1992). These factors have major impacts on plant communities, which are characterised by different floristic intricacies and diversities. Many of them exhibit a substantial degree of native species and play an important role as an enclave of the ecological corridor.

The purpose of the long-term investigations carried out in river valleys of Western Poland was to assess the phytosociological variability, species richness and floristic diversity as well as the degree of synanthropisation of flooded meadows set against the background of site conditions, primarily humidity as well as the intensity of their utilisation.

Materials and Methods

Based on approximately 1800 samples of between 75-100 m^2, phytosociological surveys were undertaken in 1967 (612 samples) and 2003 (1187 samples) using the method of Braun-Blanquet. The following parameters were assessed:

- phytosociological variability – identifying syntaxons below an association,
- floristic richness – on the basis of the number of species (total = the cumulative species richness of all floristic surveys from plant community, and mean in a floristic survey),

- floristic diversity – using the Shannon-Wiener index (H'),
- degree of synanthropisation – proportion of native, alien and synanthropic species in the total number of species (Jackowiak 1990).

The floristic status of the communities occurring in flooded meadows was evaluated against the backdrop of site conditions assessed by the Ellenberg indicator values (1992) as well as the type (cutting, cutting-pasturing) and intensity (number of cuts) of the utilisation.

Results and Discussion

The identified meadow communities of flooded areas were assigned to the *Phragmitetea* and *Molinio-Arrhenatheretea* classes based on their floristic composition. The area occupied by them as well as their floristic composition is the consequence of the geomorphological diversification of individual valleys. Because of spatial variability in the valleys some syntaxons developed lower phytosociological units as sub-associations or variants. In wide river valleys, e.g. the Warta, *Phalaridetum arundinaceae* and *Alopecuretum pratensis* covered 25-40% of their area, developing 4 syntaxons of *Phalaridetum arundinaeae* and 6 syntaxons of *Alopecuretum pratensis.* In smaller river valleys e.g. Obra, Barycz the above plant communities are usually found only in their typical forms (Table 1).

Table 1. The effect of site conditions on the geobotanical diversification of selected grass communities of flooded areas (Warta river valley, 2003)

Syntaxons	Number of serveys	Ground water level (m)	Ellenberg's indicator values	
			F	N
Phalaridetum arundinaceae				
typicum	150	0.4–0.8	8.5	4.8
alopecuretosum pratensis	180	0.7–1.1	7.9	5.2
ranunculosum repenti	43	0.8–1.2	7.1	5.7
var. with *Holcus lanatus*	32	1.0–1.5	6.2	4.9
Alopecuretum pratensis				
typicum	283	0.9–1.3	6.5	5.1
phalaridetosum arundinaceae	55	0.8–1.0	7.0	6.5
var. with *Lotus uliginosus*	30	1.1–1.4	6.3	5.4
var. with *Poa trivialis*	41	1.0–1.5	6.1	5.2
var. with *Poa pratensis*	86	1.2–1.6	5.8	6.1
trisetosum flavescentis	22	1.4–1.9	5.2	5.5

* F – soil moisture condition index; N – soil nitrogen index content

Changes in the floristic composition of grass communities which are frequently, of a temporary, inconsistent nature can be attributed primarily to the level of water in the rivers, as this governs the range of spring flood sand reduces the level of ground waters. The invasion of plant species characteristic for other phytosociological units, most often for moderate soil moisture sites, results in an increase in species richness in the floristically poor, typically rush communities. On the other hand, in the case of meadow communities of the *Molinio-Arrhenatheretea* classes, the number of plants in the sward and, simultaneously, aggressive species from the *Molinietalia* genus become dominant, e.g. *Deschampsia caespitosa, Holcus lanatus, Juncus effusus* (Table 2).

Table 2. Geobotanical and floristic diversification of grass communities from flooded areas

Syn4.9tax	Number of serve's		Characteristic plant species in years (%)		Number of species			H' in years	
					Total	Mean in servey/years			
	1967	2003	1967	2003		1967	2003	1967	2003
Caricetum gracilis	31	76	72.9	40.6	28	17.0	19.5	1.8	2.2
Phragmitetum australis	23	49	69.9	23.5	17	8.2	14.0	1.1	1.3
Glycerietum maximae	27	55	49.7	20.5	51	14.3	20.5	1.3	1.6
Sparganio-Glycerietum fluitantis	15	33	70.5	61.5	26	11.1	13.7	1.9	3.2
Phalaridetum arundinaceae									
typicum	96	150	88.4	54.5	18	8.1	11.5	1.2	1.6
alopecuretosum pratensis	106	180	45.6	38.3	22	12.3	14.2	1.5	1.9
ranuculosum repenti	18	43	62.9	45.2	31	13.1	16.9	1.7	2.1
var. with *Holcus lanatus*	15	32	68.6	51.1	35	11.0	18.7	1.9	2.3
Alopecuretum pratensis									
typicum	128	283	65.1	35.5	232	39.2	23.2	2.7	3.6
phalaridetum arundinaceae	31	55	37.4	30.0	71	11.0	14.7	1.5	2.1
var. with *Lotus uliginosus*	13	30	53.2	49.7	124	46.1	35.1	2.4	1.9
var. with *Poa trivialis*	25	41	49.5	40.3	78	22.2	20.0	1.8	1.5
var. with *Poa pratensis*	36	86	42.1	34.1	73	19.8	21.1	1.2	2.3
trisetosum flavescentis	11	22	37.9	29.5	25	21.0	14.0	3.2	2.5
Ranunculo-Agropyretum repentis	20	25	64.1	48.2	62	25.2	33.0	2.1	2.7
Ranunculo-Alopecuretum geniculati	17	27	56.1	51.9	27	9.3	19.6	2.8	3.6

Communities from flooded areas are characterised by a considerably high degree of native species. Only areas which are more easily accessible after rapidly retreating floodwaters are utilised intensively for hay and as pastures because of their greater production potential. Conseqyuently the impact of grazing and utilization on the development of these meadow communities is more apparent than the influence of site conditions. This is evident in both: their floristic richness and diversity as well as occurrence of synanthropic and alien species (Table 3).

Meadow communities utilised more intensively exhibit a lower index of floristic diversity (H') and a higher proportion of synanthropic species as well as alien species (anthropophytes). These include most commonly the sown high-yielding grass species, such as, for example, *Lolium multiflorum* or *L. perenne***.** The persistent cutting of rushes *Glycerietum maximae* which occurr in flooded areas supports the development of floristically poor patches in which the water manna grass (*Glyceria maxima*) persists in aggregates. However, high utilisation of *Phalaridetum arundinaceae* meadows causes some loosening of the sward and appearance of other plant species, such as, e.g. *Agropyron repens, Myosotis palustris, Ranunculus repens, Polygonum hydropiper* (Brzeg and Ratyńska, 1991).

The number of plant species occurring in the sward of these meadows is also influenced by the extent of eutrophication of floods which weaken floristic composition. Flooded turfs, which occur in some river valleys of Western Poland in flat-bottomed depressions – *Ranunculo-Alopecuretum geniculati* and in fresh and dry sites – *Ranunculo-Agropyretum repentis,* differ with regard to their botanical composition and floristic diversity. Nevertheless, their floristic composition is very similar to natural turfs developing in the sub-arctic regions of

Northern Europe trampled on and fertilised by grazing reindeer (Borysiak, 1994; Sykora, 1983). Pasture utilisation of these turfs supports the development of (1) tillering grass species such as *Alopecurus geniculatus* and *Agrostis stolonifera,* (2) as well as forbs like *Potentilla anserina, P. reptans, Ranunculus repens* and *Trifolium repens.* These plant species are particularly common in turfs, developed on swampy deposits and excessively grazed, which causes considerable damage due to trampling or tearing by grazing animals.

Table 3. Effect of utilisation on the floristic diversity and proportion of synanthropic species in the sward of selected meadow communities of flooded areas

Plant community	Utilisation	H'	Proportion of total number of plant species (%)	
			synanthropic	alien
Phalaridetum arundinaceae	1 *cut*	2.66	63.6	6.8
	3 cuts	1.80	68.5	10.4
Alopecuretum pratensis	1 cut	3.68	57.5	2.5
	2 cuts+ grazing	1.95	79.7	7.8
Ranunculo-Agropyretum repentis	Animal grazing	2.33	70.8	5.4
Ranunculo-Alopecuretum geniculati	Animal grazing	3.20	76.9	3.8

Conclusions

Both site conditions and utilisation affect the diversification of meadow communities growing on flooded areas as confirmed by the development of lower phytosociological units.

Newly developed meadow communities, in partial dry and swampy sites, are characterised by higher floristic richness and diversity as result of the invasion of plant species from the *Molinio-Arrhenatheretea* class, which is characteristic for sites of variable humidity.

Partial drying and the utilisation of the meadow communities from the *Molinio-Arrhenatheretea* class reduce the species richness and diversity and, at the same time, increase the number and proportion of synanthropic as well as of alien species (anthropophytes).

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Yield and quality of alfalfa grassland as affected by different strategies of fertilisation

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Abstract

In the three-year trial period 2002–2004 this research conducted in Southern Italy on a rain-fed alfalfa permanent grassland was aimed at comparing conventional mineral fertilisation (P_2O_5) with two organic composts, from municipal solid waste (MSW compost) and from olive pomace waste (OPW compost), and at studying the effect of fertiliser treatments on quantitative, qualitative and biological parameters of the legume and on some soil characteristics.
The results obtained throughout the experiment show that the organic fertilisers did not negatively affect the alfalfa performance. In fact, MSW and OPW composts were able to ensure dry matter yields and protein contents slightly lower than those obtained with inorganic P_2O_5 and a good level of persistency over time. Moreover, the organic treatments increased the total organic carbon in the soil, while no significant variation of heavy metals was observed.

Keywords: alfalfa, compost, yield, quality, persistence, heavy metals

Introduction

The reduction of inorganic fertiliser application is seen as an important issue in Italy, whether from the economic point of view (costs of production), or from the environmental one (pollution risks) (Giller *et al*., 2002), as well as the need to dispose or to usefully employ biomasses of different origin (oil-mill, distillery, dump). Therefore, the composting of organic materials and the application of composts could be an interesting agricultural practice, especially in Mediterranean conditions, where the mineralization processes are high and the soils need more organic matter, as suggested by Montemurro *et al*. (2004), even if it is necessary to ascertain the effects of possible heavy metal accumulation in the soils.
In the light of these considerations, it may be interesting to evaluate the possibility of using organic composts as fertilisers and/or amendments, able to supply nutritive elements to plants and to improve the most important physical and chemical soil parameters. On the basis of the positive results obtained in previous experiments conducted on other crops by our Institute (Montemurro *et al*., 2003; Maiorana *et al*., 2004), this research was designed to study the quantitative, qualitative and biological performances of an alfalfa crop treated with different fertilisation strategies (organic and mineral) and to check the level of heavy metals in the soil.

Materials and Methods

The experiment was carried out at Rutigliano (Southern Italy, 41°01′ latitude N, 4°39′ longitude E, 112 m a.s.l.) on the experimental farm of the Institute. The soil is a Rhodoxeralf Lithic Ruptic (according to the Soil Taxonomy USDA), with total N = 0.142%, available P (as P_2O_5) = 49 mg kg^{-1}, exchangeable K (as K_2O) = 741 mg kg^{-1}, organic matter = 2.07%, pH = 7.54. The climate is classified as ‘accentuated thermomediterranean’ (Unesco-FAO classification). On permanent grassland of rain-fed alfalfa (*Medicago sativa* L.), two fertilisation strategies were compared: 1) organic, with Municipal Solid Waste (MSW compost) or with Olive Pomace Waste (OPW compost), 2) mineral, with 75 kg P_2O_5 ha^{-1}

(Min). Each compost was applied in such quantity to supply crops the same amount of P_2O_5 applied as chemical fertiliser. The OPW compost consisted of 82% of olive pomace, 10% of poultry manure and 8% of wheat straw.

A completely randomised design, with three replicates, was applied on plots of 7 m^2 each. Green forage yields and plants persistence capacity were determined each year from 2002 to 2004 inclusive. The contents of dry matter (after oven-drying at 105 °C) and crude protein (at 70 °C) were measured later on green samples. At the beginning (t_0) and the end (t_f) of experiment the levels of the most important heavy metals (Zn, Cu, Pb) and of Total Organic Carbon (TOC) were determined in the experimental plots. Statistical analysis of data was made by using the SAS procedures (SAS Institute, 1998). Differences among the means were evaluated with the Snedecor-Newman-Keuls test (SNK-test).

Results and Discussion

The weather during the trial period was characterized by mean monthly temperatures similar to that of the long-term average 1977–2001 (15.7 °C vs. 15.8 of 2002 and 15.6 °C of 2003 and 2004). The annual rainfall was lower than the long-term average (414.5 mm vs. 593.7 mm) only in the third year (2004), while in the other two years it was higher (611.9 and 627.7 mm for 2002 and 2003, respectively). The rains showed a fairly good monthly distribution in the March–July period, particularly in 2004. This is the most important period in the semiarid conditions of South Italy, for the effects that it can have on the number of harvests per annum. In fact, though the lowest annual rainfall occurred in this year (414.5 mm), very effective rainfall (187.0 mm) was observed in the spring-summer months.

Alfalfa showed the best yield responses (green forage and dry matter, Table 1) in the second and the third trial years, with differences always statistically significant, thus confirming its ability to achieve the highest level of production in the year following sowing. In contrast, protein content was highest (23.1%) in 2002, the least productive year.

Table 1. Effect of years and fertiliser treatments on the quantitative and qualitative parameters of alfalfa

	Green forage ($t\ ha^{-1}$)	Dry matter ($t\ ha^{-1}$)	Dry matter (%)	Protein content (%)
YEARS				
2002	29.8 b	7.7 b	25.8	23.1 a
2003	59.4 a	14.4 a	24.2	19.6 b
2004	61.5 a	14.4 a	23.4	18.5 b
TREATMENTS				
MSW compost	50.2	12.0	23.9	20.9
OPW compost	47.7	11.6	24.3	20.2
Min	52.9	12.9	24.4	20.0

Values with different letters in columns are significantly different at $P \leq 0.05$ (SNK test)

With reference to fertiliser treatments (Table 1), it is of particular note that their effects have shown clear similarities; in fact, there was a tendency for all of parameters to present values slightly lower than the Min treatment, with differences never being statistically significant. In confirmation of the equivalent fertilising capability of the three treatments, DM yields were similar for all treatments in each of the three harvest years, despite the differences in level of production between the three years.

Between the composts, the best results were achieved by MSW, with good green forage and dry matter production (50.2 and 12.0 t ha^{-1}) and the highest protein content (20.9%).

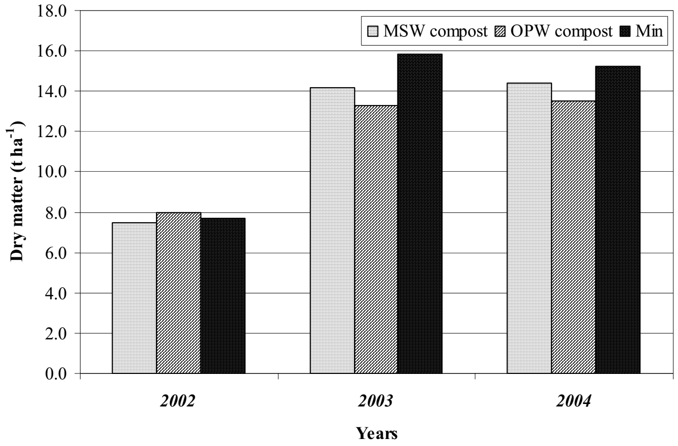

Figure 1. Effect of years and fertiliser treatments on cumulative dry matter production

The effectiveness of MSW and OPW composts was confirmed by the number of harvests made in each year (5 in 2002, 2003 and 2004), which was the same in all three treatments, and by the persistence of the alfalfa stand over time, with a degree of cover which did not vary in comparison with that of Min treatment and in any case ranging from 75 to 85% in the final trial year.
On the whole, these results confirm what found by Montemurro *et al*. (2003) and Maiorana *et al*. (2004) in tomato and sunflower crops, respectively.

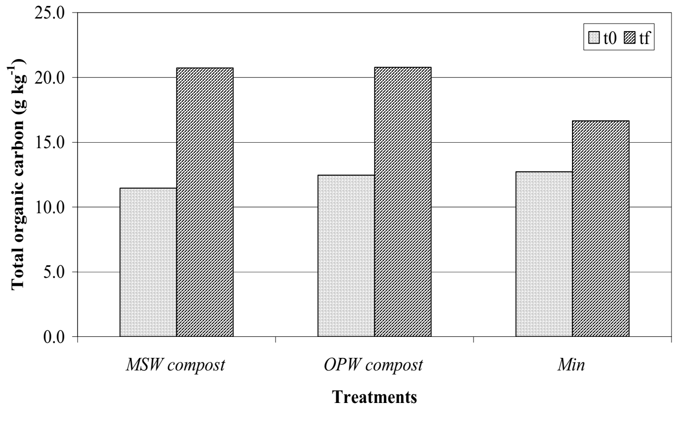

Figure 2. Effect of fertiliser treatments on total organic carbon content at the start (t_0) and the end (t_f) of the experiment

Regarding the levels of heavy metals, Murillo *et al*. (1997) found that the increase in concentration of heavy metals in legume crops was low and that it was more important to

give attention to soil contamination than to the risk of plant or animal toxicity, which was likely to occur only after repeated compost applications for a large number of years.
In our research, no significant increase in the main heavy metals (Zn, Cu and Pb) was found in the soil after three consecutive applications of MSW and OPW composts, probably due to their dilution in the soil, confirming the possible use of these organic materials in Mediterranean conditions.
The content of total organic carbon, measured at the beginning (t_0) and at the end (t_f) of the trial period for each fertiliser treatment (Figure 2), increased by about 24.6% in the plots fertilised with MSW and OPW composts, compared with the Min treatment, indicating the positive effect of amendments on organic carbon. This result highlighted the importance of organic fertilisation in the dry conditions of Southern Italy, where the high mineralization rate could decrease the soil organic matter content (Montemurro *et al*., 2004). In fact, maintaining an appropriate level of soil organic matter ensures soil fertility and minimizes agricultural impact on the environment through the sequestration of organic carbon, reducing erosion phenomena and preserving soil biodiversity.
On the whole, these results indicate the long-term value of compost amendment for supplying slow release mineral nutrients for crop growth, enhancing production, and improving soil fertility, without any risks of environmental pollution. Similar results were found by Sullivan *et al*. (2003).

Conclusions

The responses obtained in the three-year research have shown that both MSW and OPW composts:
1) provided good green forage production, dry matter yield and protein content;
2) enabled good alfalfa persistence over time, with values similar to those obtained with mineral fertiliser application;
3) did not cause significant increases in heavy metal content in the soil;
4) resulted in an increase of total soil organic carbon.

In conclusion, the findings of this study indicate that the application of organic composts to alfalfa crop grown in environments characterised by semiarid conditions seems to be a useful agricultural practice, because they are able to ensure good productive, qualitative and biological performances and to improve some parameters of soils, especially in shallow and infertile soils.

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Floristic changes in meadow swards after suspension of utilisation

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Abstract

The structural transformations in Polish agriculture have resulted in the cessation of agricultural utilisation of parts of arable land and grassland, especially those which occurred in marginal sites. The objective of these long-term investigations was to determine the degree of changes occurring in: (1) species composition of grasslands, (2) their floristic diversity (Shannon-Wiener index), (3) productivity (dry matter yield) and their utilisation value (LWU). In addition, due to decreasing utilisation intensity the impact of site conditions was becoming more dominant (assessment according to Ellenberg, 1992). During the early years, both in the communities of *Phragmitetea* and *Molinio-Arrhenatheretea*, the general and mean numbers of plant species increased and occupied "empty places" (for example, a three-fold increase of plant numbers in *Phalaridetum arundinaceae*). Longer periods of non-utilisation, extending for over 10 years, resulted in the development of new syntaxons where new, more aggressive and expansive species such as *Deschampsia caespitosa, Holcus lanatus, Rumex acetosa, Urtica dioica, Potentilla reptans* began to dominate. Subsequently, seedlings of bushes and trees like *Rosa canina, Alnus sp., Populus sp.* emerged and the number of grassland species in the sward gradually declined.

Keywords: meadow swards after suspension of utilization, floristic diversity, productivity, utilisation value

Introduction

The abandonment or restriction of meadow and pasture utilisation as well as negligence in the maintenance of amelioration facilities and in fertilisation leads to floristic alterations in the sward of meadow communities. A gradual quantitative increase of dicotyledonous plants, in particular nitrophyles or expansive grasses as well as segetal species (which inhabit 'empty places') contribute to the degradation of meadow communities. This results in the development of unstable, transitory floristic communities, secondary communities or even forest-bush communities (Barabasz-Krasny, 2002; Grzegorczyk *et al*., 1999; Kryszak *et al*., 2004; Stypiński and Grobelna, 2000). Bearing in mind the need to maintain meadow communities, both for forage and conservation reasons, it is essential to prevent the on-going negative changes in their floristic composition.

The objective of the performed investigations was to describe the influence of the restriction and abandonment of agricultural utilisation of meadows on changes in the floristic composition and the site conditions of these grassland communities.

Materials and Methods

In the course of long-term experiments, the impact of a gradual restriction and abandonment of the utilisation of meadows and pastures on the sward floristic composition and site conditions was determined. In addition, the productivity and use value of the meadows were examined. The investigation comprised phytosociological surveys (approximately 2000) taken by the method of Braun-Blanquet in several river valleys of western Poland. About 500 surveys where taken from the same area of 75 to 100 m^2 plots during four consecutive successions.

Changes in the sward species composition were assessed on the basis of the total number of species (the cumulative number of all sample quadrats within all fields belonging to the plant community), floristic composition, floristic diversity (Shannon-Wiener index, H') and share of "empty places". The productivity of the examined communities was evaluated on the basis of the dry matter yield and "fodder value scores" (FVS) defined by Filipek (1973), in which "10" – equated to high quality fodder. The following parameters were used to evaluate site conditions: Ellenberg's indicator values (1992) – moisture content (F), soil reaction (R) and soil nitrogen content (N).

Results and Discussion

The restriction or neglect of meadow and pasture utilisation disrupts the community structure. Especially during the initial years after the abandonment, this influence is strong. However, with the passage of time, a relative stabilisation of species composition is achieved in the newly developed communities. This allowed three stages of succession to be identified: (1) initiation – period of 7 –10 years, (2) transistory – period of 10-12 years and (3) final – over 12 years. Each of the succession stages is accompanied by changes in site conditions and decreasing utilisation intensity leading to the development of new communities of different species richness. An example of this kind of succession can be:

1) *Phalaridetum arundinaceae typicum* → *Phalaridetum arundinaceae* var. with *Alopecuretosum pratensis* →*Phalaridetum arundinaceae* var. with *Deschampsia caespitosa* → var. with *Urtica dioica*

2) *Alopecuretum pratensis* → *Alopecuretum pratensis* var. with *Arrhenatherum elatius* → ass. with *Poa pratensis – Festuca rubra*→ ass. with *Calamagrostis epigeios*

3) *Lolio-Cynosuretum* → *Lolio-Cynosuretum* var. with. *Juncus effuses* → *Epilobio-Juncetum effusi* → ass. from *Artemisietea vulgaris* class e.g. *Potentillo-Artemisietum abisinthii*

4) *Arrhenatheretum elatioris* → *Arrhenatheretum elatioris* var. with *Holcus lanatus* → *Holcetum lanati* → ass. from *Artemisietea vulgaris* class e.g. *Artemisio-Tanacetum vulgaris* (Table 1).

The cessation of cutting or grazing also contributes to the accumulation of considerable quantities of non-decomposed organic matter and increase of nitrogen content in the soil. In addition, it supports the invasion of "empty places" by plant species alien to meadow-pasture communities. Meadow species of wide ecological spectrum such as: *Glechoma hederacea, Galium aparine, Cirsium arvense, Anthemis arvensis*, frequently nitrophypes, begin to appear as well as plants from the neighbouring arable land. This leads to changes in the floristic structure of meadow communities in which plants of *Artemisietea, Agropyretea intermedio-repentis* and *Stellarietea mediae* classes increase their share (Table 2).

In addition, the abandonment of utilisation of meadow communities results in a gradual decline of their productivity and fodder value score which is associated with a decreasing proportion of high-yielding cultivated grasses and leguminous plants (Table 3).

Table 1. Changes in species richness and diversity (H') as well as site conditions (Ellenberg's indicator values) of selected grassland communities at various periods after cessation of utilisation

Plant community	Total number of plant species	H'	Ellenberg's indicator values		
			F	R	N
Typical forms					
Phalaridetum arundinaceae	19	1.12	7.7	6.0	4.8
Alopecuretum pratensis	48	2.70	6.8	6.0	4.7
Lolio-Cynosuretum	37	2.14	5.3	5.5	5.2
Arrhenatheretum elatioris	43	2.95	5.1	5.7	4.6
Stage of succession initiation – period of 7–10 years					
Phalaridetum arundinaceae var. with *Alopecurus pratensis*	47	1.58	7.3	4.7	4.5
Alopecuretum pratensis var. with *Arrhenatherum elatius*	61	2.91	6.5	5.9	5.5
Lolio-Cynosuretum var. with *Juncus effusi*	63	2.74	5.8	6.2	5.8
Arrhnatheretum elatioris var. with *Holcus lanatus*	50	3.25	4.8	5.8	4.9
Transitory stage – period of 10–12 years					
Phalaridetum arundinaceae var. with *Deschampsia caespitosa*	99	1.84	6.0	3.4	3.4
with *Poa pratensis-Festuca rubra*	87	2.17	4.8	4.3	4.2
Epilobio-Juncetum effusi	91	2.06	5.7	4.9	4.5
Holcetum lanati	61	1.94	5.1	4.4	4.3
Final stage – over 12 years					
with *Urtica dioica*	18	1.60	4.9	4.3	6.7
with *Calamagrostis epigeios*	27	1.35	4.5	6.0	4.9
Potentiilo-Artemisetum abisinthii	31	1.75	3.9	3.7	4.3
Artemisio-Tanacetum vulgaris	57	1.64	3.7	4.1	3.8

Table 2. Changes in the phytosociological structure of selected meadow-pasture communities at 7-10 years after the cessation of utilisation (in % of characteristic species)

Plant community	Empty places*/ (%)	Characteristic species for class			
		Phragmitetea	*Molinio-Arrhenatheretea*	*Artemisietea*	Other
Phalaridetum arundinaceae	15.0	15.4	51.5	10.5	22.6
Alopecuretum pratensis	19.4	7.7	61.8	7.2	23.3
Lolio-Cynosuretum	21.2	3.2	54.2	14.7	27.9
Arrhenatheretum elatioris	24.1	1.8	44.2	21.3	32.7

*/ mean from all surveys

After 10–12 years of abandonment, the sward of meadow communities in this transistory stage is invaded by non-cultivated, expansion grass species such as *Deschampsia caespitosa, Holcus lanatus* and dicotyledonous plants as *Rumex acetosa*, *Urtica dioica*, *Cirsium arvense*, *Potentilla reptans.* In later stages seedlings of bushes and trees e.g. *Rosa canina*, *Alnus incana*, *Populus sp*. establish. Their greater numbers, even to over 10%, are found in the loose sward communities *Phalaridetum arundinaceae, Alopecuretum pratensis* with a higher share of "empty places", as also confirmed by studies carried out by Michalik (1990). This process can be attributed to a better light availability for germinating seeds of bushes and trees carried by wind. On the other hand, these species do not appear in very dense phytocenoses of nitrophytes, e.g. from *Urtica dioca*.

Table 3. Proportion of cultivated grasses, DM yield and fodder value score (FVS) of selected meadow-pasture communities before (A) and 7 years after the cessation of utilisation (B)

Plant community	Cultivated grasses (%)		Legume (%)		DM yield (t ha^{-1})		FVS	
	A	B	A	B	A	B	A	B
Phalaridetum arundinaceae	45.3	17.3	1.0	4.7	11.2	6.7	4.8	3.5
Alopecuretum pratensis	30.0	22.8	4.9	2.5	8.1	5.0	5.8	3.9
Lolio-Cynosuretum	42.1	12.4	8.1	5.8	6.4	3.2	6.6	4.1
Arrhenatheretum elatioris	31.5	18.0	9.3	4.3	6.0	2.8	5.5	4.3

These substantial floristic changes in meadow communities, developed after the cessation of utilisation, are unfavourable not only from the agricultural point of view but also from the ecological one. Together with succession changes, quite frequently, plants of narrow ecological scale, rare or even protected like *Dactylorhiza sp*. and *Trollius europeus* disappear from the sward. Therefore, the maintenance of meadow-pasture communities is associated with their utilisation, albeit extensive.

Conclusions

On the basis of the performed long-term and comprehensive investigations, it can be stated that the cessation of utilisation (abandonment of meadow cutting or pasture grazing) of grassland communities leads to:

1. sward floristic changes. Initially, these changes are associated with the settlement of numerous plant species of a broad ecological scale in the loosened sward. During the later stages of succession, the sward is further impoverished due to the dominance of expansive grasses and dicotyledonous plants or even appearance of bush and tree seedlings.
2. decline of productivity as well as their fodder value score which is associated, among others, with the declining proportion of high-yielding cultivated grasses and leguminous plants as well as species sward impoverishment.

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Vegetation pattern after ten years of grazing on meadow and forest pastures

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Abstract

The effects of grazing on vegetation and animal production have been studied in a multi-disciplinary project at Tohmajärvi, Finland, since 1994. The study area consisted of 4.0 ha meadow and 13.3 ha forest. In total 9 pairs of permanent sampling areas (one 12 × 12 m fenced sampling area as a non-grazed control, and an adjacent grazed one) were established, 3 pairs on meadow and 6 pairs in the forested areas. The area was grazed with suckler cows using stocking rates of 0.4–0.6 livestock units ha^{-1}. In 2004 the total number of plant species was higher in grazed forest sampling areas than in control ones, and lower in grazed meadow sampling areas. There was no difference between grazed and control in total coverage of vascular plants, but coverage of bryophytes was, in general, greater in control sampling areas. Geostatistical analyses showed even and intensive grazing in meadow, mean height of the highest plants was only 15 to 19 cm. Patch size in meadow control was about 5 m, and the grazed patches were about 4 m. In forested areas the grazed patches were smaller – less than 2 m. Patch size in forested controls varied up to about 5 m but patch structure was not always very clear. Grazing increased ecological variation of the areas creating new niches for more diverse biotic assemblages, but species diversity increased only in the forested areas.

Keywords: species diversity, vegetation structure, suckler cows, geostatistics

Introduction

Due to intensification of farming practices traditional landscapes – old fields, natural meadows, forest pastures etc – have partially disappeared. An essential part of present biodiversity – numerous plant, animal and insect species - depends on grazing and extensive pastures. According to Rassi *et al*. (1992) over 21 % of endangered insect species in Finland live in culture environments. From this point of view it is important to increase the abundance of traditional landscapes. Since the production potential and feed demand of suckler cows are lower than those of modern dairy cattle, suckler cow production could be an alternative to increase the abundance of extensive pastures and traditional landscapes. In order to study simultaneously both the agricultural production and the effect of grazing on vegetation and animal production, a multi-disciplinary project was started at Tohmajärvi, Finland, in 1994.

Material and Methods

The study area consisted of 4.0 ha of meadow and 13.3 ha of forest divided into 5 paddocks. The area was rotationally grazed with spring calving suckler cows with calves during the summer months (June – August; 65–84 days per year). At the beginning of the project mean stocking rate (SR) was 0.4 livestock units (LU) ha^{-1} but, over the course of the project it was increased to 0.5 and then to 0.6 LU ha^{-1}. Live weight (LW), and body condition score

(Scottish Agricultural College 1984) of animals were recorded. Vegetation was analysed on three of the used paddocks (MEADOW, a semi natural meadow; MIXEDFOR, a mixture of aspen (*Alnus incana* L.), birch (*Betula pendula* L.) and Scots pine (*Pinus silvestris* L.) forest, and BIRCHFOR, a combination of birch (*Betula pubescens* L.) and spruce (*Picea abies* L.) forest). On each paddock, three pairs of permanent sampling areas were established in 1994, each pair containing a 12 × 12 m fenced area as a non-grazed control, and an adjacent grazed area, making together nine grazed and nine control areas. These pairs of sampling areas are indicated with A, B and C in results. The effects of grazing on vegetation during the early part of the study is presented in Tuupanen *et al.* (1997) and the effect of grazing on Carabidae is presented in Hokkanen *et al.* (1998). This paper focuses in the measurements of vegetation structure.

Vascular plants were studied in 1994, 1996 and 2004 in July by determining percentage cover of vegetation from five permanent 1 m^2 quadrats from each sampling area (together 90 vegetation quadrats). Bryophytes were studied in 1998, 2001, 2003 for percentage cover of species, also from five permanent quadrats per sampling area. The cover of bryophytes, vascular plants and litter was defined together with the percentage of disturbed soil. This analysis gives the results for bryophytes 2003 and vascular plants 2004.

In 2004, to reveal the patchiness structure of the vegetation, six North – South transects were placed 2 m apart from each other in across each sampling area(the length of each transect was 10 m). Maximum height of the vegetation was recorded along the transect in 20 cm intervals from 10 × 10 cm quadrates (n = 300 per sampling area). Semivariance analysis was performed using GS+ (Gamma Design Software) geostatistical package.

Results and Discussion

During the first three years the SR used was considered too low compared to the productivity potential of the meadow. Therefore the SR was increased during the experiment in 1997 to 0.5 LU $ha^{-1}$and again in 2001 to 0.6 LU ha^{-1}. This lead to higher utilization of herbage and consequently higher animal production expressed as LU grazing days per hectare (Fig 1). In MIXEDFOR BIRCHFOR the number of grazing days decreased slightly whereas the number of grazing days was rather unchanged on MIXEDFOR. The mean calf LW gain was 1.36 kg d^{-1} (SD over years 0.08 kg d^{-1}). The mean initial LW of cows was 647 kg (SD over years 76 kg) and the LW change of cows during grazing was 0.095 kg d^{-1} (SD over years 0.206 kg d^{-1}). In 6 out of the 10 years the body condition score of the cows was near target (3.0), but in some years it remained low. The length of grazing period varied between 65 and 84 days.

The number of vascular plant species gradually increased in the grazed forest areas, and the cover of most common plant species decreased simultaneously (Table 1). However, the number of species in meadow is clearly decreasing due to grazing, and also the cover of bryophytes was clearly smaller in grazed meadow. In forest areas the cover and number of bryophyte species had no consistent trend (Table 1).

Cattle grazing had a substantial effect on bryophytes. A group of species, such as family *Brachytheciaceae* and *Atrichum undulatum,* has increased in the grazed areas. Strong disturbance of soil on the pasture and less shadowy fielded layer might be the main reasons for the observed changes.

Table 1. Vascular plant and bryophyte numbers and percentage cover in MEADOW and forested paddocks (A, B and C denote for pairs of sampling areas)

	BIRCHFOR					
	A		B		C	
	Control	Grazed	Control	Grazed	Control	Grazed
Nr of vascular plant species	34	39	25	24	23	33
Nr of bryophyte species	6	8	6	8	5	15
Total nr of species	40	47	31	32	28	48
Cover of vasc.plants (%)	94.1	93.2	118.5	102.9	102.3	106.9
Cover of bryophytes (%)	13.6	7.2	25.2	2.6	1.7	15.7
	MIXEDFOR					
	A		B		C	
	Control	Grazed	Control	Grazed	Control	Grazed
Nr of vascular plant species	35	40	31	35	18	23
Nr of bryophyte species	18	16	10	18	15	13
Total nr of species	53	56	41	53	33	36
Cover of vasc.plants (%)	100.8	100.2	109.7	111	104.6	89.4
Cover of bryophytes (%)	51.5	37.8	3.3	13.2	22.9	14.3
	MEADOW					
	A		B		C	
	Control	Grazed	Control	Grazed	Control	Grazed
Nr of vascular plant species	33	25	23	15	19	15
Nr of bryophyte species	16	13	17	9	8	6
Total nr of species	49	38	40	24	27	21
Cover of vasc.plants (%)	106.7	92.8	99.1	86	107.4	61.1
Cover of bryophytes (%)	21.9	8.5	19.8	6.7	52.9	2.9

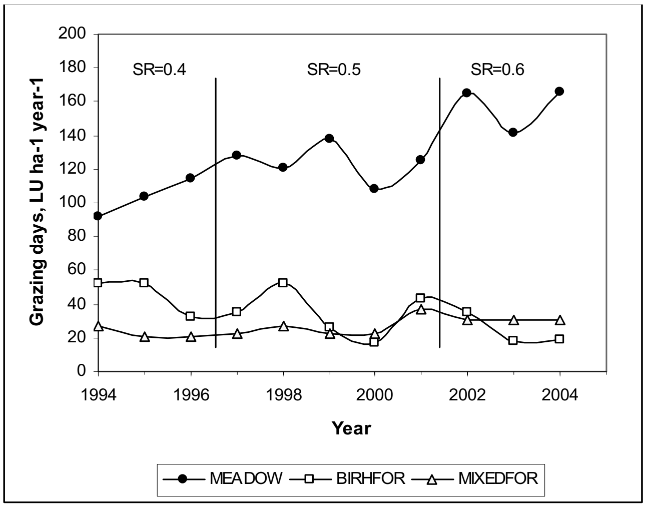

Figure 1. Production of three paddocks as LU grazing days per hectare per year. Vertical lines represent periods with increasing stocking rates (SR) during the experiment

Intensive grazing changes edaphic conditions of pasture and should predetermine species composition of eutrophic soils being tolerant to nitrogen. This may change proportions of major groups of plants in flora, but particularly that of liverworts and mosses (Potemkin, unpublished, Czernyadjeva *et al.,* 2005). Bryophytes, especially liverworts and hornworts are poor competitors compared with vascular plants (Czernyadjeva *et al.,* 2005). Despite the fact that many liverworts are inhabitants of bare soil, they are very sensitive to eutrophication of soil (e.g., Arnell, 1956; Duell, 1991).

Table 2. Semivariogram model data for BIRCHFOR and MEADOW

Sampling area	Model	Nugget Co	Sill Co+C	Range A0 or 3A0	Proportion C/(Co+C)	R2	Rss
BIRCHFOR contr	Spherical	414	2650	1052	0.844	0.93	1.43E+06
B. grazed	Exponential	191	825	105	0.768	0.469	157343
MEADOW contr	Exponential	1004	2009	2109	0.5	0.89	234312
M. grazed	Exponential	0.04	0.168	315	0.762	0.889	3.19E-03

In control sampling areas field layer vegetation height was roughly similar in meadow and forests. The mean height of the highest field layer vascular plants in the three MEADOW control areas varied from 79 to 105 cm, and in BIRCHFOR from 53 to 98 cm. Semivariograms (Fig 2., Table 3) indicate that patch sizes extend to almost five metres in both MEADOW and BIRCHFOR. MEADOW was, in general, grazed low – the mean height of the highest plants varied from 15–19 cm, while the grazed BIRCHFOR varied from 21 to 69 cm. The figures from control areas demonstrate the general variability of vegetation height in these environments. The differences have been amplified by grazing. Semivariograms show decreasing autocorrelation and greater patches in grazed sampling areas in the even and uniform meadows (up to 4 m) than in more variable forested areas (up to less than 2 m).

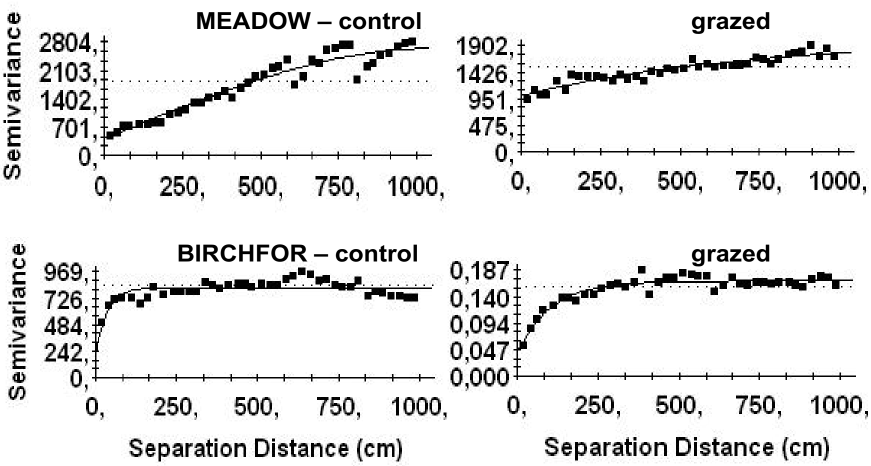

Figure 2. Isotropic variograms of vegetation maximum height from exemplary BIRCHFOR and MEADOW sampling areas in Tohmajärvi grazing experiments (n of pairs in each point of the variograms = 219 – 2654)

Table 3. Variability of vegetation maximum height from exemplary BIRCHFOR and MEADOW sampling areas. Logarithmic transformation (offset by 4) was used for grazed meadow samples before calculating semivariograms. N.a. = not applied

Sampling area	Mean (cm)	SD	Var	Min (cm)	Max (cm)	N	Skewness	Kurtosis	Transfor-mation
BIRCHFOR contr	98.2	42.8	1827.5	0	200	281	0.45	–0.7	n.a.
B. grazed	69.6	29	841	0	156	275	0.88	0.49	n.a.
MEADOW contr	105.3	39.1	1530.7	0	180	300	–0.36	–0.62	n.a.
M. grazed	19.7	10.37	107.54	0	67	300	1.53	2.97	log., off 4

Cows keep the field layer vegetation lower also in grazed forest areas than in the forest control. The key forage species have been eaten first (unpublished observations), and these species also tend to be highly reproductive and form dense covers. Grazing thus decreases competition between field layer plants by decreasing highly reproductive plants and creates new niches (Carabids, see Hokkanen *et al.,* 1998). Open, even bare soil supports different biotic assemblages than dense vegetation. This phenomenon clearly increases biodiversity, and changes species composition. Many species thriving in grazed forest areas are endangered in Finland, and the biodiversity changes induced by grazing with stocking rate of 0.4–0.6 LU ha^{-1} are positive according to our study.

Conclusions

Ten years of experimental grazing in Finnish forest and meadow pastures has changed vegetation patterns differently. In meadow vegetation diversity has decreased and in forest increased. Meadow has been grazed evenly and vegetation diversity has decreased in grazed areas compared with the control areas. Grazed patches extend to 4–5 m according to geostatistical analysis. In forests grazing has created new open habitats because grazing is only here and there intensive – grazed patches are up to 2 m. Our results show that grazing in forests with stocking rate of 0.4–0.6 LU ha^{-1} increases species diversity. In spite of the low stocking rate the activity has also significant animal production in the experimental conditions.

Acknowledgements

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Choice of inter-SSR markers for identification of inter-specific clover hybrids between *Trifolium pratense* L. and *Trifolium diffusum* Ehrh.

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Abstract

The aim of the present study was to employ ISSR (inter-simple sequence repeats) markers for the identification of hybrids in crosses between the clover species *T. pratense* x *T. diffusum*. DNA profiles of the interspecific hybrids *T. pratense* x *T. diffusum* were evaluated and compared them with their parental species. Thirteen primers out of 17 tested generated characteristic DNA profiles which differentially marked the two species.

Primers $(CTC)_5$, $(AG)_8T$, $(TC)_8A$, $(CT)_8RG$, and $(AC)_8CG$ generated species-specific fragments for both parents, and these fragments were also found to be present in the hybrids. Fingerprints based on the $(AGAC)_4GC$, $AC(GACA)_4$ $(GACA)_4GT$, $(ATG)_5GA$, and $(AC)_8YA$ primers were complemented by 'novel' fragments not found in the parents. When primers $(CA)_7GA$ and $(TC)_8G$ were used, DNA profiles of all F_1 hybrids were identical to the parental pollinator species, *T. diffusum*. The primers $(ATG)_{5,}$ $(GAA)_5CG$ and $(AC)_8G$ were not suitable for the confirmation of hybridity, since they generated DNA profiles which were either identical to the maternal *T. pratense* species or were indistinct.

Keywords: *T. pratense, T. diffusum,* interspecific hybrids, ISSR fingerprinting, primers

Introduction

The cytological analysis of interspecific clover hybrids is complex, especially in cases where parental species have identical or similar chromosome numbers. Various molecular methods, including analysis of proteins, enzymes and DNA are currently being used for hybrid identification (Hahn, Schoberlein, 1999; Marshall *et al.,* 2003). Molecular markers can be used at various stages of the breeding process, i.e. for the assessment of initial material, selection of pairs for hybridisation, identification of hybridity, and tracking of changes in the genome. DNA markers are widely used in genetic studies and in the breeding of cereals and industrial crops, but this area is not developed to the same extent in forage grasses and legumes. Specific DNA profiles for related species of ryegrass and fescue have been obtained (Pašakinskienė *et al.,* 2000). Using DNA fingerprinting, estimation of genetic diversity of some grass species was carried out (Pulli *et al.,* 2003). Genetic diversity of clover species has been estimated using various DNA fingerprinting methods (Bennett, Mathews, 2003; Ulloa *et al.,* 2003). Recently, the first attempts to employ DNA markers for marking of white clover morphological characters that determine productivity have been reported (Abberton *et al.,* 2003; Marshall *et al.,* 2003).

The objective of this study was to carry out a search for ISSR markers suitable for discrimination between the clover species *T. pratense* L., *T. diffusum* Ehrh. and for the identification of their hybrids.

Materials and Methods

The following clover species and hybrids were studied: 1) *T. pratense* L. (2n = 2x = 14, cross-pollinator), variety 'Liepsna'- high forage yield, medium seed setting, non-resistant to

diseases; 2) *T. diffusum* Ehrh., (2n = 2x = 16, self-pollinator), wild accession – low forage yield, high seed setting, disease resistant; 3) F_1 interspecific hybrids *T. pratense* L. x *T. diffusum* Ehrh. (2n = 4x = 30).
Inter-specific hybrids were developed at the Laboratory of Genetics and Physiology by pollinating the emasculated *T. pratense* flowers with *T. diffusum* pollen and using embryo culture for embryo rescue. F_1Co hybrids (2n = 2x = 15) were sterile: their fertility was restored by a combination of colchicine treatment with embryo/meristem culture and micro-cloning (Dabkevičienė, 2000). The allotetraploids obtained (2n = 4x = 30) produced seeds both by cross-pollination and self-pollination.
DNA samples of *T. pratense* and *T. diffusum* were isolated from the mixture of 30 plants. Twenty plants of inter-specific hybrids were assayed with each primer. DNA was extracted from young leaves by a micro-method following the DNA extraction protocol of Doyle and Doyle (Doyle&Doyle, 1990). Polymerase chain reactions (PCR) were carried out in 25 µl volume in an Eppendorf Master Cycler Gradient thermocycler. Amplification products were analysed in 1.5% agarose gel, and electrophoresis was carried out in 1xTAE buffer. GeneRuler™ DNA Ladder Mix (Fermentas) was used as the DNA fragment size marker.

Results and Discussion

For DNA fingerprint analysis of *T. pratense, T. diffusum* and their F_1 hybrids, 17 microsatellite tetra-, tri- and dinucleotide repeats were used as primers. These primers generated different fingerprints composed of fragments which varied in length from 400 to 3000 bp. Using tetranucleotide motif primers $(AGAC)_4GC$ and $AC(GACA)_4$ 4–6 fragments were obtained (Table 1). Species-specific fragments were obtained that allowed discrimination between the species, although some fragments were common to both species. However, low number of fragments were amplified by the primer $(GACA)_4GT$: one for *T. pratense* and two for *T. diffusum*. It was found that the profiles of hybrids obtained by using tetranucleotide repeats not only provided fragments specific to parental forms, but were also supplemented by 'novel' fragments which were not present in the fingerprints of parental clover species.
Trinucleotide motif primers also generated species-specific fragments. The profiles of the hybrids amplified by the primer $(ATG)_5GA$ were supplemented by 'novel' fragments, while the ones obtained with $(CTC)_5$ had fragments that were parent-specific. Profiles of species and hybrids obtained by the primers $(GAA)_5CG$ and $(AC_{)8}G$ had species-specific fragments that were weakly expressed, which made assessment of hybridity difficult. Profiles of hybrids amplified by $(ATG)_5$ were identical to the maternal parent *T. pratense*, consequently this primer was considered as unsuitable for the identifcation of hybridity.
Most of the dinucleotide motif primers generated species-specific fragments allowing discrimination between *T. pratense* and *T. diffusum.* Fingerprints of hybrids obtained by using $(TC)_8G$ and $(CA)_7GA$ primers were identical to the *T. diffusum* parent species, and this confirmed their hybridity. In some cases the fingerprints obtained with dinucleotide repeats, apart from fragments specific to parental species, were complemented by 'novel' fragments. *T. pratense* and *T. diffusum* DNA profiles obtained by using $(TC)_8C$ and $(AC)_8T$ repeats were identical in fragment composition and size.
These results suggest that ISSR profiles of interspecific hybrids of *T. pratense* x *T. diffusum* can be of 4 types: 1 – identical to *T. pratense;* 2 – identical to *T. diffusum*; 3 – representing *T. pratense* and *T. diffusum* DNA fragments; 4 – representing *T. pratense* and *T. diffusum* and 'novel' DNA fragments that are not present in the parental species. When using tetranucleotide repeat primers, in most cases DNA profiles of hybrids are represented not only by fragments

specific to the parents but also by 'novel' fragments that are not represented in either of the parents (Table 2). One third of trinucleotide motif primers generated DNA profiles of *T. pratense* x *T. diffusum* hybrids identical to the maternal *T. pratense* species, the rest of the primers generated profiles composed of fragments specific to parental forms as well as new-type fragments. When using dinucleotide repeats as primers, hybridity was confirmed by the DNA profiles of three types: (i) identical to *T. diffusum*; (ii) representing *T. pratense* and *T. diffusum* – specific DNA fragments, and (iii) showing *T. pratense* and *T. diffusum* – specific and 'novel' fragments.

Table 1. Number and the range of sizes of ISSR fragments amplified in DNA profiles of *T. pratense, T. diffusum* and their hybrids

Primer code	Oligo-nukleotide sequence	*T. pratense*		*T. diffusum*		*T. pratense* x *T. diffusum*	
		Number of bands	MW range, bp	Number of bands	MW range, bp	Number of bands	MW range, bp
77H	$(AGAC)_4GC$	6	700–3000	6	800–3000	4–11	600–3000
78H	$AC(GACA)_4$	4	700–2500	5	700–2500	3–7	700–2500
104H	$(GACA)_4GT$	1	1050	2	900–950	2–5	550–1050
GO8	$(ATG)_5GA$	2	450–950	1	450	2–4	450–800
UBC807	$(GAA)_5CG$	3	500–750	2	580–850	2	450–550
UBC864	$(ATG)_5$	3	400–750	3	300–700	3	400–750
UBC866	$(CTC)_5$	4	400–1250	3	1000–1350	6	400–1350
UBC822	$(TC)_8A$	3	400–700	7	400–900	4–5	400–900
UBC823	$(TC)_8C$	4	500–900	4	500–900	4	500–900
UBC824	$(TC)_8G$	1	400	1	850	1	850
UBC825	$(AC)_8T$	2	600–800	2	600–800	2	600–800
UBC845	$(AC)_8G$	7	750–1500	5	650–1500	5–7	750–1500
UBC856	$(AC)_8YA$	6	500–1600	8	500–1600	7–10	500–1600
UBC857	$(AC)_8CG$	5	550–2000	8	300–1500	3–8	300–2000
GO7	$(AG)_8T$	3	600–1200	2	650–950	2–4	600–1200
155H	$(CA)_7GA$	3	850–1100	2	1000–1300	2	1000–1300
UBC847	$(CT)_8RG$	2	550–600	4	400–1900	3	400–600

ISSR fingerprints revealed genetic distinctiveness between individual hybrid plants. The highest DNA polymorphism between F_1 hybrids was identified with $(GACA)_4GT$ and $(AC)_8CG$ primers, where 8 different profile types were obtained. When the $(AG)_8T$ primer was used, the hybrids had profiles of 5 different types. A small part (6.7%) of the profiles obtained by this primer were identical to the *T. diffusum* parent, others had all or some of the fragments from both parents. Profiles of hybrids amplified by $(ATG)_5GA$ had 1–3 new supplementary fragments according to which the tested individuals were divided into 3 groups. When $(AGAC)_4GC$, $AC(GACA)_4$ and $(AC)_8YA$ primers were used two types of DNA profiles were amplified in the hybrids. However, when $(CTC)_5$, $(TC)_8A$, $(TC)_8G$ and $(CA)_7GA$ primers were used, DNA fingerprints were identical for all tested hybrids.

Table 2. Hybridity confirmation in the interspecific *T. pratense* x *T. diffusum* hybrids by ISSR fingerprinting presented by characteristic profile frequency (%) for different primer motifs

Primer motif	Profile identical to *T. pratense**	Profile identical to *T. diffusum*	*T. pratense* and *T. diffusum* fragments are present	*T. pratense* and *T. diffusum* and 'novel' fragments are present
Tetra-repeats	0	0	14.3	85.7
Tri-repeats	33.3	0	33.3	33.4
Di-repeats	0	29.5	68.3	2.2

* profile identical to *T. pratense* (female component species) does not allow confirmation of hybridity

Conclusions

Twelve primers out of 17 di-, tri- and tetranucleotide repeats tested by PCR provided us with a useful ISSR fingerprint system for hybridity confirmation of *T. pratense* and *T. diffusum* hybrids.

Hybridity was confirmed by three types of DNA profiles: (i) profile identical to *T. diffusum* (pollinator parent), (ii) profile with the fragments common to *T. pratense* and *T. diffusum*, (iii) profile with the fragments of *T. pratense* and *T. diffusum*, and 'novel' fragments present.

The primers $(GACA)_4GT$, $(ATG)_5GA$, $(AC)_8CG$ and $(AG)_8T$ were shown to have high potential for revealing polymorphism within individual hybrid genotypes.

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Pre-sowing seed inoculation as a factor to improve yield and quality of perennial legumes on acid soils

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Abstract

In the trials set up on the two localities of low productivity, i.e. acid soils, over a 3-year period, lucerne and red clover swards were analysed for yield and quality, after using pre-sowing seed inoculation.
Lucerne seeds of cultivars Medijana and Slavija were inoculated with two pH resistant strains of *Rhizobium meliloti* and one cultivar of red clover, Kolubara, with one strain *Rh. leguminosarum* bv *trifolii* (R).
The inoculation of acid tolerant rhizobial strains in lucerne and red clover seed down on to acid soils gave a significant increase in dry matter yield. The strains used for inoculation proved to be persistent so resulting in a visible yield increase in the third year of utilisation even in the locations with a low soil pH value. In general, the symbiotic performances of the chosen Rhizobium strains have justified the selection of strains tolerant of stressful factors, particularly of acidity, and therefore the use of such strains when growing perennial legume crops on acid soils.

Keywords: lucerne, red clover, inoculation, yield, quality

Introduction

As suggested by Graham and Vance (2000, 2003), the problem of growing legume crops on acid soils can be overcome by selecting tolerant plant species and cultivars as well as the rhizobial germplasm possessing the genes for such a tolerance. A large number of acid soils on which legume crops are grown seem to be deficient in the number of appropriate Rhizobium strains for maximizing biological nitrogen fixation. The populations of *Rhizobium meliloti* indigenous to the lucerne symbiont (*Medicago sativa* L.) i.e. *Rhizobium leguminosarum* bv. *trifolii* to the red clover symbiont (*Trifolium pratense* L.) are present on acid soils, but their symbiotic performances and nitrogen fixing abilities are variable. It follows that specific and efficient strains, competitive for nodule formation and tolerant of stressful factors (acidity, desiccation, high temperatures, salinity, pesticides, pollutants) should be selected. Acidity constrains nitrogen fixation, thereby limiting viability and persistence of rhizobia and reducing inoculation. As *Rhizobium meliloti* seems highly sensitive, strains showing satisfactory activity at rather low values of pH were selected (Clarke *et al*., 1993; del Papa *et al*., 1999; Jarak *et al*., 2003).
Another approach to enhancing nitrogen fixation may be selecting Rhizobium strains (Delic *et al*., 2004) or construction of recombinant strains with enhanced nitrogen fixation capability (Bosworth *et al*., 1994; Schupam *et al*., 1996) for which their performances should be checked in acid substrata.
Low pH reduces the number of cells of *Rhizobium leguminosarum* bv. *trifolii* causing ineffective nodulation (Ibekwe *et al*., 1997). Its performances in terms of symbiosis and nitrogen fixing potential in acid soils are better insofar as the strains were isolated from such soils (Zahran, 1999). In this manner, the acid tolerant strains have already been isolated (Chen *et al*., 1993; Jarak *et al*., 2003).
The paper focussed on the impact inoculation of lucerne seed and red clover by acid tolerant strains *Rh. meliloti* i.e. *Rh. leguminosarum* bv. *trifolii* has on yield and fodder quality.

Materials and Methods

The experiment was set up on two localities: Cacak (Mojsinje) the trial field of the Faculty of Agronomy located on the smonitza (pH – 5.1) and Kraljevo (Adrani) on a privately owned holding on a sandy soil in the stage of becoming smonitza (pH – 6.2), using a randomized block design with four replications. The plot size was $6m^2$, with seeding performed on March 27^{th} 2001. Two cultivars of lucerne (NS Medijana ZMS V, NS Slavija) and one of red clover (Kolubara) were sown.

Pre-sowing inoculation of the lucerne seed was carried out using two acid tolerant strains *Rhizobium meliloti* (R1, R2), the red clover seed also inoculated with the acid tolerant strain *Rhizobium leguminosarum* bv. (R). The strains under consideration belong to the collection of microorganisms of the Institute of Field and Vegetable Crops in Novi Sad.

The experiment was comprised of the following factors: A – lucerne cultivar B – seed inoculation (nil , R1 and R2) and C – location for lucerne, and B_1 – seed inoculation (nil and R) and C_1 – location for red clover, respectively.

Over the 3 years 2001–2003, the total dry matter yields (t/ha^{-1}) of lucerne and red clover, the content of crude protein (CP), crude cellulose (CC), crude fat matter (CFM), crude ash (CA), nitrogen-free extractive matter (NFE) and energy values: the net energy for lactation – NEL and net energy for growth and meat production – NEM, were determined.

The obtained yield results were processed using the analysis of variance of the three-factorial trial for lucerne (cultivar x inoculation x location); and two-factorial trial for red clover (inoculation x location), the individual and interaction differences determined by LSD test with variation coefficient (CV) determined for quality parameters.

Results and Discussion

After using pre-sowing inoculation of lucerne seed, the average increase in the dry matter yield achieved in both cultivars and in both locations over the 3-year period amounted to 9.70% (Table 1). Considering that lucerne is a perennial plant, the long-term effects of inoculants on the dry matter yield should be established. On a yearly basis, the increase in yield using inoculation ranged from 8.70% in the first, 8.29% in the second to 10.99% in the third year compared with the control. As suggested by Schupam *et al*. (1996), the long-term effects of inoculation were manifested in a significantly increased yield of fodder by 2.7 to 3.8% over four years. In addition, Jarak *et al*. (2004) recorded a noticeable increase in lucerne fodder of 10.78% using the inoculation of the acid tolerant *Rhizobium* strains.

Cultivar x strain (R1, R2) interactions were observed in the first and in the second research year. Further, in the trials with three lucerne cultivars and two rhizobium strains selected, Delic *et al*. (2004) noticed not only a considerably higher dry matter yield and total and fixed nitrogen, but also the presence of the interaction cutlivar x strain. The interactions cultivar x inoculation, inoculation x location in the individual years as well as the cultivar x inoculation x location are likely to be the result of changes taking place in the presence of strains of the existing microorganism population and inoculants used. As suggested by Careli *et al*. (2000), the structure of symbiotic microorganism population varies depending on the soil, cultivar, individual plants within the cultivar and on the environmental circumstances, too. Therefore, for being general rather than specific according to researches, the selection *Rh. meliloti* ought to be directed to the tolerance of stressful conditions, primarily acidity of soil as well as to the enhanced ability of nitrogen fixation.

Table 1. Dry matter yield (t ha^{-1}) of lucerne and red clover over three years

Year		2001.			2002.			2003.			$\overline{X}$
Luce-rne	Inoc.	Čačak	Kraljevo	$\overline{X}$	Čačak	Kraljevo	$\overline{X}$	Čačak	Kraljevo	$\overline{X}$	2001–2003
Medi-jana	∅	8.89	8.82	8.85	15.17	22.43	18.80	14.24	21.91	18.07	15.24
	R1	9.88	8.85	9.36	15.78	22.24	19.01	15.41	23.70	19.55	15.97
	R2	10.59	9.74	10.16	16.40	24.02	20.21	16.66	24.39	20.53	16.97
Slavija	∅	9.95	7.15	8.55	16.12	19.61	17.86	16.07	21.10	18.58	15.00
	R1	9.90	8.94	9.42	17.77	22.45	20.11	17.50	23.42	20.46	16.66
	R2	9.41	8.38	8.89	18.03	22.08	20.05	17.85	23.78	20.82	16.59
Red clover											
Kolu-bara	∅	6.48	7.16	6.82	8.13	10.83	9.48	4.61	7.85	6.23	7.51
	R	7.44	7.37	7.41	8.46	11.83	10.15	5.19	8.82	7.01	8.19
LSD Lucerne		0.05	0.01		0,05	0,01		0,05	0,01		
	A	0.391	0.529		0.359	0.486		0.232	0.314		
	B	0.478	0.648		0.439	0.596		0.284	0.385		
	C	0.391	0.529		0.359	0.486		0.232	0.314		
	AB	0.677	0.917		0.622	0.842		0.402	0.544		
	AC	0.552	0.748		0.507	0.687		0.328	0.444		
	BC	0.677	0.917		0.622	0.842		0.402	0.544		
	ABC	0.957	1.296		0.879	1.191		0.568	0.770		
Red clover											
	B_1	0.614	0.893		0.228	0.331		0.371	0.539		
	C_1	0.614	0.893		0.228	0.331		0.371	0.539		
	B_1C_1	0.868	1.264		0.322	0.468		0.524	0.763		

Table 2. Mean values of quality parameters (g kg^{-1}) and energy values (MJ kg^{-1} SM) of dry mater in lucerne and red clover

Lucerne	Inoc.	CP	CF	CA	CC	NFE	NEL	NEM
Medijana	∅	19.40	1.70	8.33	31.00	39.57	5.95	6.51
	R1	19.80	1.60	9.13	30.00	39.47	5.95	6.53
	R2	20.90	1.34	8.94	28.00	40.82	6.06	6.71
Slavija	∅	19.50	1.59	9.83	29.00	40.08	5.92	6.50
	R1	19.80	1.68	9.17	26.00	43.35	6.09	6.74
	R2	18.70	1.80	9.06	32.00	38.44	5.84	6.33
$\overline{X}$		19.68	1.62	9.08	29.33	40.29	5.97	6.55
CV		3.65	9.65	5.30	7.36	4.20	1.55	2.31
Red clover								
Kolubara	∅	17.90	2.00	10.10	29.00	41.00	5.66	5.69
	R	18.30	2.10	9.66	30.00	39.94	5.68	5.71
$\overline{X}$		18.10	2.05	9.88	29.50	40.47	5.67	5.70
CV		1.56	3.45	3.22	2.40	1.88	0.25	0.25

Further, the increased dry matter yield of red clover using inoculation (Table1) ranged from 7.01% (2002) to 12.44% (2003) in relation to the control. Its significant increase recorded in the last utilization year suggested the persistence of the strain *Rhizobium leguminosarum* bv. *trifolii* used

even in the location with a low pH value. Thus, Jarak *et al*. (2003) and Jarak *et al*. (2004) established an increase in red clover biomass yield of 10–15% with acid tolerant *Rhizobium* strains.
Protein yield using inoculation was also significantly higher than being in the control (data not presented), which was in agreement with findings of Schupam *et al*. (1996).
Lastly, in terms of other quality indices (CC, CFM, CA, NFE) and energy value (NEL and NEM) no significant differences were observed.

Conclusions

Using acid tolerant strains of *Rh. meliloti* in lucerne and *Rh. leguminosarum* bv. *trifolii* in red clover on acid soils, inoculation helped achieve a significant increase in dry matter yield.
The content of the basic nutritional parameters as well as the energy value did not significantly vary according to the treatments.
The strains used for inoculation indicated persistence manifested in a significantly increased yield in the third utilisation year even in locations with low pH. The results show the value of selecting the *Rhizobium* strains tolerant of stressful factors, particularly that of acidity, when growing perennial legume plants on difficult soils.

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Evolution of species richness in anti-erosion revegetation in North-Eastern Italy

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Abstract

Forage or turfgrass species sown to revegetate bare areas should not prevent the return of the native species and the formation of natural vegetation. In 2001, a plot experiment was initiated to compare re- vegetation on a landslide located at about 1050 m a.s.l. on calcareous moraine. The re vegetation was carried out with four propagation materials (1. natural meadow hay (Nh), 2. Nh + natural meadow seed (Nhs), 3. Nh + s + commercial seed (Nhsc), 4. Nh + c (Nhc) combined with four types of natural meadow hay where propagation material came from. Floristic surveys took place in years 2002 to 2004. In all treatments, the total number of species increased, mainly due to the increase of meadow species and to the entry of local species from the surrounding area but also due to the establishment of sown or not sown commercial species. Treatments that received only seed and/or hay from natural meadows (propagation materials 1 and 2) showed a considerably higher number and cover of species coming from natural meadows than treatments sown also with commercial seed (propagation materials 3 and 4).

Keywords: revegetation, native species, commercial species, species richness

Introduction

The current methods employed to re vegetate areas prevent erosion efficiently. However, little consideration is given to the impact on the biodiversity of the established vegetation. In semi natural environments, the re-vegetation of bare or degraded areas, such as a landslide, should not prevent the return of native species and the formation of natural vegetation. For this reason, this study analyses the development of the diversity of vegetation covers resulting from different propagation materials in order to evaluate the possible exploitation of natural meadows for biodiversity preserving re-vegetations.

Materials and Methods

The study was conducted on the Gravon landslide (Trento Province, NE Italy) at 1070 m a.s.l. on a calcareous moraine with neutral soil containing gravel at 73 % of the soil and sand, silt and clay at 87, 10 and 3%, respectively, of the soil sieved at 2 mm. Mean annual temperature is 8.5° C and mean precipitation 1230 mm, mainly distributed in April–November.

In a completely randomized design, on 10/09/2001 a revegetation plot experimentation was initiated on the stabilized slope of the landslide. Experimental treatments were obtained by combining four propagation materials with four natural meadows types where seed or hay used for propagation came from. The four propagation materials were: 1. Natural meadow hay (Nh), 2. Nh + natural meadow seed (s) (15 g m^{-2}) (Nhs), 3. Nh + s (15 g m^{-2}) + commercial seed (c) (10 g m^{-2}) (Nhsc), 4. Nh + c (25 g m^{-2}) (Nhc). Hay was spread as a mulch layer over the plot at a quantity of 500 g m^{-2} dry matter. The four meadows types were: 1. A meadow dominated by *Agrostis tenuis* and *Anthoxanthum odoratum* (meadow A); 2. A meadow dominated by *Bromus erectus* (meadow B); 3. A meadow dominated by *Cynosurus cristatus* and *Anthoxanthum odoratum* (meadow C); 4. A meadow located near the landslide dominated by *Arrhenatherum elatius* (meadow L). At the collection of the hay and of the seed, the number of species in fructification was 35 in meadows A and B, 37 in meadow C and 29 in meadow L. The meadows A, C and L had a top soil pH of 6, 6.4 and 6.2, respectively, and were cut twice yearly and poorly fertilised. The meadow B had a soil pH of 7, was cut once yearly and not fertilised. Of the sixteen obtained revegetation treatments, the combinations NhsA, NhscC, NhcB, NhL, NhsL, NhscL were missing due to insufficient availability of propagation material. The commercial seed mixture contained *Lolium perenne* Belinda, *Poa pratensis* Balin, *Festuca rubra* Echo, *F. rubra commutata* Wilma (respectively 15, 6, 36 and 24% of seed mixture weight), six legumes and three forbs. Plot size was 3 m^2 and treatments were replicated 3-4 times.

In the three years after sowing, plant ground cover and floral composition (by visual estimation of the % cover of each species) were surveyed on four dates: 13/7/2002, 28/8/2002, 10/8/2003 and 27/7/2004 (coded with 1, 2, 3 and 4). Species were identified and named according to Pignatti (1982). In order to study the 'naturalness of the vegetation', the species were classified according to the categories given in Tab. 1. Using the 'naturalness scores', for each treatment two 'Species Naturalness Indexes' (SNI) were calculated as means of the scores of the present species, weighted (SNIAb) or not (SNIpa) by their abundance. Analyses of variance and regression were made with SAS (1985).

Table 1. Classification of species and naturalness scores (from Scotton and Piccinin, 2004)

Code	Naturalness category	Naturalness score	Code	Naturalness category	Naturalness score
1	Native species		2	Exotic species	
11	typical in primary biotopes[1]		21	Already present in the area, adventitious or naturalized cultivated specie	
111	native ecotype	10	211	native ecotype	4
112	non native ecotype	5	212	non native ecotype	2
113	commercial variety	5	213	commercial variety	2
12	typical and exclusively in secondary biotopes[2]		22	Absent in the area, introduced during revegetation	
121	native ecotype	7	221	non native ecotype	1
122	non native ecotype	4	222	commercial variety	1
123	commercial variety	4			

[1] Natural biotope, not disturbed. [2] Pioneer re-colonizing species, typical of disturbed biotopes (deuteroapophyte) (Poldini, 1991).

Results and Discussion

On average all treatments, total species number increased significantly ($p<0.01$) from 12.6 at the first date to 18 at the third date, followed by a slight decrease at the last date (17.4). Propagation materials Nhsc and Nhc showed a significantly higher ($p<0.01$) species number (about 19.5 at the third date) than Nh and Nhs (about 15–17 at the third date) (Fig. 1).

Species recorded on the plots belonged to the naturalness categories 111, 121, 113 and 213. At the last date, in the five Nh or Nhs treatments, native ecotypes (cat. 111 and 121) and commercial varieties (cat. 113 and 213) made up respectively 75–90% and 10–25% of the total number of species, respectively (Fig. 2a). The natural meadow type with the greater cat. 111 contribution to species number was the B one. For the Nhsc and Nhc treatments the contribution of 111+121 species was much lower (54–69%) and of 113+213 species much higher (31–46%). The difference of the contribution to ground cover of two species groups is greater than to species number: species 111+121 made up 80÷96 % in treatments Nh and Nhs and less than 60% in treatments Nhsc and Nhc (Fig. 2b).

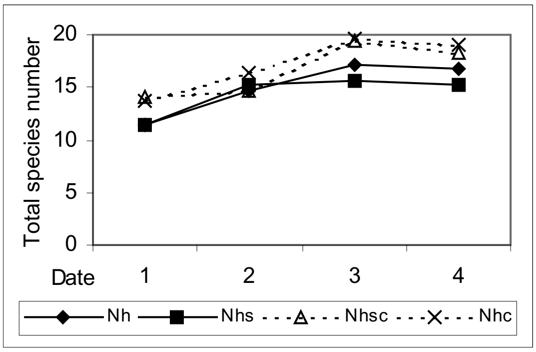

Figure 1. Total species number of the four propagation materials

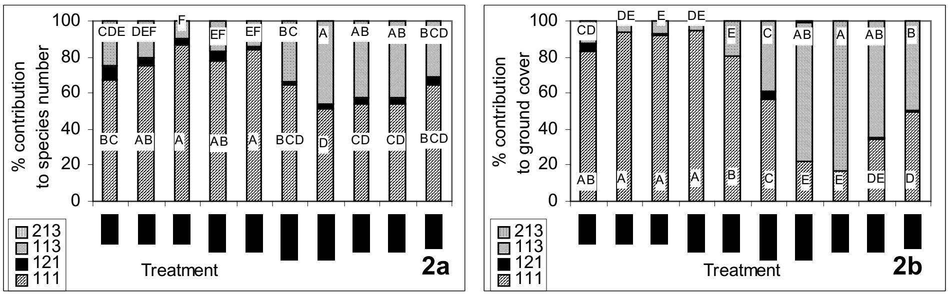

Figure 2. The % contribution of the naturalness categories to the species number (2a) and to the ground cover (2b) in the different treatments at the last survey date (capital letters refer to among treatments Duncan test of species 111 and 113: means without common letters differ significantly at the p<0.01 level)

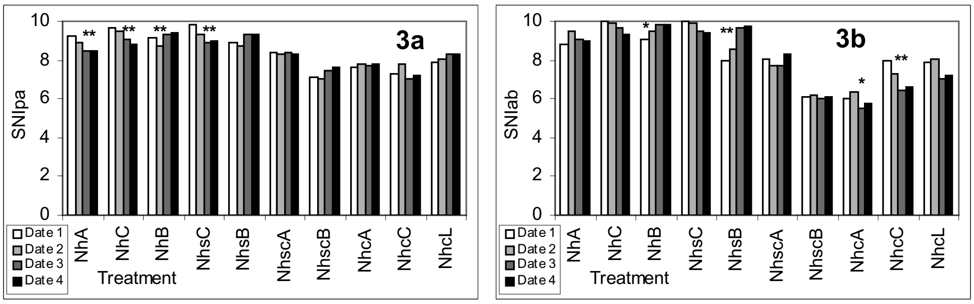

Figure 3. Development of SNIpa (3a) and SNIab (3b) in the different treatments (* and **, Duncan test giving differerences within treatments among dates significant at $p<0.05$ and <0.01 respectively)

With reference to the five treatments where only native species were used, SNIpa and SNIab decreased slightly in time in NhA, NhC and NhsC and increased in NhB and NhsB (Fig. 3), maintaining values higher than 8.5. In the five treatments with commercial seed, SNIpa and

SNIab values were lower (5.6–8.4) and more or less stable (NhscA and NhscB) or decreasing in time (NhcA and NhcC). As expected, the main factor that influenced the naturalness of the vegetation was the type (only native or native + commercial) of propagation material.
The changes of SNIpa and SNIab are due to the possible disappearance of the sown species and entry of new ones. In order to analyse this effect, the species were divided into the following four groups depending on seed origin: a. natural meadow species sown; b. native species invading the plots spontaneously from adjacent plots or surrounding areas; c. commercial species sown; d. commercial species invading the plot spontaneously from adjacent plots or surrounding areas. As shown in Figure 4, the group a species of the meadows A and C don't change much, whereas the meadow B ones increase in number and % ground cover, showing a slower settlement but a good adaptation to the site. On the other side, the commercial species tend to increase where they were sown (+ 0.5–2 species and + 12–41% ground cover) but also to spread in the less adapted meadow A and C Nh and Nhs treatments where they were not sown (+ 1.75–3 species and + 5–10% ground cover).
In the treatments with commercial seed, the occurence of native species is considerably influenced by the cover of the sown commercial species and especially of *Festuca rubra*.

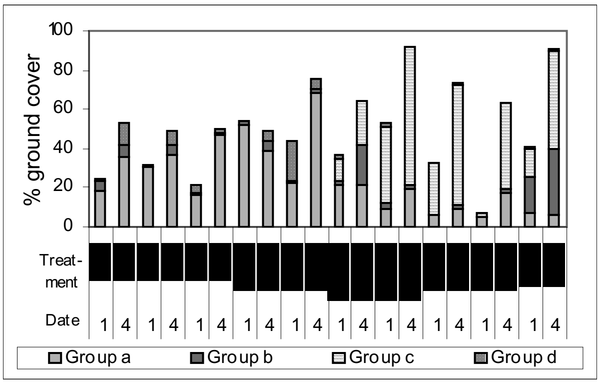

Figure 4. Contribution of the a-d species groups to the ground cover in the different treatments at the first and last dates. Dates 1 and 4 differ significantly at p<0.05 or <0.01 in these cases: Group a: NhA, NhB, NhscB and NhcC; Group b: never; Group c: NhscA, NhscB, NhcA an NhcC; Group d: NhA, NhC, NhsC and NhsB

Figure 5 shows that this species tends to increase in time from maximum values of about 40% in 2002 to 60 % in 2004. At the same time, also the number of not sown native species increases, the amount being strongly dependent on the cover of *Festuca rubra* (Fig. 5). *Festuca rubra* should not exceed a cover of 30 % in order to facilitate the establishment of native species.

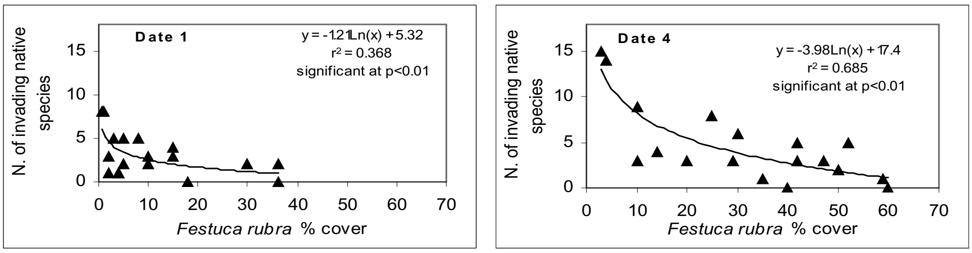

Figure 5. Effect of the *Festuca rubra* cover on the establishment of native species

Conclusions

In order to achieve more natural revegetations, the best propagation material is the n. m. hay + n. m. seed but good results can be obtained also with only n. m. hay. The meadow type had a significant effect. The closer the soil conditions of the meadows used as the seed source and the target site are, the higher will be the restoration success. When combining native propagation material with commercial seed, the establishment of the native species is considerably limited, especially where competitive species reach a high cover (in our case, *Festuca rubra* cover greater than 30%). Moreover, the commercial species tend to invade into sites where only native species were sown. Thereby, the naturalness of the vegetation decreases.

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The quality and chemical composition of *Phacelia tanacetifolia* Benth. and lucerne silages

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Abstract

The ensiling experiment with *Phacelia tanacetifolia* Benth. was done in experimental silos with volumes of 60 dm^3 and organized as a three-factorial layout (2 × 2 × 2), where factor A was the vegetation phase of phacelia (the budding phase or the end of flowering phase), factor B was without or with lucerne, ratio 1 : 1, and factor C was phacelia without or with fertilizer, N = 45 kg ha^{-1}. Maize meal 5% was added to all silages.

Silages from phacelia cut at the budding phase and at flowering, had on average lower pH values (5.37 : 5.89), lower lactic acid (26.47 : 60.53 g kg^{-1} DM), lower acetic acid (59.57 : 73.72 g kg^{-1} DM), and higher butyric acid (15.54 : 0.11 g kg^{-1} SM), respectively. The addition of lucerne produced a high effect on acid content ($P < 0.05$). Silages made from phacelia and lucerne had lower pH values (4.99 : 6.28), higher lactic acid (62.20 : 24.80 g kg^{-1} DM) content, and contained no butyric acid (0.00 : 15.65 g kg^{-1} DM). Nitrogen fertilization of phacelia had no effect on silage quality. The addition of lucerne increased the content of crude protein, and decreased the contents of crude fibre and ash. According to the DLG method (1997), ensiling the material after flowering produces better silage and improves its quality, while combining with lucerne improves the quality to an even greater extent.

Keywords: silage, *Phacelia tanacetifolia* Benth., vegetation stage, lucerne, fertilizer N

Introduction

Phacelia tanacetifolia Benth. is one of the most productive honey yielding plants, in that it produces a lot of nectar and pollen for bees (Engels *et al*., 1994). It is also grown as plant fertilizer. In many countries it is well known as a bio-cleaner of soil as it reduces the number of nematodes, which is essential in soils where roots and tubers are to be produced. Phacelia has a high green mass productivity, a factor that makes it interesting as a forage plant. Due to its specific scent and structure, ruminants do not find it palatable, neither in its green nor in its dried form (hay), while possibilities for its ensiling have not been investigated enough. The aim of this experiment was to investigate the ensiling of phacelia at different vegetation stages, as a monoculture or with fertilizer, or combined with lucerne, which would hopefully increase the silage's nutritive value and improve its acceptability.

Materials and Methods

The ensiling of phacelia, cultivar "Blanca", was done during the spring of 2004 in experimental silos with 60 dm^3 volumes. Phacelia was produced with and without mineral fertilizer (N = 45 kg ha^{-1}) application. It was ensiled at budding and after the flowering phase (after a wilting period). The first phase was chosen assuming that phacelia might be produced for forage, while the second one was selected assuming that it is grown for honey after which it would be used as ruminant feed. Phacelia was ensiled individually and combined with wilted lucerne from the first and second cuts (Mediana, ZTMS 5, cultivar). Maize meal was added to all treatments at the level of 5% as a stimulant for lactic acid fermentation. The experiment was tri-factorial, where factor A was the vegetation phase of phacelia (A_1 = budding phase, A_2 =

after flowering); B factor was added lucerne (B_1 = no lucerne added, B_2 = lucerne added at 1:1 ratio phacelia, at budding stage); factor C was phacelia, budding stages without and with fertilizer application (C_1 = no fertilizer, C_2 = with fertilizer).
With the compression of the ensiled mass the average volume/mass ratio of 600 g/dm^3 was achieved. After compression, the surface of the ensiled mass was covered with PVC film, N ensiled, weighed down and sealed. Silos were opened and samples for analyses taken 56 days later. Chemical analysis of the initial material and silages were done according to AOAC (1984); the content of lactic, acetic and butyric acid were measured according to Wiegner, and pH value was measured on the MA-5722 pH-meter. Statistical analysis of the obtained values (ANOVA and Tukey HSD test) were done by Statistica v. 6.0.

Results and Discussion

The chemical composition of phacelia, lucerne and maize meal is shown in Table 1. Compared to lucerne, phacelia had less protein and NFE, but more cellulose and ash in both investigated phases. High protein content in the budding phase (175.78 g kg^{-1} DM), and after flowering (137.20 g kg^{-1} DM) – show that phacelia does have potential to be utilized as a forage species.

Table 1. Chemical composition of the starting material

Starting material	Dry matter, g kg^{-1}	g kg^{-1} DM				
		Crude protein	Crude fiber	Ether extract	NFE	Ash
Phacelia without fertilizer, the budding phase	241.30	174.82	316.61	36.52	301.51	170.54
Phacelia with fertilizer, the budding phase	224.30	176.73	312.37	34.27	307.75	168.88
Phacelia without fertilizer, the end of flowering	321.60	137.66	411.28	31.44	243.31	176.31
Phacelia with fertilizer, the end of flowering	336.83	136.74	423.93	29.69	237.32	172.32
Lucerne, I cut	338.53	227.84	281.53	35.76	331.20	123.67
Lucerne, II cut	404.78	208.18	290.03	35.12	334.62	132.05
Maize meal	889.34	84.31	23.46	46.72	628.26	163.25

The vegetation phase had a significant influence on the composition of phacelia. After flowering it had less protein and NFE and increased amount of fibre and ash (Table 2). By mixing lucerne with phacelia the protein and NFE content was increased while fibre and ash contents were decreased. The percentage of ether extract was higher in silages compared to the starting material. This could be explained by the lactic acid partial extraction with diethyl ether (Barnett, 1954). However, there was no significant influence on the investigated factors of ether extract.
Silages made from more mature material had higher pH values, which was result of their higher dry matter content (Table 3). The same silages had more lactic and acetic, but less butyric, acid. However, the dryer medium was not favourable for the proteolytic enzyme activity and the amount of ammonia nitrogen was significantly lower. pH value and dry matter content are the most important factors that control intensity of proteolysis, but they cannot completely stop it (Carpintero *et al*., 1979).

Table 2. Chemical composition of silages

Investigated factors, average	Dry matter, g kg^{-1}	g kg^{-1} DM				
		Crude protein	Crude fibre	Ether extract	NFE	Ash
A_1)Phacelia budding stage	280.97	191.35	294.12	52.48	319.26	142.79
A_2) After flowering	429.53	153.58	375.64	54.68	271.75	144.34
B_1) Phacelia alone	316.82	156.18	361.36	52.54	269.68	160.24
B_2) Phacelia + lucerne	393.68	188.76	306.40	54.62	321.33	126.89
C_1) Phacelia without fertilizer	370.56	172.34	334.66	52.58	297.40	143.02
C_2) Phacelia with fertilizer	339.94	172.59	333.10	54.58	293.61	144.11
Significance of results	A, B, C=*** A×B, B×C, A×C=*** A×B×C=***	A, B=***	A,B=*** A×B=*** A×B×C=**	NS	A, B=*** A×B=***	B=*** A×B, B×C,=*** A×B×C=***

NS = not significant, * = P<0.05; ** P<0.01, *** = P<0.001, Note: Phacelia at budding stage in B_1,B_2,C_1,C_2.

Table 3. Biochemical changes in investigated silages

Investigated factors, average	pH	NH_3N, g kg^{-1} N	g kg^{-1} DM			Class by DLG
			Lactic acid	Acetic acid	Butyric acid	
A_1) Phacelia	5.37	126.92	26.47	59.57	15.54	V
A_2) After flowering	5.89	78.27	60.53	73.72	0.10	IV
B_1) Phacelia alone	6.28	108.92	24.80	73.33	15.65	V
B_2) Phacelia + lucerne	4.99	96.27	62.20	75.77	0.00	II
C_1) Phacelia without N fertilizer	5.58	110.78	31.86	78.76	0.10	V
C_2) Phacelia with N fertilizer	5.68	94.41	55.14	70.34	15.54	IV
Significance	A, B, C=*** A×B, B×C, A×C=*** A×B×C=***	A, B, C=*** A×B, B×C, A×C=*** A×B×C=***	A, B, C=*** B×C=*** A×B×C=***	A=** C=*** B×C=*** A×B×C=**	A,B,C=*** A×B, B×C, A×C=*** A×B×C=***	

NS = not significant, * = P<0.05; ** P<0.01, *** = P<0.001

The obtained low levels of ammonia nitrogen are not consistent with the basic characteristic of ensiled lucerne and that is having high percentages of soluble and degradable protein (Hatfield *et al*., 1996). The possible explanation is that phacelia's fitoncyde properties very likely influence the activity of proteolytic enzymes (Butler and Bailey, 1973). Favourable conditions for lactic acid fermentation were achieved by combining lucerne and phacelia. The fermentation was increased 2.5 times. In contrast, the percentage of acetic acid was not much different, while butyric acid was not detected. Fertilization of phacelia had no significant influence on the most of investigated parameters.

The quality of obtained silages was estimated using the DLG method (1997), which takes into account pH value and relative ratios of organic acids. According to this method, ensiling the mass after flowering produces better silage and improves its quality, while combining with lucerne improves the quality even more (Table 3).

Conclusions

In order to completely utilize all available resources for feeding domestic animals it is suggested that phacelia may be used for silage production combined with plants, which have higher nutritive value and are more acceptable such as lucerne. Phacelia should be ensiled after the flowering period, that is, after honey bees utilize its nectar and pollen. Combined with lucerne it is possible to achieve significant increase in nutritive value of the silage.

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Patterns of plant species distribution in ryegrass-white clover pastures

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Abstract

The aim of the presented studies was to investigate whether there is a pattern in plant species composition on cattle pastures or not and – in case there is a pattern – which species contribute to the pattern and how they are related to each other. On 24 permanent plots (1 m x 1 m), species and their percentage of total yield were recorded on each of the 100 subplots (10 cm x 10 cm) three times a year over five years. Dissimograms indicated a relation between the Euclidean distances between subplots and their spatial distances. In general, plant species were not randomly distributed, but by rules which lead to patterns in composition. Cross-semivariograms showed spatial relationships between species pairs. Clearest negative correlations were found for dominant species such as *Lolium perenne, Agrostis stolonifera* and *Poa pratensis.* The correlation of the temporal development between species pairs yielded similar results.

Keywords: coexistence, cross-semivariogram, geostatistics, vegetation pattern

Introduction

Species composition of a plant community is determined by many factors which are acting on different spatial scales (Wagner, 2003). Much is already known about the influence of environmental conditions; thus, it is already possible to assign species to specific site conditions. The influence of disturbances – another more dynamic factor – is a rather temporal one. Disturbances occur on different spatial and temporal scales. Many studies already exist on the effect of disturbances by grazing animals (Adler *et al.,* 2001). Factors acting on a very small spatial scale are the intra- and interspecific competition. They determine the pattern of species composition within the plant community. Models were created to get an impression of such individual or species interactions (Schwinning and Parsons, 1996). The present study uses field data analysis. First it is shown whether or not there is a small-scale spatial pattern in species composition of the investigated pastures. The relation in the spatial occurrence of species pairs is then analysed and finally spatial relationships are compared to temporal ones.

Materials and Methods

Studies were conducted at the Grünschwaige research station in Southern Germany (mean annual rainfall 800 mm, mean daily temperature 8.6 °C). It is a former fen area which was first drained about 100 years ago; now the soil is a more or less mineralized peat soil (25–80 cm). The six surveyed paddocks (P1-P6) are on permanent grassland (established for more than 50 years). In the year 2000 on each paddock four permanent plots were installed. They were 1 m x 1 m and divided into 100 subplots of 10 cm × 10 cm. On each subplot plant species and their percentage of total yield were recorded three times a year (May, July, September). In order to identify vegetation patterns within the plots, dissimograms were built: Euclidean distances between the subplots of one plot were calculated and plotted against their spatial distances (Mistral *et al.,* 2000). Cross-semivariograms should give an indication of which species interact with each other (Walter *et al*., 2002). The species pairs were chosen due to their dominance and due to results of one more type of analysis: temporal patterns in species interactions are shown by the correlation of species development within one subplot (Herben, 1996). Temporal patterns are shown for the durations of one year and of four years.

Results

In Figure 1A) an example of a dissimogram is shown. For all of the plots dissimilarity (Euclidean distance) due to species composition increased with spatial distance. R^2 is very low in most cases, but it is always significant with $p<0.001$ (Table 1). In Table 1 the R^2 of dissimograms of one plot of each paddock at the second vegetation survey (July) of the five years are shown. Figure 1B) shows a cross-semivariogram. The example corresponds with that in Figure 1A). Table 1 shows the R^2 of some more cross-semivariograms.

Table 1. Coefficients of determination (R^2) of the dissimograms of plot 1 of each paddock at the second vegetation survey in each year (linear regressions) and R^2 of cross-semivariograms of corresponding plots and time (exponential model); Rr: *Ranunculus repens*; As: *Agrostis stolonifera*; Fp: *Festuca pratensis*; Ll: *Lolium perenne*; Pr: *Potentilla reptans*; Dg: *Dactylis glomerata*; Ar: *Agropyron repens*; Tr: *Trifolium repens*

Paddock	year	R^2 (dissimo-gram)	species a	species b	R^2 (cross-semivario-gram)	paddock	year	R^2 (dissimo-gram)	species a	species b	R^2 (cross-semivario-gram)
P1	1999	0.22	Rr	As	0.75	P4	1999	0.02			
	2000	0.12	Fp	Pp	0.34		2000	0.04			
	2001	0.002					2001	0.16	Pp	As	0.91
	2002	0.03	Rr	Pp	0.84		2002	0.19	Pr	Dg	0.59
	2003	0.01					2003	0.08	Pp	Ar	0.35
P2	1999	0.10				P5	1999	4.E-06			
	2000	0.02	Ll	As	0.45		2000	0.09	Pp	As	0.32
	2001	0.02	Rr	Ll	0.61		2001	0.07	Ll	Pp	0.14
	2002	0.04	Ll	Pp	0.25		2002	0.09			
	2003	0.02					2003	0.07	Ar	As	0.7
P3	1999	0.05				P6	1999	0.05	Ll	Pp	0.41
	2000	0.03					2000	0.03			
	2001	0.04	Ll	Pp	0.45		2001	0.01	Ll	Pp	0.37
	2002	0.002	Ll	As	0.38				Ll	Tr	0.46
	2003	0.03	Rr	Pp	0.42		2002	3.E-04			
							2003	0.01			

All of the shown correlations were negative ones. On P1 interactions between *Ranunculus repens* and *Poa pratensis* and between *R. repens* and *Agrostis stolonifera* obviously occurred

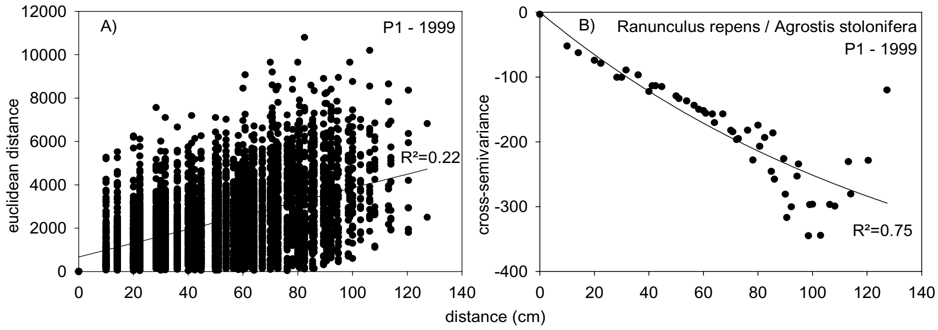

Figure 1. A) Dissimogram of paddock P1 (plot 1) in July 1999 with linear regression; B) cross-semivariogram of *R. repens* and *A. stolonifera* at time and plot corresponding to A); an exponential function is fit to the plot

On P2 and P6 *Lolium perenne* interacted with other grasses such as *P. pratensis* (P2, P6) or *A. stolonifera* (P2) and dicots such as *R. repens* (P2) and *Trifolium repens* (P6). On P3 and P4 *P. pratensis* is negatively correlated with other grass species and *R. repens* and on P4 and P5 *A. stolonifera* and *Agropyron repens* play a role in species interactions. In Table 2 the correlation of the temporal development of two species is shown. Most of the correlations were negative. In general, the grass species *A. stolonifera*, *L. perenne* and *P. pratensis* showed most and the clearest negative correlations. On P1 *Festuca pratensis* and *R. repens* also interacted with other species. A conspicuous number of species is listed on P3.

Discussion

Although patterns are not very clear there is a dissimilarity gradient within the plots. A similar method of data analysis was applied by Jonsson and Moen (1998): an increase in semivariance based on the position of the plot on a DCA-axis with lag-distance induced increasing dissimilarity with distance and, thus, a pattern in plant species distribution. Patterns were mainly caused by negative interactions between the dominant species. Walter *et al.* (2002) concluded that the cross-semivariance is negative if the correlation between two species is negative and according to Bolker and Pacala (1999) negative cross-covariance always indicates competitive systems. However, in relation to temporal interactions Herben (1996) found out that an increase of one species when another one in the cell decreases does not inevitably indicate an underlying competitive interaction.

Conclusions

Patterns found in pasture vegetation were mainly caused by dominant species, which were about the same on spatial and temporal scales. According to the literature it is not clear whether patterns in species interactions are caused by competitive systems or by other factors.

Table 2. Temporal correlation between species; correlations are shown when r (Pearson) >0.3; –: negative correlation within one year; (–): negative correlation within four years; +: positive correlation within one year; (+): positive correlation within four years; !: r>0.5

		Agropyron repens	*Capsella bursa-pastoris*	*Cirsium arvense*	*Dactylis glomerata*	*Festuca pratensis*	*Glechoma hederacea*	*Lolium perenne*	*Plantago lanceolata*	*Poa pratensis*	*Poa trivialis*	*Potentilla reptans*	*Ranunculus repens*	*Stellaria media*	*Taraxacum officinale*	*Trifolium pratense*	*Trifolium repens*	*Veronica serpyllifolia*
P1	*Agrostis stolonifera*					–				–	–							
	Dactylis glomerata					–										–		
	Poa pratensis					–(–)!							–					
	Ranunculus repens					(–)				–							–	
P2	*Agrostis stolonifera*							–(–)!		–								
	Dactylis glomerata									–								
	Lolium perenne									–(–)!	–		–					
P3	*Agropyron repens*											+						
	Agrostis stolonifera							–(–)										
	Bellis perennis								(+)						–			
	Carum carvi			–!					(+)									
	Cirsium vulgaris				–!													
	Lolium perenne									–(–)!	–							
	Poa pratensis							–(–)!			–		–					
	Polygonum aviculare													–				
	Veronica chamaedrys																	–!
P4	*Agropyron repens*									–	(+)							
	Agrostis stolonifera		–							–(–)!	–							
	Dactylis glomerata							–				–!						
	Lolium perenne									–(–)!					–		(–)	
	Poa pratensis							–(–)!			–				–			
	Taraxacum officinale							–		–								
P5	*Agrostis stolonifera*	–(–)					(–)			–(–)!	–	–						
	Lolium perenne									–(–)!								
	Poa pratensis						(–)				–							
	Trifolium repens											–						
P6	*Agrostis stolonifera*							(–)		–	–							
	Alopecurus pratensis	–																
	Lolium perenne									–(–)!							–	
	Ranunculus repens										(–)							
	Trifolium repens							–		–								

The dominant species with clearest negative interactions in time and space were the grass species *A. stolonifera, P. pratensis* and *L. perenne* (Table 1, 2). Purves and Law (2002) also found *A. stolonifera* and *L. perenne* negatively correlated on a very small spatial scale (2 cm). Both *A. stolonifera* and *P. pratensis* are clonal growing, the first one stoloniferous and the latter one rhizomatous (Grime, 1988). Although *L. perenne* is regarded as tufted species (Grime, 1988) Silvertown *et al.* classified it as much more invasive than *P. pratensis*.

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Genetic variability of yield and its components in spring vetch cultivars

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Abstract

Breeding of both winter and spring common vetch and creation of new cultivars are based upon a rather wide variability of morphological traits within the species of *Vicia sativa* L. A three-year (2002–2004) small-plot trial was conducted at the Institute's Experiment Field at Rimski Šančevi. It included five spring vetch cultivars of different origin: Novi Beograd from Serbia and Montenegro, Slavej from the FYR of Macedonia, Serva-174 from Spain, Tazza from Germany and RCAT066401 from Hungary. The greatest plant height was found in RCAT066401 (120 cm), while the smallest plant height was found in Serva-174 (79 cm) and Tazza (77 cm). Number of stems per plant ranged from 1.3 in Slavej to 3.3 in Serva-174, while number of internodes ranged from 13.1 in Tazza to 19.0 in Novi Beograd and 20.1 in RCAT066401. RCAT066401 had the largest plant mass (43.83 g), while Tazza had the smallest plant mass (23.92 g). RCAT066401 also had the highest yield of fresh weight (33.0 t ha^{-1}), closely followed by Novi Beograd (31.8 t ha^{-1}) and Slavej (31.0 t ha^{-1}). Due to the highest proportion of dry matter, Slavej and Novi Beograd had the highest yield of hay (8.6 t ha^{-1} and 8.3 t ha^{-1}).

Keywords: cultivar, spring vetch, genetic variability, yield, yield components

Introduction

Of all *Vicia* L. species, it is common vetch (*V. sativa* L.), Hungarian vetch (*V. pannonica* Crantz) and hairy vetch (*V. villosa* Roth) that are traditionally cultivated in Serbia and Montenegro. Being most significant of the three, common vetch is used mainly in the fresh form or as hay, silage and green manure (Miladinović, 2001). Recently it was reported that common vetch had a great potential as a grain legume too (Mihailović *et al.*, 2004c), as well as to be one of the highest quality forage catch crops in organic farming and sustainable agriculture (Ćupina *et al.*, 2004).

The Institute of Field and Vegetable Crops in Novi Sad remains the only place in Serbia and Montenegro where both winter and common vetch cultivars are developed. Breeding work on spring common vetch began more than fifty years ago (Mišić, 1967). Since wide distribution of wild populations of common vetch throughout the country, it is local strains that were the most important source for developing the first domestic cultivars, mostly by individual selection. Later breeding programmes included the pedigree selection from hybrid progenies and resulted in advanced cultivars that are still higher yielding and of better quality than the foreign ones (Mihailović *et al.*, 2003).

Common vetch breeding is based upon utilisation of great genetic variability, mainly through making a collection of accessions of diverse morphological traits and geographical origin (Potokina *et al.,* 2002), and is aimed at understanding the interrelationships among yield and single agronomic characters (Çakmakçi *et al.*, 2003). Therefore the aim of our study was to determine the genetic variability of yield and its components in five spring vetch cultivars of different agronomic characteristics and geographical origin, as well as to evaluate their genetic potential for future breeding programmes and development of new spring vetch cultivars.

Materials and Methods

A three-year small-plot trial was established at the the Rimski Šančevi Experiment Field of the Institute of Field and Vegetable Crops in Novi Sad from 2002 to 2004. It included five spring vetch cultivars of different origin from the Annual Forage Legumes Genetic Collection (AFLGC) of the Forage Crops Department: Novi Beograd from Serbia and Montenegro, Slavej from the FYR of Macedonia, Serva-174 from Spain, Tazza from Germany and RCAT066401 from Hungary. The experiment was set up as a split-plot randomized design with three replicates and a plot size of 5 m^2. All six cultivars were sown as early as possible (Temel and Tan, 2002), usually in late February or early March, at a crop density of 150 viable seed per m^2, and were cut in early June, when the first pods began to appear (Mišković, 1986).

A study on genetic variability of yield and its components of these spring vetch cultivars was carried out by monitoring plant height (cm), number of stems per plant, number of internodes, plant mass (g), yield of fresh weight (t ha^{-1}) and yield of hay (t ha^{-1}). Plant samples for the analysis of plant height, number of stems per plant, number of internodes and plant mass were taken shortly before cutting. Yield of fresh weight was measured *in situ* immediately after cutting, while yield of hay was determined on the basis of field dry weight.

The results were processed by the analysis of variance with the *LSD* test applied.

Results and Discussions

Plant height represents one of the most important components of fresh weight and hay in common vetch and other annual forage legumes, since in most cases it has a direct impact on plant mass and yield of forage (Mihailović *et al.*, 2004d). There were significant differences in average values of plant height between five examined spring vetch cultivars (Table 1). The greatest plant height was in RCAT066401 (120 cm) and Novi Beograd (111 cm), meaning that these two cultivars can be successfully utilised as gene donors for this trait. The lowest average plant height was in Tazza (77 cm) and Serva-174 (79 cm).

Table 1. The average values of the agronomic characteristics of spring vetch cultivars during 2002–2004 at Rimski Šančevi

Cultivar number in AFLGC	Cultivar name	Plant height (cm)	Number of stems per plant	Number of internodes	Plant mass (g)
VIC 003	Novi Beograd	111	2.0	19.0	39.56
VIC 009	Slavej	103	1.3	16.3	29.59
VIC 010	Serva-174	79	3.3	14.1	26.71
VIC 025	Tazza	77	2.8	13.1	23.92
VIC 042	RCAT066401	120	2.1	20.1	43.83
LSD	$P<0.05$	13	1.8	2.7	8.20
(2002–2004)	$P<0.01$	19	2.6	3.8	11.67

Sharing the same tendency with other common vetch cultivars that are utilised mainly for grain (Mihailović *et al.*, 2004b), Serva-174 had the greatest number of stems per plant (3.3). The cultivar Slavej had significantly fewer stems per plant (1.3). There were no significant differences in this characteristic between all five common vetch cultivars.

Closely following the same trend as plant height and being in close relationship with plant mass and yield of both fresh weight and hay (Mihailović *et al.*, 2004a), number of internodes was greatest in RCAT066401 (20.1) and Novi Beograd (19.0). Significantly lower numbers of internodes were recorded in the other three cultivars, especially in Tazza (13.1).
The largest plant mass was in RCAT066401 (43.83 g) and Novi Beograd (39.56 g), while the lowest plant mass was in Tazza (23.92 g). There were significant differences in average values of plant mass between five examined spring vetch cultivars.
The highest yields of both fresh weight and hay were during the rather rainy growing season of 2004, while the lowest ones were during the extremely dry growing season of 2003, with significant differences between the values of both characteristics in all three years among all examined cultivars (Table 2).

Table 2. Yields of fresh weight and hay (t ha^{-1}) of spring vetch cultivars during 2002–2004 at Rimski Šančevi

Cultivar number in AFLGC	Cultivar name	Yield of fresh weight				Yield of hay			
		2002	2003	2004	Mean	2002	2003	2004	Mean
VIC 003	Novi Beograd	33.4	22.9	39.1	31.8	8.7	6.0	10.2	8.3
VIC 009	Slavej	31.9	23.3	37.8	31.0	9.0	6.2	10.6	8.6
VIC 010	Serva-174	27.3	21.3	29.5	26.0	6.7	4.6	7.8	6.3
VIC 025	Tazza	13.9	9.9	18.4	13.7	4.9	3.4	5.7	4.7
VIC 042	RCAT066401	34.7	23.8	40.6	33.0	8.1	5.5	9.4	7.7
LSD	P<0.05	2.9				1.3			
(2002–2004)	P<0.01	6.2				3.0			

Yield of fresh weight varied from 9.9 t ha^{-1} in Tazza in 2003 to 40.6 t ha^{-1} in RCAT066401 in 2004, while yield of hay ranged from 3.4 t ha^{-1} in Tazza in 2003 to 10.6 t ha^{-1} in Slavej. A significantly higher average yield of fresh weight was found in RCAT066401 (33.0 t ha^{-1}), followed by Novi Beograd (31.8 t ha^{-1}) and Slavej (31.0 t ha^{-1}), what confirmed great potential of common vetch for high yields of fresh weight (Mihailović *et al.*, 2004e). Due to larger portion of dry matter in fresh weight, Slavej had the highest yield of hay (10.6 t ha^{-1}), together with Novi Beograd (10.2 t ha^{-1}) and RCAT066401 (9.4 t ha^{-1}). Significantly lower yields of both fresh weight and hay were in Tazza (13.7 t ha^{-1} and 4.7 t ha^{-1}), mostly due to a shorter growing season. This fact leaves the open question of the possibility of utilisation of such cultivars as gene donors for other purposes if not for fresh weight or hay, in the first place for higher yield of grain, as well as for pest and disease resistance.

Conclusions

On the basis of significant differences in yield and its components between five examined cultivars, the existence of great genetic variability of morphological and agronomic traits in spring common vetch is confirmed, especially in accessions of different geographic origin. This variability offers an essential and quality basis for successful breeding and development of new spring vetch cultivars with higher yields of both fresh weight and hay. Genotypes with great plant height and number of internodes, such as RCAT066401 and Novi Beograd, represent good parental components for hybridisation, as well as genotypes with higher portion of dry matter in fresh weight and higher yields of hay, like Slavej. Since only medium values of number of stems per plant are desirable, a closer examination of the specific influence of this characteristic on stand density and yield should be conducted. Genotypes with lower and poor yields of fresh forage and hay, such as Serva-174 and Tazza, could be screened for and taken into consideration as gene donors of other agronomic characteristics like yield and quality of grain and pest and disease resistance.

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Effects of fertilization on floristic diversity and herbage production in a grazed natural rangeland

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Abstract

Fertilization of natural rangelands may increase herbage yield. Herbaceous species respond differently to fertilization. The purpose of this study was to investigate the effects of fertilization on floristic diversity and herbage production in a grazed natural rangeland over a period of three years. The research was conducted in a natural rangeland in the area of Kilkis in northern Greece. NH_4NO_3 fertilization was applied in October 2000 and in February 2001. The rangeland was grazed for a period of 30 years. Field measurements were taken in 2001, 2002 and 2003. Species richness, evenness and herbage production were measured. Shannon – Wiener and similarity indexes were calculated. Results indicated that fertilization decreases species richness and species diversity. Fertilization increased mean herbage yield by approximately 20%.

Key words: diversity index, sheep grazing, N fertilization, P fertilization

Introduction

Nitrogen and phosphate are important environmental factors limiting plant growth and herbage production in rangeland ecosystems (Snyman, 2002). In rangeland fertilization experiments nitrogen enrichment nearly always increases herbage production but it reduces floristic diversity by promoting the dominance of a few highly competitive species (Huenneke *et al.,* 1990; Pysek and Leps, 1991; Tilman, 1997). In contrast to N fertilization moderate P fertilization usually does not decrease the species richness of grassland communities (Bobbink, 1991)

Moderate grazing has been shown to increase floristic diversity on Mediterranean grasslands by reducing the dominance of highly competitive species (Noy-Meir, 1998). Olff and Ritchie (1998) suggest that grazing tends to reduce diversity on nutrient poor soils where plants are poorly defended against herbivory, but to increase diversity on richer soils where plants have been exposed to more herbivory and thus have evolved higher levels of grazing tolerance. Effects of livestock grazing on productivity tend to be stronger when the rangelands are grazed for many years.

As N and P fertilization and long term grazing affect floristic diversity and productivity in different ways the further investigation of their interaction is important. The purpose of this study was to investigate the effects of fertilization on floristic diversity and herbage production in a grazed natural rangeland over a period of three years.

Materials and Methods

The experimental area was a grassland near to the village of Herso, 70 km northwest from Thessaloniki (22°8΄10΄΄ GL, 41°1΄5΄΄ GW). The area is characterized by long and dry summer periods and cold winters. Soil depth was less than 50cm. The species that dominated the grassland were the perennial grasses *Dichanthium ischaemum, Chrysopogon gryllus,* *Dactylis glomerata, Cynodon dactylon* and the annual legumes *Trifolium campestre* and *Trifolium hirtum*.

The grassland was divided in two test sites of 5 ha each and fertilization was applied in one of them. $S_2(NH_4)_2PO_4$ (250 kg/ha) and NH_4NO_3 (100 kg ha^{-1}) fertilization was applied in October 2000. In February 2001 NH_4NO_3 (150 kg ha^{-1}) fertilization was applied. The whole area was grazed by a flock of 500 sheep for an average grazing time of 2 hours per day for six months.

Species number and abundance were measured from eight 0.5 × 0.5m fixed, resampled each year, sampling quadrats in each site for the years 2001, 2002 and 2003. The data were analyzed by the "Ecosim" software (Gotelli and Entsminger, 2001).

In all sites ground cover and species composition were recorded at the end of the growing season in each year using the line point method (Cook and Stubbendieck, 1986). Herbage production from eight randomly selected 0.5 × 0.5m sampling quadrats was determined by cutting and oven-drying at 65°C the above ground biomass.

Floristic diversity was determined by the Shannon-Weiner index of *α*-diversity (H′), evenness of the Shannor-Weiner index of diversity (E) and species richness (N). The formulae of the indices are given below (Henderson, 2003):

$$H' = -\sum_{i=1}^{S} p_i \ln p_i \qquad (1)$$

$$E = \frac{H'}{H_{\max}} = \frac{H'}{\ln S} \qquad (2)$$

$$N \qquad (3)$$

where, S is the maximum recorded number of taxa, p_i is the proportional abundance of the i-th taxa, N is the number of taxa.

The experimental design was a simple factorial with fertilization treatment (fertilized site, control site) and sampling dates (2001, 2002 and 2003) as factors. The data were subjected to analysis of variance using the MSTAT program while the Duncan test was used for means comparison (Snedecor and Cochran, 1967).

Results and Discussion

Floristic α-diversity

Fertilization affected floristic diversity only for the first two years after the application. Species richness (N) was significant higher ($P<0.05$) in the control treatment during 2001 (Figure 1). Shannon-Weiner index of *α*-diversity (H′) and evenness of Shannon-Weiner index of diversity (E) were significant higher ($P<0.05$) in the control treatment only during 2002 (Figure 2, Figure 3). Other trials have shown that P fertilization increases legume cover (Henkin *et al.,* 1996) and biomass (Stocklin *et al.,* 1998) and it is expected to increase their dominance but legumes are selectively eaten by sheep more than other less palatable species. Grazing by sheep probably explains the fact that floristic diversity was only slightly affected by fertilization and only during 2001 and 2002. Gough and Grace (1998) have also found that fertilization decreases plant diversity only in plots protected from herbivory.

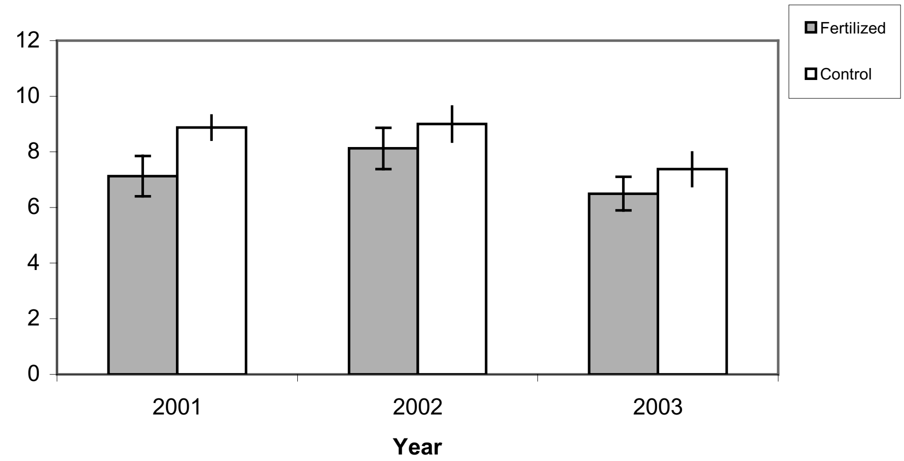

Figure 1. Species richness of fertilized and control treatments during 2001, 2002 and 2003

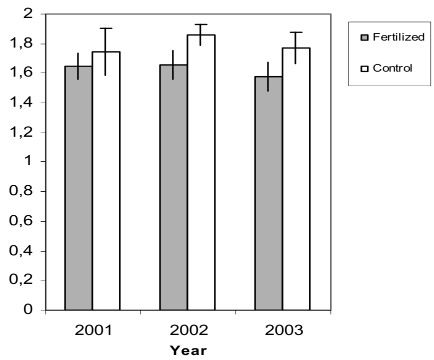

Figure 2. Shannon-Weiner index of α-diversity of fertilized and control treatments during 2001, 2002 and 2003

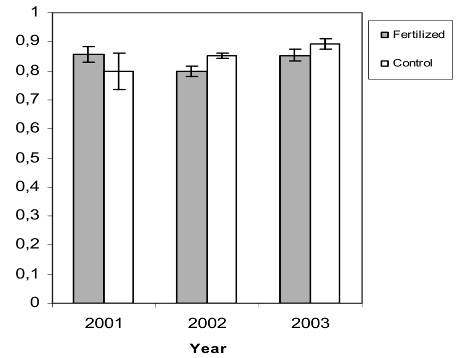

Figure 3. Evenness of Shannor-Weiner index of diversity of fertilized and control treatments during 2001, 2002 and 2003

Herbage production

Herbage production in the control treatment did not vary significantly during the three years of the study (Figure 4). Fertilization almost doubled sward biomass in the first year after application. Herbage production was higher in the fertilized test site compared to the control during all years but this difference was statistically significant only during the first year after the application of the fertilizers. This probably occurred because N fertilization increases herbage yield only during the first year after application (Henkin *et al.,* 1996). Residual effects diminished from year to year but were still evident in the third year of the trial. Decreased herbage production during 2002 and 2003 in both treatments is possibly due to the drier soil conditions. It seems that the limiting factor for plant growth in Mediterranean grasslands is soil water content.

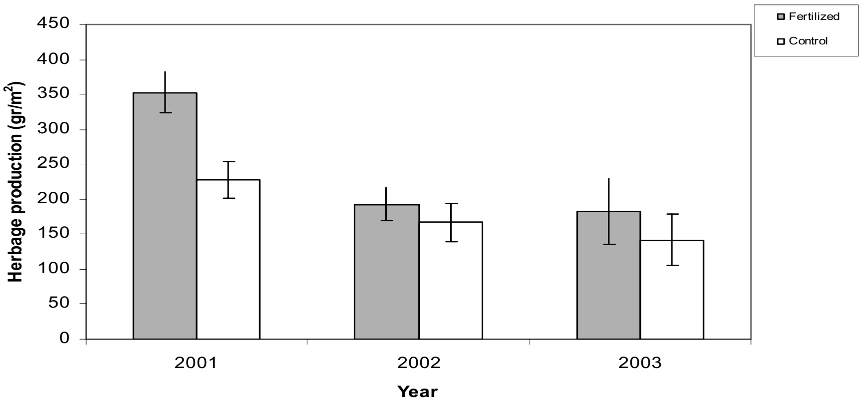

Figure 4. Herbage production (gr m^{-2}) of fertilized and control treatments during 2001, 2002 and 2003

Conclusions

P and N fertilization increased herbage production and decreased floristic diversity. These effects lasted for 2 years only. Sheep grazing increased floristic diversity. During the third year after the application of P and N no significant differences in herbage yield and in floristic diversity indexes were recorded.

Acknowledgements

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Effect of different long-term sward management on botanical composition of winter pasture in the Wielkopolska region of Poland

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Abstract

In the period from 2000–2004, at the Brody Experimental Station, Poland, a replicated field experiment was carried out on a low-input pasture of a Lolio-Cynosuretum community dominated by *Poa pratensis*. The aim was to investigate the influence of the term of pre-utilization in summer (last use at the beginning of: a/June, b/July, or c/August) and the date of harvest in winter (at the beginning of November, middle of December, and end of January) on the proportion (as determined from separated and weighed samples) and quantity of plant species in the sward. Botanical analyses were performed in the spring and autumn of each year. The lengthening of the regrowth time and delaying the date of the sward harvest in winter increased the proportions of *Agropyron repens*, *Cirsium arvense* and other unfavourable species (in terms of fodder quality), while simultaneously reducing the proportion of agriculturally valuable grasses in the sward. In such sward management conditions, the number of plant species in the sward also decreased. The stability of the sward botanical composition on winter pastures of a Lolio-Cynosuretum community dominated by *Poa pratensis* was maintained if pre-utilization in summer was carried out at the beginning of August with additional sward defoliation in June.

Keywords: botanical composition, low-input grassland, sward management, winter pasture

Introduction

Recently, especially in western European countries, there has been an increasing trend towards year-round keeping of beef cattle outdoors at pasture. During recent years weather conditions were sufficiently favourable to keep cattle on pastures until late autumn and early winter (Opitz von Boberfeld, 1997). It appears that in Poland also, there are conditions to introduce a similar technology of beef cattle production based on winter pasturing. One of the problems facing farmers using such technology is a decreasing quality of fodder consumed by animals kept on pastures (Opitz von Boberfeld and Wolf, 2002). Prolonged utilization of the sward and the late dates of harvesting in winter change the competitiveness between species, which has an effect on botanical composition of the winter pasture. The objective of this work was to evaluate the effect of long-term different sward management on botanical composition of winter pasture in the Wielkopolska region.

Materials and Methods

In the period from 2000–2004 an experiment with a randomised Latin square design with three replicates was carried out on a low-input pasture of a Lolio-Cynosuretum community dominated by *Poa pratensis*. The site was at the Brody Experimental Station of August Cieszkowski Agricultural University Poznań, Poland (52º 26´ N, 16º 18´ E; 92.0 m a.s.l.; long-term mean annual rainfall 590.0 mm, and mean air temperature 8.0 °C). The soil was a poorly mineralized muck having the following factors (results of 2000 year analyses): pH $_{(0.01\ M\ CaCl2)}$ 6.5; total nitrogen 0.61%; and 16.5, 12.1 and 5.1 mg of P_2O_5, K_2O and Mg per 100 g of soil, respectively. The purpose of this experiment was to investigate the influence of the period of pre-utilization in summer (i.e. last use at the beginning of: a/June, b/July, or c/August) and the date of harvest in winter (at the beginning of November, middle of December, and end of January) on the proportion and quantity of plant species in the sward. Details of the experimental treatments are presented in Table 1. The botanical analyses were performed in the spring and autumn of each year. The net plot area of each replicate was 20 m^2 (2 m × 10 m). In the second half of August each year the pasture was fertilized with ammonium nitrate at 50 kg N per hectare, in order to simulate (in part) the nutrient return of faeces of grazing animals. Sward samples (ca. 1 kg) were taken from each plot, separated and the fractions were dried for 48 h at 106 °C in an air-forced stream drying box and weighed.

Table 1. Treatments in winter pasture experiment

Treatment	Term of pre-utilisation in summer	Date of harvest in winter
1.1	beginning of June	beginning of November
2.1	beginning of June + beginning of July	beginning of November
3.1	beginning of June + beginning of August	beginning of November
1.2	beginning of June	middle of December
2.2	beginning of June + beginning of July	middle of December
3.2	beginning of June + beginning of August	middle of December
1.3	beginning of June	end of January
2.3	beginning of June + beginning of July	end of January
3.3	beginning of June + beginning of August	end of January

Results

The botanical composition of the sward in spring 2000 was: *Poa pratensis* – 31.8%, *Agropyron repens* – 18.3%, *Lolium perenne* – 14.5%, *Poa trivialis* – 9.8%, *Festuca pratensis* – 5.5%, *Trifolium repens* – 2.4%, *Taraxacum officinale* – 3.7% and other species – 14.0%. Figure 1 summarizes the changes in botanical composition of the winter pasture sward, harvested in November, in relation to the period of pre-utilization in 2000–2004.

In the treatment with pre-utilization in June (1.1) the proportion of the dominant sward component *Poa pratensis* decreased from 31.8% in 2000 to 21.0% in 2004. This sward management also had the effect of increasing the proportion of *Agropyron repens* up to 65% in the last year of investigations and of decreasing legumes and fodder grasses, such as *Lolium perenne*. The number of species decreased from 26 in 2000 to 14 after four years of utilization. In the other treatments, 2.1 and 3.1, the similar qualitative and quantitative changes in sward botanical composition were observed. However, the proportion of *Agropyron repens* stabilized in the last three years at the 35–38%. In comparison with 2000, *Poa pratensis* increased slightly, in contrast to other fodder grasses.

In the other sward management treatments, with harvest dates in December (1.2, 2.2, 3.2) and January (1.3, 2.3, 3.3) an increase in *Agropyron repens* was also observed over successive years of utilization (Figure 2 and 3).

A particularly high proportion of *Agropyron repens* in the botanical composition was recorded in the treatment with pre-utilization in June and harvest in January (1.3). In 2004 it reached at the level of 85.3%. The increased proportion of *Agropyron repens* was limited by the additional pre-utilization in August, mainly in treatment 3.3. Under this type of sward management higher proportions of *Poa pratensis* (38%) and herbs (ca. 17%) were observed. Also, the number of plant species in the sward in 2004 was not changed in comparison with

2000. Furthermore, at the end of the period of this research the number of species in the treatment with pre-utilization in June and additional defoliation in August increased from 26 to 31.

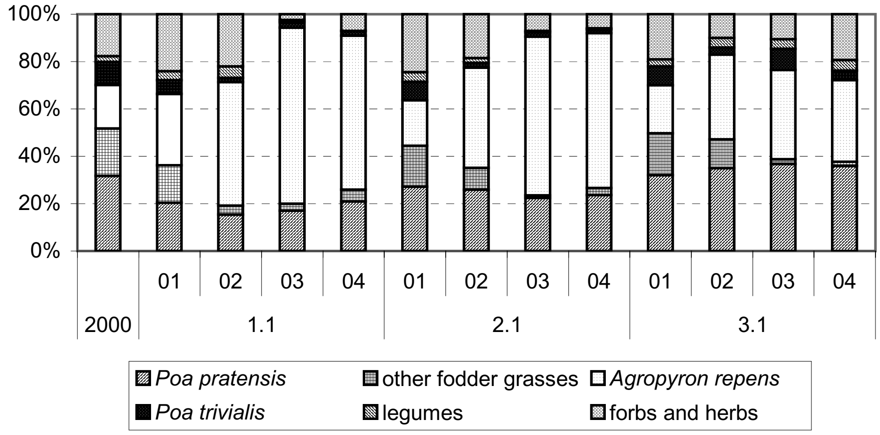

Figure 1. Changes in the proportion (%) of species in botanical composition from 2000–2004 of winter pasture harvested in November, for the pre-utilization treatments 1.1, 2.1 and 3.1

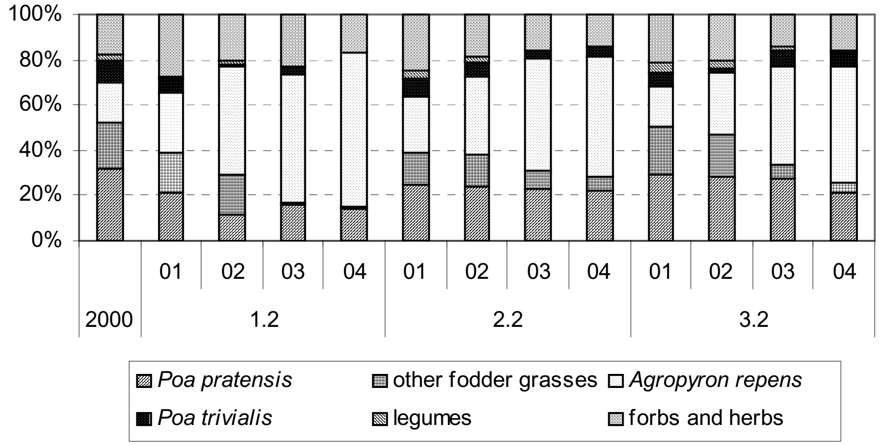

Figure 2. Changes in the proportion (%) of species in botanical composition from 2000–2004 of winter pasture harvested in December, for the pre-utilization treatments 1.2, 2.2 and 3.2

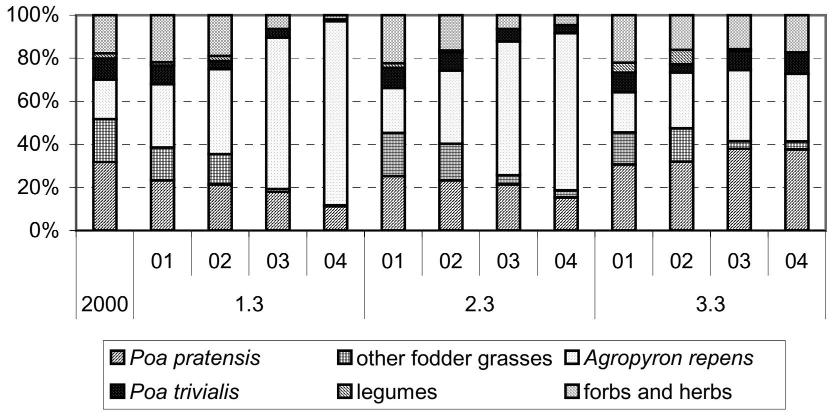

Figure 3. Changes in the proportion (%) of species in botanical composition from 2000–2004 of winter pasture harvested in January, for the pre-utilization treatments 1.3, 2.3 and 3.3

Discussion

In each treatment legumes and fodder grasses, like *Lolium perenne, Festuca pratensis* and *Phleum pratense*, decreased their proportion in the sward botanical composition of winter pasture over successive years of utilization. According to Opitz von Boberfeld (1997) these species are not so important on winter pasture because of poor winter hardiness and low fodder quality under prolonged sward utilization. Woledge *et al.* (1990) clearly show the biomass decrease of *Trifolium repens* in winter, which is connected to a high rate of leaf death. In the work reported here, change of sward management from pasture with 4–5 rotations to extensive winter pasture strongly influenced the competitiveness of species in the sward, so that after four years of utilization the botanical composition was fully transformed. In the experimental area *Agropyron repens* was most competitive. Pre-utilization in August was found to be the best method of stabilization of botanical composition of winter pasture.

Conclusions

The lengthening of the regrowth time and delaying the date of the sward harvest in winter increased the proportions of *Agropyron repens*, *Cirsium arvense* and other unfavourable species (in terms of fodder quality), while simultaneously reducing the proportion of agriculturally valuable grasses in the sward. In such sward management conditions, the number of plant species in the sward also decreased. The stability of the sward botanical composition on winter pastures of a Lolio-Cynosuretum community dominated by *Poa pratensis* was found to be maintained if pre-utilization in summer was carried out at the beginning of August, with additional sward defoliation in June.

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Impact of different management systems and location parameters on floristic diversity of mountainous grassland

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Abstract

Within the Man and Biosphere project ‘Grassland in mountainous regions of Austria’, which was initiated by the Austrian Academy of Science, comprehensive studies have been carried out in 8 representative grassland regions in Austria. More than 1700 botanical assessments have been carried out and were linked with important location properties and aspects of various management systems. The total number of vascular plants found on pastures and meadows reached a maximum of 115, depending on livestock intensity and land use type. It could be demonstrated that the Austrian grassland is not only characterized by high species diversity but also by a rich diversity of different plant communities.
The research findings clearly indicated the positive impact of low input farming systems on floristic diversity of grassland but failed show any significant benefit to organic farming compared with other farming methods when compared at similar livestock intensities. Beside forage plants, a high number of red list species were found in meadows and pastures, depending mainly on land type and intensity of utilisation. Therefore, the different grassland types in Austria, which cover approximately 60% of the total agricultural used land, represent an indispensable part of the cultural landscape.

Keywords: species diversity, mountainous grassland, low-input farming, organic farming

Introduction

Grasslands accounts for 60% of the total agricultural used area in Austria, 90% of which is permanent grassland and not ploughed for at least 20 to 25 years. Extensive managed grassland dominates the western and central production areas of “Hochalpen”, “Voralpen” and “Alpenvorland”. Ley farming areas are concentrated in the more favourable regions in the eastern and southern part of the country. Grassland not only provides forage for cattle and sheep production but also fulfils multifunctional tasks for society including the maintenance of biodiversity.
Agriculture has, in general, a large impact on the cultural landscape but also has significant influences on the conservation, development and diversity changes within this important ecosystem. Species and habitat diversity, as well as aspects of landscape, have been a focal point of the mid-term review according to the EU-ordinance 1257/99. Three main criteria and eight special indicators have been used to study different aspects of biodiversity. This paper presents some selected results of a current study, which was prepared and used in the Austrian mid-term review.

Materials and Methods

Within the multi-disciplinary Man and Biosphere project ‘Changing Agriculture and Landscape: Secondary grassland in the mountain regions of Austria’, botanical studies have been carried out in eight representative grassland regions in Austria. More than 1700 comprehensive botanical assessments have been made and were linked with important location properties and different management systems. Beside the recording of α-diversity based on the modified method of Braun-Blanquet (1951), additional investigations on β-diversity of grassland were carried out. Apart from the official Austrian grassland classification, fifteen utilisation types were differentiated to specify the results and to consider the great variation of alpine and mountainous grassland (Poetsch and Blaschka, 2003).

Results and Discussion

The species diversity of grassland is strongly depending on the type of land use, which again is characterised by different intensity levels. Figure 1, shows the abundance of vascular plant species, which were detected in diverse grassland types. The box plots include the median (horizontal line within the box), the quartiles (lower and upper bound of the box) and all values within the bar with the exception of outliers and extreme values.

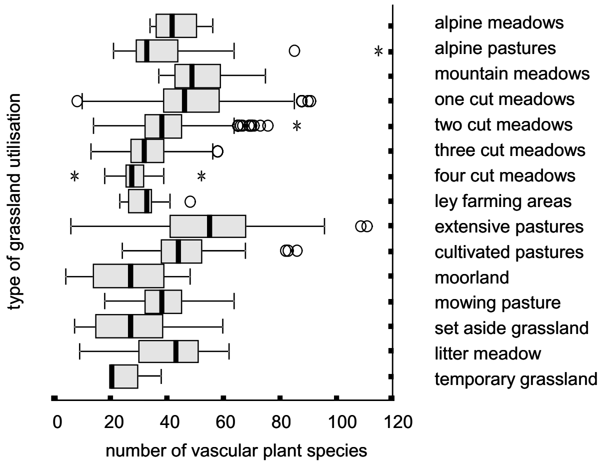

Figure 1. Species diversity of different grassland types in Austria

The highest number of vascular plant species was observed on extensive pastures (N = 115) and mountain meadows, followed by one and two cut meadows. In more intensively used ley farming areas an average number of 32 species could be detected which was higher that the numbers observed by Bassler (2002). The grassland types with the lowest species number are the four cut meadows and temporary grassland areas. In total, 869 different vascular plant species could be observed in the eight project areas, thus strongly demonstrating the sustainability of the Austrian grassland management. Grassland and dairy farmers still consider the traditional and regional conditions and constraints for production and are still willing to use less productive, but species rich grassland types.

Forty percent of the Austrian grassland and ley farming areas are located at elevations of 600 m or less, 23% being found at altitude of 600 to 800 m and 34% are located at altitudes greater than 800 m. Approximately 40% of the grassland areas have a slope greater than 25%, with some being more than 50%, thus causes major problems in their management, especially in relation to harvesting, fertilising and resowing (Poetsch *et al*., 2005). Figure 2, shows the relationship between species diversity and the altitude of grassland. There is a significant increase of plant species with rising altitude, which is caused mainly by the geographical distribution of the different grassland types. More extensive grassland types can be found at higher altitude being associated with lower livestock numbers and lower fertilising intensity, both of which strongly influence plant biodiversity.

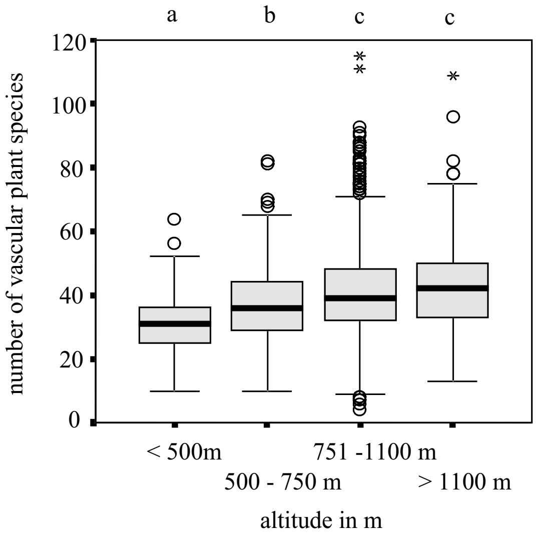

Figure 2. The relationship between floristic diversity and altitude

At higher altitudes there is an increase of organic farming, whereas conventional farming systems can be found in more favourable production areas in the lowlands. Over a range of grassland types it could be shown that a higher share of extensive and basically species rich grassland types exist on organic grassland and dairy farms (Poetsch, 2000). Nevertheless, in relation to species diversity, there was no significant difference between organic and conventional farming when compared at similar intensity level.

A non-linear relationship was observed between the species diversity and the management intensity. The highest number of plant species could be observed at a moderate intensity level ranging from 0.5 to 1.5 livestock units per ha grassland. The number of different plant species decreases with increased farming intensity, however a similar reduction was noticed at an intensity level lower than 0.5 livestock units per ha grassland.

Beside a high number of plant species, extensive grassland types also show a higher proportion of red list species, which are of great importance for aspects of nature conservation. Within this study 152 red list species could be observed, most of them were found on extensive pastures (up to 16 red list species), moor land, set aside grassland and litter meadows.

The Austrian environmental program for agriculture enhances diversification and discourages intensive and monoculture farming systems. For two selected regions, the diversity of land utilisation was illustrated by means of a GIS-analysis. A high utilisation diversity, which results in a diversified and well structured landscape, could be demonstrated. For different reasons, many Austrian grassland areas and regions are nowadays endangered by a migration of both farming and settlement. This development will not only lead to negative consequences for infrastructure, tourism and landscape but also for biodiversity. Therefore, the national and the European agrarian policy aim for sustainable and practicable solutions to avoid a dramatic change in this sensitive living space.

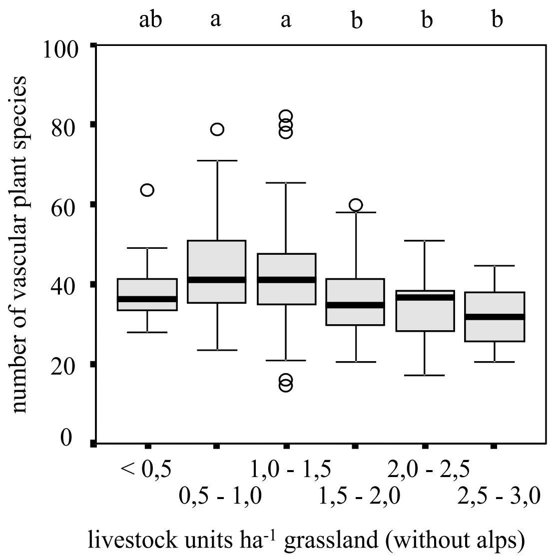

Figure 3. Relationship between floristic diversity and livestock intensity

Conclusions

The results clearly indicate that high species diversity can be found on the different Austrian grassland types. The Austrian environmental programme for agriculture "OEPUL", which is well accepted by farmers, contributes both to the maintenance of the farm structure and to the conservation of biodiversity. However, some special measures within that programme, aimed at nature conservation should be improved for the coming period to enhance their acceptance and efficiency. To advance the awareness of these relationships, farmers should be better informed about the association between farming, environment and nature protection issues. However, in spite of all efforts, a strong tendency for the abandonment of farming, especially in disadvantaged areas, can be noticed. Aiming at the sustainable preservation of cultural landscape and diversity of habitats, fauna and flora, there must be a strong improvement in the development of the rural space, including the productivity of grassland and dairy farming in alpine and mountainous regions. In the future, as well as payment for farm produce, agriculture will need to rewarded for the care of the landscape, the care of which is seen as being in the common good of society.

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Effects of sowing date on seedling growth of *Scorpiurus subvillosus* L.

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Abstract

Self-reseeding legumes are an essential component of Mediterranean natural pastures. *Scorpiurus subvillosus* L. is such a legume species particularly important as a fodder for sustaining animal husbandry in southern Italy. This legume species, in fact, has a high protein and low fibre content. The objective of this study was to acquire information on the biological behaviour and growth of *Scorpiurus*. Ten sowing dates (from August to July) and two different ecotypes (Pozzallo and Parabuto), from different altitudes, were studied. The trial was carried out in pots using scarified seed. On each sowing date, seventy days after sowing, below and above-ground biomass, leaves number and leaf area were recorded. It was noted that there was a greater effect on *Scorpiurus* for sowing date, than for ecotype. The highest daily growth rate during the first 70 days after sowing was measured in late spring and in the summer sowings. The seedlings of Parabuto ecotype showed the highest leaf number, while Pozzallo seedlings showed the widest leaf dimension.

Keywords: *Scorpiurus subvillosus*, growth rate, sowing date

Introduction

The importance of native forage plants in pastures is widely known. In fact, native forages usually show better local adaptation when compared to introduced species or cultivars. Among these, annual legumes are a spontaneous feed resource of semi-arid pasture of the Mediterranean basin and play an important role in the extensive grazing systems by improving pastures quality and, thanks to their nitrogen fixation capability, improving soil fertility useful to subsequent crops (Dear *et al*., 2003; Ewing, 1999). These species grow throughout the favourable season and overcome the hot and dry period as seed.

Among spontaneous annual legumes of the Mediterranean basin, prickly scorpion's tail (*Scorpiurus subvillosus* L.), a very palatable species to livestock, is quite common in Morocco, Algeria, the South France, South Italy (Bensalem *et al*., 1990; Beale *et al*., 1991). In natural pastures, *Scorpiurus* appears after the first autumn rainfall and grows for about 5-6 months, usually between November and May. Its distribution in pastures is not uniform. Generally, plants of this species are found together within pasture in patches (Abbate and Maugeri, 2005) and its persistence is strictly linked to dormancy due to the hard seed coat (Patanè, 1998). However, the best growth conditions for this species are not clearly defined. Likewise, little is known about the effect of different weather conditions on germination and early seedling development, which are probably the most critical stages of vegetative growth.

In semiarid regions the surface soil often dries very quickly after the late summer rain. As a result of this rapid drying, seedlings die with the exception of those which develop a root system rapidly. Early root growth also varies greatly among plant species and is usually affected significantly by temperatures (Cohen and Tadmor, 1969). The root and shoot growth

at seedling stage may be a critical parameter in determining, among the ecotypes, the potential establishment rates.
In order to understand better the biological behaviour of this species, this study was undertaken to assess the response of two populations of Scorpiurus subvillosus over ten sowing dates.

Materials and Methods

Pods were collected during May and June of 2002 from two sites in South East Sicily: Pozzallo (30 m a.s.l.) and Parabuto (560 m a.s.l.).
Since seeds of two ecotypes apparently differed in the degree of hardness of their seed coat (based on previous researches – data not showed) and to achieve rapid, uniform and high germination, seeds from two ecotypes were subjected to mechanical scarification by sand paper.
The following summer, the ecotypes were sown in 7.6 litres pots (22 cm diameter and 22 cm deep), in a randomised complete block design with four replications, in a clay soil at the experimental station of the Agronomy Department of University of Catania (80 m a.s.l., Southern Italy), over 10 sowing dates: 30 July (S_1), 3 September (S_2), 4 October (S_3), 7 November (S_4), 5 December (S_5), and 5 January (S_6), 7 February (S_7), 2 March (S_8), 6 April (S_9) and 6 July (S_{10}).
The pots were overseeded and at seedling stage were thinned to only two plants per pot. To ensure optimal growth conditions, the pots were watered when necessary and weeds were controlled by hand hoeing.
Seventy days after sowing (DAS), below and above ground part of the plant were harvested, washed, weighted and dried in a forced-air drier at 60°C until there was a constant dry weight. In order to obtain the rate of daily dry matter accumulation, the above ground biomass data were divided for the number of days from sowing. Leaves number and leaf area were also recorded.
Temperature data were available from a weather station located next to the experimental site: average of maximum and minimum value and absolute minimum value are reported in table 1.

Table 1. Temperatures recorded during the growing period (70 days) for each sowing date

	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9	S_{10}
MAX (average)	30.1	26.1	21.8	17.9	17.0	18.4	19.8	20.3	24.6	31.8
MIN (average)	18.8	16.0	12.4	8.9	7.7	7.2	7.8	9.1	13.3	20.9
Absolute MIN	16.9	15.5	9.2	8.1	5.3	3.3	3.3	2.5	6.2	18.7

Data were submitted to a two way ANOVA with ecotypes and sowing dates as factors. SNK test (Student- Neuman and Keuls test) was used to detect any significant differences ($p \leq 0.05$).

Results and Discussion

Results indicate that sowing date, rather than the ecotype, significantly influenced all growth parameters studied on plants at 70 DAS. There was no significant difference between the ecotypes, except for leaves number ($p<0.001$) (Table 2).
Generally, *Scorpiurus* sown in spring and summer resulted in plants that accumulated a higher amount of total above ground dry matter per plant than those planted between October and February (Figure 1a). The daily growth rate of S_1 was 0.030 g day^{-1} of dry matter (on average

of ecotypes), which was significantly higher than the other sowing dates. It was as much as 7 fold greater than the autumn and winter sowing dates (October to February); the other summer and spring sowings showed a reduction ranging from 24 to 45% of above ground daily growth rate than S_1. Some authors ascertain that temperature has a significant effect on early growth of several annual pasture species (Turner et al., 2001; Fukai and Silsbury, 1976). Although temperatures were still favourable, S_3 showed a lower value of dry matter than in November. This finding may be related to the abundant rainfall during late October and the beginning of November (300 mm, data not showed), which limited the crop growth.

Table 2. Results of the analysis of variance of the studied factors

Source of variation	Above-ground growth rate			Leaves number			Leaf Area		
	F	P	LDS	F	P	LDS	F	P	LDS
Main factor									
Ecotype (E)	0.121	0.730	n.s.	233.6	<0.001	–	3.08	0.08	n.s.
Sowing date (S)	40.62	<0.001	0.004	1094.4	<0.001	–	217.2	<0.001	24.4
Interaction									
E x S	0.379	0.938	n.s.	10.16	<0.001	2.02	3.615	0.002	n.s.

Sowing time strongly influenced the above-ground biomass/root ratio (p<0.001), and no significant difference could be detected between the two ecotypes (p=0.782). In summer and spring sowings, above-ground biomass was as much as nine times greater than the roots, while during the autumn and winter period, was about twice that (Figure 1b).

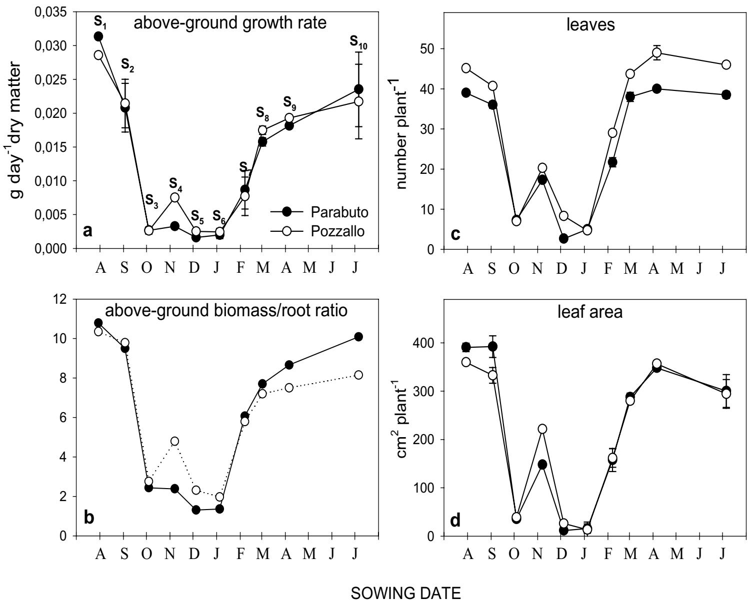

Figure 1. Above ground growth rate (a), above ground biomass/root ratio (b), leaves number (c) and leaf area (d) recorded 70 DAS. Each point is related to a sowing date. Vertical line indicates standard error

The number of leaves per plant was significantly affected by both the ecotypes and sowing time. 'Pozzallo' had higher leaf number than 'Parabuto', when the growth rate was more elevated (S_1, S_2, S_8, S_9 and S_{10}). Leaves number in the autumn and winter sowing was lower (among 48% to 84%) when compared to spring and summer sowings (Figure 1c).
Unlike leaf number, leaf area per plant was affected only by sowing date ($p<0.001$). Generally, late spring and summer sowings showed higher values, ranging between 280 and 392.3 cm^2 $plant^{-1}$ (Figure 1d).

Conclusions

These results represent the first attempt to explore the biological behaviour of *Scorpiurus subvillosus*.
Results show that the first-stage growth rate of *Scorpiurus* was greatly influenced by temperatures. Sowing date, rather than the ecotype, significantly affected all growth parameters. Highest daily growth rate of the first 70 DAS, was detected in late spring and summer sowings.
Even though they came from different climates and altitudes, the ecotypes showed differences only in leaf number. A greater number of leaves were recorded for Parabuto when compared to Pozzallo, even when both ecotypes shared a similar leaf area. This outcome is certainly related to a bigger leaf dimension.

Acknowledgements

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Vegetation and plant production of unfertilized grassland with increasing soil moisture

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Abstract

Extensively managed grassland on organic soil is expected to become increasingly wet given that maintenance of drains and ditches is diminishing. To adjust management accordingly there is a need to know how the vegetation is influenced by increasing moisture. The aim of this investigation was to monitor the development of vegetation on organic soil, where the soil moisture increased, at continuous grazing, cutting and abandonment during a four-year period. The effect on botanical biodiversity, production and forage quality was measured. The most marked change in vegetation over years was a decrease of *Poa pratensis* (L.) and a rise of *Deschampsia caespitosa* (L.) Be. In general there was a small increase in species number over years. The density of flowering plants decreased at abandonment and increased at cutting. Production of DM decreased from 4.6 to 3.0 t per ha from 1st to 4th year and IVOMD decreased from 55 to 42 % in the same period. Management and grazing intensity need to be adjusted according to the change in sward conditions and aims for the specific area.

Keywords: Organic soil, cutting, continuous grazing, abandonment, forage quality

Introduction

Much of the agricultural land on organic soil is used as extensively managed grassland or it is abandoned. The maintenance of drains and ditches is too expensive and the area may become increasingly wet. To keep these areas as open landscapes and maintain or improve nature quality it is important to know how management influences the botanical composition and productivity at increasing soil moisture. The objective of this study was to measure the development in botanical composition, the forage production and quality at a wet compared to a reference site under continuous grazing, cutting and abandonment.

Materials and Methods

The investigation was carried out on long term grasslands not fertilised since 1989 and alternately cut or grazed. The species density was low, dominated by *P. pratensis* and with a few herbs only. The water flow in soil was slow. The upper 20 cm soil had 69% organic matter, 3.0% total N, and soil pH ($CaCl_2$) was 4.6. The water table was regulated to simulate disconnection of drains and ditches. This area (WET) was compared with a nearby area without regulation of water level (REFE). On both area types, three blocks with continuous grazing, cutting and abandonment were established. The size of plot was 144 m^2 for cutting and abandonment, and the plots for grazing were laid out in connection with bigger paddocks. Under cutting management, the first cut was taken about 15 July and the second cut two months later, with a stubble height of 7 cm. Under continuous grazing with young steers the compressed sward height was on average over the four years 14.9 and 11.6 cm in respectively WET and REFE. In the grazed plots DM-production was measured in a uniform area of

8 m[2] in which one half of the area was cut at 2 cm and the other half enclosed by a fence for a 6–8 week period to measure the production. Three measurements were carried out during the season, each time at a new part of the sward. The DM production at grazing was calculated.

Table 1. Average number of species per plot (5m^2, n = 3 blocks) in relation to time after change in wetness and average change for the years compared to the conditions in 1997. Botanical analyses in 1997 were carried out before the change in soil moisture

Area:		WET			REFE		
Treat-ment:		abandonment	cutting	continuous grazing	abandonment	cutting	continuous grazing
Year	1997	9.7	8.7	8.7	11.0	12.0	9.0
	1998	12.0	8.3	8.0	9.0	10.3	12.0
	1999	12.0	10.7	8.3	10.7	13.0	11.3
	2000	13.0	9.7	9.3	13.3	14.3	11.7
	2001	11.7	11.0	11.0	13.0	12.3	11.5
Average change compared to 1997		2.0	1.0	0.4	0.4	0.6	2.0

GLM analyses. WET: number of species= year (treat.) + treat.; $P_{year(treat.)}$ =0.0001; $P_{treat.}$ =0.96; P_{model} = 0.0003. REFE: number of species= year (treat.) + treat.; $P_{year(treat.)}$ =0.014; $P_{treat.}$ =0.73; P_{model} = 0.045.

Table 2. Sum of points for flowering species (G-point) at plot level (5 m^2) in relation to treatment, type of area (WET/REFE) and year. Establishment of WET completed after analyses in 1997

Area:		WET			REFE		
Treat-ment:		abandon-ment	cutting	continuous grazing	abandon-ment	cutting	continuous grazing
Year	1997	35	35	44	30	30	20
	2001	20	39	36	19	46	43

Model: G-Point per plot=type of area+treat.+year+type of area*treat.+treat.*year(type of area). P_{model}=0.0004, R^2=0.73. $P_{treat.}$=0.0009, $P_{treat.*year(type\ of\ area)}$=0.0005. Others were not significant.

Forage quality measured as IVOMD, NDF, crude protein and ash, as well as species compositions on a DM-basis were monitored. Botanical diversity and density of flowering species was monitored by extended Raunkiær analysis (Hald and Petersen, 1992). The water level was below soil surface and was measured by piezometers. Soil was sampled each year in spring and autumn to measure the content of mineral N. A statistical analysis of the species on a DM-basis focused on the development over time of the single species – and also the DM-production and forage quality – and whether this development was dependent on treatment and type of area. PROC MIXED from SAS was used (Littell *et al*., 1996).

Results and Discussion

During the experimental period the water level in both WET and REFE became higher in May-July, from –38 to –13 cm due to increased spring precipitation. The expected difference in ground water level between WET and REFE was not obtained, but mean soil moisture measured in spring and autumn was higher in WET (75.4 %) than in REFE (72.5 %). Thus, the change in wetness over years was more marked than the difference between WET and REFE. The experimental period was too short and the number of potential species too low to obtain major changes in species diversity but there was a small increase over the years (Table 1).

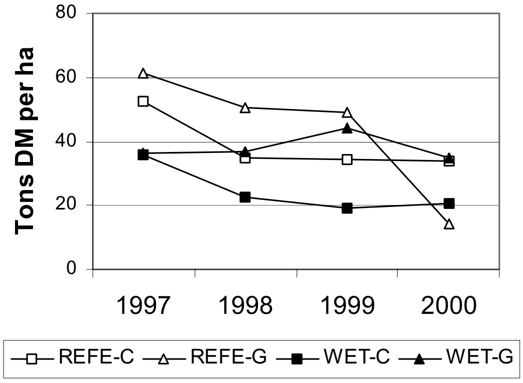

Figure 1. DM-production at cutting (C) or continuous grazing (G)

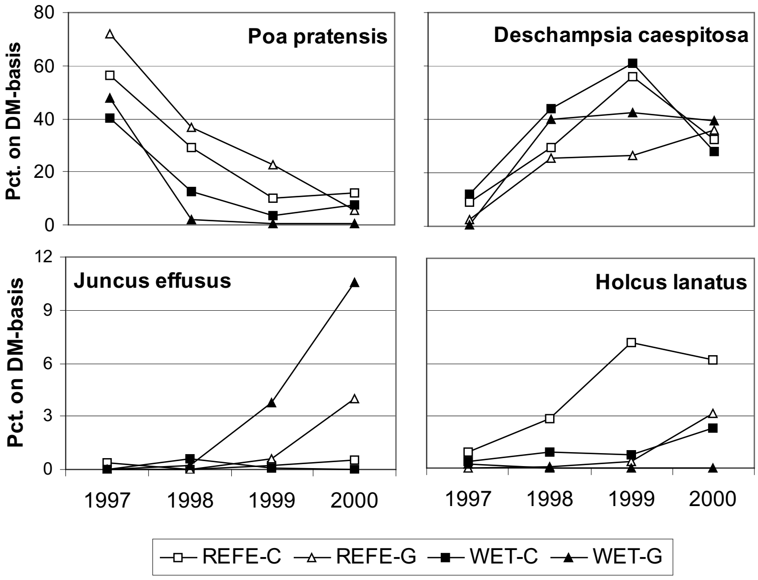

Figure 2. Development in species composition in a four year period. The results are shown on DM-basis. Data from each time of sampling adjusted for production in the corresponding time of the growing season. Legends as Fig. 1

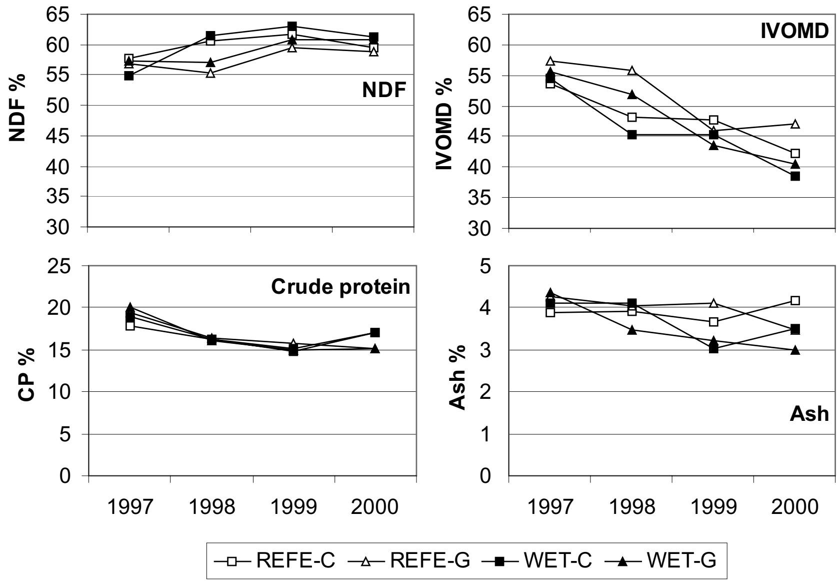

Figure 3. Quality of the crop with data from each time of sampling adjusted for production in the corresponding time of the growing season. Legends as Fig. 1

The density of flowering plants decreased at abandonment, possibly an effect of increased litter on *Ranunculus repens*. Density of flowering plants increased under cutting in both area types, but under continuous grazing it decreased in WET and increased in REFE (Table 2). The increasing water level in May-July resulted in a decrease in production from 4.6 to 3.0 t per ha (Fig. 1). The most marked changes in vegetation on a DM-basis were a decrease of *P. pratensis* and a rise of *D. caespitosa* (Fig. 2). The changes seemed primarily caused by the rise in water level in May-July and to a smaller extend by the treatments, with a faster decrease of *P. pratensis* and a faster increase of *D. caespitosa* in grazed compared to cut plots. Forage quality also decreased on both area types (Fig. 3), especially IVOMD, with a decrease from 55% to 42% in the period (Table 3).

The content of mineral N in the soil decreased from 138 to 84 kg N per ha over years in spring (0–70 cm) which may be one of the reasons for a lowering in DM-production. These data corresponded with an increase in the proportion of *D. caespitosa*, which is favoured by a low supply of N (Mountford *et al*., 1993). A similar decrease in DM-production with higher water level was not found in a Dutch experiment where cutting, mulching and sod removal were compared with and without a rise in water level on a heavy clay soil with a high content of organic matter (Oomes *et al.,* 1996) and where the water level was around –30 cm in the WET plot in May-July. Type of soil, water level and water movement will be important for the outcome of changes in soil moisture. The change in forage quality corresponded with the difference in species quality of the dominating species, with *D. caespitosa* having a lower value of IVOMD than *P. pratensis* (Nielsen and Søegaard, 2000).

Table 3. P-values for analyses of species composition on DM-basis (log-transformed), crop production in DM and quality. Quality data are results from samples taken through the season and weighted according to production in the period for the single analysis; one value is used per year, area, treatment and block

	Treatment	Trend over years	Trend *area	Trend *treatment	Trend *treatment *area
P. pratensis	n.s.[1)]	<0,0001	0,04	0,0002	0,02
D. caespitosa	0,03	0,09	n.s.	0,02	n.s.
H. lanatus	<0,0001	0,005	0,01	n.s.	n.s.
J. effusus	0,01	0,03	n.s.	0,04	n.s.
DM	n.s.	0,002	0,007	n.s.	0,05
NDF	0,04	0,03	n.s.	n.s.	n.s.
IVOMD	0,03	<0,0001	n.s.	n.s.	n.s.
Protein	n.s.	0,09	n.s.	0,005	n.s.
Ash content	n.s.	0,0006	0,01	0,04	n.s.

[1)] n.s. Not significant.

Conclusions

As the natural change in water level during May-July was more important than the difference in moisture between WET and REFE, the results found are an overall response to the effect of precipitation and treatments. Evaluating the effect on the sward it is concluded:

- Number of species showed no effect of type of area or treatment, but increased over years.
- Flowering decreased as an effect of abandonment and increased under cutting.
- *P. pratensis* on DM-basis decreased and *D. caespitosa* increased at both cutting and grazing, in both WET and REFE.
- *H. lanatus* on DM-basis increased significantly in REFE compared to WET.
- *J. effesus* on DM-basis increased at low grazing intensity in both area-types.
- DM-production decreased over years in both area types, except under grazing in WET, where the amount of *J. effuses* increased the most.
- IVOMD decreased over years, not related to type of area or treatment.

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Influence of some physical and biological factors on seed germination of *Scorpiurus subvillosus* L.

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Abstract

Prickly scorpion's tail (*Scorpiurus subvillosus* L.) is a forage plant, with a high quality for animal husbandry, spontaneous in grass pastures of Mediterranean basin. It exhibits seed coat dormancy, that delays and reduces germination.
With the aim of studying the influence of physical and biological factors upon germination of its seeds, the effects of two seed treatments (control and scarification), eight germination temperatures (from 5 to 40 °C, with steps of 5 °C) and three storage periods (35, 137, 200 days after seed harvest) were evaluated in the laboratory.
Seed germination increased gradually as temperature was raised. It peaked at 20 °C (50% for control and 100% for scarified seeds), then declined with further increases of temperatures over 25 °C.
Seed scarification enhanced germination percentage with values up to 100% within a wider temperature range (10–30 °C) than untreated seed. Storage time affected seed germination in both untreated and scarified seeds.

Keywords: *Scorpiurus subvillosus*, hard seed coat, germination, scarification, temperature, storage time

Introduction

Many Mediterranean forage species have mechanisms for preventing germination immediately after ripening. 'Dormancy' inhibits the germination of fresh seeds even if optimum conditions of temperature and soil moisture occur. Seed dormancy is a fundamental ecological mechanism which allows a long term survival in the natural pasture seed banks, however it represents a limit for the cultivation of a forage species as a pure crop, whose establishment requires a prompt and high levels of germination. Various factors can be involved in maintenance of dormancy such as morphologically immature embryos, mechanical restraints to radicle protrusion, specific light or temperature requirements, or chemical inhibitors (Bewley and Black, 1978). In many legume species, such us *Medicago* spp., only the impermeability of the seed coat (commonly defined 'hard') seems to prevent imbibition of water and, thus, germination, and a simple seed coat scarification can allow a better germination rate (Patanè and Bradford, 1993).
Prickly scorpion's tail (*Scorpiurus subvillosus* L.) is an annual legume forage plant, spontaneous in the Mediterranean basin, which produces a conspicuous biomass (Abbate and Maugeri, 2004) and presents a good soil erosion prevention capability as a result of its spread leaf apparatus (many leaves broadly obovate) at or near soil surface. There are very few references on this species, but due to its geographical distribution and high adaptability to a large range of semi-arid environmental conditions (soil type, soil nutrient status, altitude and climate) (Beale *et al*., 1991; Bensalem *et al*., 1990). *Scorpiurus* could represent a very interesting species for the Mediterranean areas.
In order to increase knowledge of this species, a research project was carried out to study the

influence of i) seed scarification, ii) germination temperature, iii) storage time after harvest, upon seed germination of *Scorpiurus subvillosus*.

Materials and Methods

Pods of S*corpiurus. subvillosus* L. were collected in 2003 in a restricted area at 500 m a.s.l in south-east Sicily (South Italy). Immediately after collection, the seeds were extracted from pods, and only those intact considered viable. The seeds were stored in paper bags under laboratory conditions (RH 40–60% at 18–28 °C), for the following periods 35, 137 and 200 days after harvest (DAH), until germination tests were performed.
As in other forage legumes, *Scorpiurus* spp. exhibit a coat-imposed dormancy (Patanè, 1998), which can be overcome through scarification. A small portion of seed coat was carefully removed by rubbing each seed with 100 grit sandpaper. A control of unscarified seeds was used.
The seeds were placed on Whatman No.3 filter paper in 9 cm Petri dishes and moistened with 5 ml of distilled water. The dishes were covered and placed in a germinator in the dark at one of the following constant temperatures: 5, 10, 15, 20, 25, 30, 35 and 40 °C. For each treatment, three replicates of 50 seeds each were used. Water was replenished as needed.
Radicle protrusion (minimum 2 mm long) was scored daily up to the 15th day, and germinated seeds were removed from the Petri dishes. Finally, the percentage of germinated seeds was calculated.
The percentage values were arcsin √% transformed and analysed by ANOVA applied to the experimental design adopted (eight temperature x three storage periods), using COSTAT (CoHort Software). Tukey's test was used to detect any significant difference ($p \leq 0.05$) in the comparison between pairs of treatments. Percentage values are reported in the text. Since no germination occurred at 40°C, this temperature is not included in results and discussion.

Results and Discussion

A significant influence of both *temperature* and *storage period* upon germination was observed in untreated seed (Table 1; Figure 1). *Scorpiurus* seeds showed a higher germination within a range of temperatures from 10 to 30 °C and peaked at 137 DAH. The unscarified seeds tested at 35 DAH showed the lowest germination percentage (never exceeding 18%, this last recorded at 25 °C) when compared to the other storage times.

Table 1. Results of ANOVA

Parameters	df	Untreated seeds			Scarified seeds		
		F	P	LSD	F	P	LSD
Main effect							
Temperature (T)	7	229.7	<0.001	–	697.3	<0.001	–
Storage time(S)	2	195.8	<0.001	–	76.2	<0.001	–
Interaction							
T x S	14	25.2	<0.001	5.54	11.5	<0.001	6.26

The amount of these 'softcoated' seeds, which anyway germinate with no scarification, is in agreement with those observed in other *legume* species (Tàrrega *et al*., 1992; Roberts and Boddrell, 1985); these seeds allow the species to germinate in the same year of production, even in the absence of mechanisms producing cracks on the impermeable coat.

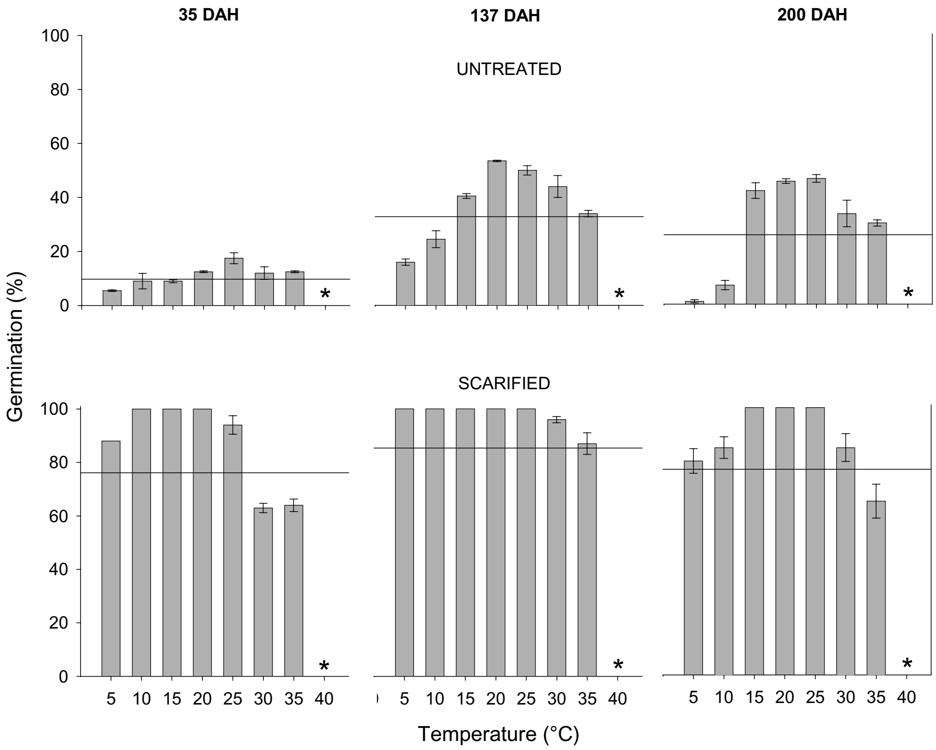

Figure 1. Final germination percentages (mean ± S.E.) of untreated and scarified seeds in relation to temperature and storage time. Horizontal line indicates the mean value. *No germination occurred at 40 °C

At 137 DAH seeds seem to respond more strongly to temperature. Germination increased with temperature reaching a peak at 20 °C, at which the highest percentage (51.5%) corresponded; afterwards germination declined. This is in agreement with the findings of other researchers such as Baskin and Baskin (1988), who reported that as dormancy is overcome, seeds germinate at the optimum temperatures only, but after an additional period, they are able to germinate in a wider range of temperatures.

Similar germination values were observed at 200 DAH, but with lower percentages recorded at the lowest temperatures (5 and 10 °C). These apparent contrasting results can be explained by cyclic changes which annually occur in seeds (Egley, 1995) and which could be more evident at suboptimal temperatures. The existence of seasonal cycles in germination has been proven in other leguminous species (Baskin and Baskin, 1998; Van Assche *et al.*, 2003).

Scarification of seed coat resulted in a pronounced increase of germination percentage, with final values ranging between 63 and 100%, irrespective of the storage time. Scarified seeds also showed a wider adaptability to germination temperature (10–35 °C) when compared to those untreated.

At 137 DAH, scarified seeds germinated fully at almost all temperatures. In the other two storage times (35 and 200 DAH), seed germination reached 100% at a wide range of temperature, but a greater sensitivity in terms of germination to the extreme thermal conditions was observed. This germination response reflects the seeds' behavior when untreated.

Conclusion

The untreated seeds of *Scorpiurus* showed an evident germination preference in a range of temperatures from 15 to 30 °C, with optimum conditions between 20 and 25 °C. Scarification of the seed coat resulted in a pronounced increase of germination percentage and at optimal temperature it ensured full seed germination. Seed coat abrasion extended the range of temperatures at which seed germinated.

Seed storage time affected the untreated seeds, improving their germination capacity, even if a seasonal pattern in germination was ascertained. This is the first time that a seasonal germination pattern has been observed on *Scorpiurus subvillosus*.

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Effects of fertilizer level and cutting frequency on yield and forage quality of grasslands

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Abstract

At four sites in the Czech Republic we evaluated long-term small plot trials at four levels of utilisation in 2003 and 2004 (four, three, two and one cut) and four levels of fertilizer application (zero fertilizer, PK, N_{90}PK, N_{180}PK). The overall average dry matter production of grasslands was over two years for all sites, 6.80 t ha^{-1}, and it significantly decreased (P 0.01) from 7.20 t ha^{-1}, resp. 7.34 t ha^{-1}, to 5.95 t ha^{-1}, resp. 6.71 t ha^{-1} when utilised in four and three cuts in comparison with two-cut utilisation. Nitrogen fertilizer application in averaged over two years significantly increased dry matter production in comparison with zero fertilised treatments resp. only PK fertilised from 5.33, resp. 5.72 t ha^{-1} to 7.44 t ha^{-1} when N fertilised at the rate of 90 kg ha^{-1} and 8.70 t ha^{-1} when N fertilised with 180 kg ha^{-1}. 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 127 (I_4) to 183 (I_1) g kg^{-1} DM, NEL (net energy of lactation) concentration (from 5.27 to 5.93 MJ kg^{-1} DM), NEV (net energy of fattening) concentration (from 5.07 to 5.72 MJ kg^{-1} DM), PDIE (ingested digestive protein allowed by energy) concentration (from 74.4 to 86.0 g kg^{-1} DM) and PDIN (ingested digestive protein allowed by nitrogen) concentration (from 76.6 to 109.6 g kg^{-1} DM), and it significantly decreases (P 0.01) fibre concentration from 292 to 207 g kg^{-1} DM. Level of fertilisation, especially graded N-fertilisation in comparison with the control and PK fertilisation significantly (P 0.01) increases CP concentration from 151 to 160 g kg^{-1}DM, and PDIN concentration from 90.1 to 96.2 g kg^{-1} DM. Species diversity increased territorially, in total 103 plant species were identified. Of species, *Dactylis glomerata* reacted most to N fertilizer application in terms of increase in treatments with nitrogen. Higher level of fertilizer application moderately decreased proportion cover of *Agropyron repens*, *Arrhenatherum elatius* and *Taraxacum officinale*. Legumes increased in the treatments without nitrogen.

Keywords: grasslands, cutting frequency, forage quality, biodiversity

Introduction

Permanent grasslands in the Czech Republic (CR) cover an area of 950,000 ha, comprising 22.2% of agricultural land (4,280,000 ha). The decrease of cattle numbers from 1,236 thousand heads in 1990 to 590 thousand heads in 2003 resulted in poorer management and utilisation of grasslands (803 thousand ha were utilised in 2002) because 50 % of cattle are located in lowlands where the basis of feeding ratio are forages on arable land, silage corn and concentrates (Kohoutek, 2002). Gruber *et al.* (2000) also states 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. Effect of feedstuffs on dairy production was correspondingly 11.4, 17.2 and 23.0 kg milk (FCM) per a cow per day.

Material and Methods

The long-term small plot trials were performed on permanent grasslands at the sites at Jevíčko, Liberec, Rapotín and Zubří in 2003, each consisting of 16 treatments, in 4 replications, with a 10 m^2 harvest plot size. The vegetation of grasslands on the experimental stands Jevíčko, Rapotín, Liberec and Zubří was classified as *Arrhenatherion*.
The intensity of utilisation:
I_1= (1st cut until May 15th, 4 cuts per year – cuts at 45 day interval),
I_2= (1st cut between 16th and 31st May, 3 cuts per year at 60 day interval),
I_3= (1st cut between 1st and 15th June, 2 cuts per year at 90 day interval) 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 and potassium as potash salt, and nitrogen as calcium ammonium nitrate. For all sites the total annual dry matter production and botanical composition of vegetation were measured. Forage quality in terms of crude protein (CP), fibre, NEL (net energy of lactation), NEV (net energy of fattening), PDIE (ingested digestive protein allowed by energy), PDIN (ingested digestive protein allowed by nitrogen) were predicted using NIRSystems 6500 instrument. Our paper evaluates averages in harvest years 2003 and 2004. The measured results were statistically evaluated with two-factor analysis of variance with one observation in the subclass, the differences between the averages were tested with the Tuckey test ($DT_{0.05}$, $DT_{0.01}$).

Results and Discussion

Overall average dry matter production of grasslands (Table 1) was 6.80 t ha^{-1} for sixteen treatment combinations for four sites for two years (2003 and 2004). Dry matter production (Table 2) significantly decreased (P 0.01) from 7.20, resp. 7.34 t ha^{-1} when under four and three cuts compared to 5.95 t ha^{-1}, resp. 6.71 t.ha^{-}1 in for two-cuts. The effect of N-fertilizer application over two years was to significantly increase (P0.01) dry matter production compared to nil fertilizer application, resp. PK fertilised treatments from 5.33, resp. 5.72 t ha^{-1} to 7.44 t ha^{-1} when N fertilised with 90 kg ha^{-1} and 8.70 t ha^{-1} when N fertilised with 180 kg ha^{-1}. Similarly Gruber *et al.* (2000) on the basis of evaluation of long-term trials carried on at BAL Gumpenstein states that graded frequency of cutting decreases the yield from grasslands, especially four-cut utilisation (8.65, 8.05, 6.51 t ha^{-1} DM, with 2, 3 and 4 cut-utilisation). The highest yield of energy was acquired in 3-cut utilisation.
The number of plant species at the sites was from 40 to 65, comprising 13 to 16 grass species, 2 to 10 legumes, and 22 to 40 other native species.
In terms of cover and agro-botanic plant groupings, grasses comprised the highest proportion (57%), with legumes having a very low share (up to 5%) and herbs more than a third (38%). However, highly caespitose grasses still prevail and there is moderate decrease in proportion of couch-grass. Distribution of permanent native species remains the same. Different intensity of utilisation (given by the number of cuts) resulted in a higher area of *Taraxacum officinale* in more frequent cuts systems, compared with *Crepis biennis* which showed a decrease in area coverage. Out of grasses the proportion of *Arrhenatherum elatius* decreased most. Of the species, *Dactylis glomerata* reacted most to N fertilizer application by increasing in treatments including nitrogen. Higher level of fertilizer application moderately decreased proportion of *Agropyron repens*, *Arrhenatherum elatius* and *Taraxacum officinale*. Legumes increased in the treatments not fertilised with nitrogen.

Table 1. Dry matter production and forage quality of grasslands at different levels of intensity of utilisation and fertilisation in the average of four sites and years 2003–2004

Treatments intensity of utilisation	Dry matter	CP	Fibre	NEL	NEV	PDIE	PDIN
	(t ha^{-1})	(g kg^{-1} DM)	(g kg^{-1} DM)	(MJ kg^{-1} DM)	(MJ kg^{-1} DM)	(g kg^{-1} DM)	(g kg^{-1} DM)
I_1F_0	4.74	178	197	6.01	5.73	85.3	106.6
I_1 F_{PK}	5.03	180	204	5.94	5.69	85.6	107.2
I_1 F_{PKN90}	6.42	181	214	5.85	5.70	85.9	108.3
I_1 F_{PKN180}	7.60	193	213	5.91	5.76	87.2	116.3
I_2F_0	5.21	164	213	5.87	5.65	83.6	97.8
I_2 F_{PK}	5.65	165	222	5.74	5.51	83.2	97.4
I_2 F_{PKN90}	7.33	164	231	5.70	5.55	83.3	97.8
I_2 F_{PKN180}	8.65	179	227	5.77	5.69	85.2	106.6
I_3F_0	5.63	133	257	5.50	5.28	77.5	78.8
I_3 F_{PK}	6.23	133	266	5.43	5.20	77.5	78.8
I_3 F_{PKN90}	8.05	127	281	5.28	5.13	76.2	74.1
I_3 F_{PKN180}	9.44	133	290	5.26	5.32	76.7	80.3
I_4F_0	5.74	128	278	5.38	5.15	75.0	77.3
I_4 F_{PK}	5.96	129	286	5.26	4.98	74.7	77.2
I_4 F_{PKN90}	7.97	117	302	5.22	5.12	73.1	70.2
I_4 F_{PKN180}	9.12	133	303	5.21	5.04	74.8	81.7
Average	6.80	152	249	5.58	5.41	80.3	91.0
$DT_{0.05}$	0.97	10	13	0.14	0.34	1.7	6.4
$DT_{0.01}$	1.13	12	15	0.17	0.40	1.9	7.5

The forage quality (Table 2) is in all treatments/years significantly influenced by two factors. The intensive utilisation (I_1) in comparison with the extensive one (I_4) significantly (P 0.01) increases CP concentration from 127 to 183 g kg^{-1} DM, NEL concentration (from 5.27 to 5.93 MJ kg^{-1} DM), NEV concentration (from 5.07 to 5.72 MJ kg^{-1} DM), PDIE concentration (from 74.4 to 86.0 g kg^{-1} DM), and PDIN concentration (from 76.6 to 109.6 g kg^{-1} DM), it significantly (P 0.01) decreases the fibre concentration from 292 to 207 g kg^{-1} DM.

The level of fertilizer application, esp. graded N-fertilisation in comparison with the nil fertilizer application control (F_0) and PK fertilised (F_{PK}) treatment significantly (P 0.01) increased CP concentration from 151 to 160 g kg^{-1} DM, and PDIN concentration from 90.1 to 96.2 g kg^{-1} DM. The concentration of fibre from N fertilised treatments moderately increased from 236 g kg^{-1} DM to 258 g kg^{-1} DM. NEL concentration moderately decreased and NEV and PDIE concentrations were not affected significantly by fertilisation from the average of all sites. These findings are in agreement with the findings of Gruber (2000) who has stated that increasing frequency of utilisation increases CP concentration and decreases fibre concentration (331, 291, and 246 g kg^{-1} DM). This corresponds with morphological changes of the plant leading towards increased proportion of stalks and their continuing lignification. In accordance with Kühbauch and Anger (1999), higher cutting frequency is more favourable because it requires fewer animals per ha and lower consumption of grain feedstuffs (import of nutrients to the farm).

Table 2. Dry matter production and forage quality of grasslands in relation to: (A) intensity of utilisation (the average levels of fertilizer application) and (B) level of fertilization (in the average of utilisation intensities) in the average of four sites and two years (2003–2004) of utilisation

Intensity (in the average of fertilisation levels), resp. utilisation (in the average of utilisation intensities)	Dry matter	CP	Fibre	NEL	NEV	PDIE	PDIN
	($t\ ha^{-1}$)	($g\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($MJ\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)	($g\ kg^{-1}$ DM)
A							
I_1	5.95	183	207	5.93	5.72	86.0	109.6
I_2	6.71	168	223	5.77	5.60	83.8	99.9
I_3	7.34	132	273	5.37	5.23	77.0	78.0
I_4	7.20	127	292	5.27	5.07	74.4	76.6
Average	6.80	152	249	5.58	5.41	80.3	91.0
$DT_{0.05}$	0.36	4	5	0.05	0.13	0.6	2.4
$DT_{0.01}$	0.44	5	6	0.06	0.15	0.7	2.9
B							
F_0	5.33	151	236	5.69	5.45	80.4	90.1
F_{PK}	5.72	152	245	5.59	5.34	80.2	90.1
F_{PKN90}	7.44	147	257	5.51	5.37	79.6	87.6
F_{PKN180}	8.70	160	258	5.54	5.45	81.0	96.2
Average	6.80	152	249	5.58	5.41	80.3	91.0
$DT_{0.05}$	0.36	4	5	0.05	0.13	0.6	2.4
$DT_{0.01}$	0.44	5	6	0.06	0.15	0.7	2.9

From the ecological viewpoint, higher cutting frequency is more favourable as it requires fewer cattle per ha and lower consumption of grain feedstuff (delivery of nutrients to the production place) (Kühbauch and Anger, 1999).

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Arnica montana, an endangered species and a traditional medicinal plant: the biodiversity and productivity of its typical grasslands habitats

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Abstract

Arnica montana occurs in *Nardus stricta* grasslands on siliceous soils in mountain areas. This habitat type (Code 6230) is listed in the EU-FFH-directive (92/43) and the species *Arnica montana* is listed in Annex V (92/43). The maintenance of *Arnica* populations is closely bound to traditional farming systems. The habitats are threatened by conversion to more intensive agriculture. To stop this, the farmer needs to be compensated to maintain these habitats. The sustainable use of *Arnica* flower heads can contribute to this. Productivity and biodiversity of its habitats were determined by carrying out an inventory of the meadows from a conservation and economic perspective. The habitats are diverse, but production is low. There is a wide range of productivity, biodiversity, *Arnica* cover and species composition within the habitats. Biodiversity and productivity are positively correlated, but biodiversity and cover are negatively correlated. To maintain the high biodiversity of the grassland and to improve yield of this medicinal plant a balanced meadow management must be found.

Keywords: *Arnica montana*, species-rich *Nardus* grasslands, Natura 2000, productivity, sustainable collection, medicinal plants

Introduction

Romania is one of the main source countries of dried *Arnica montana* flower heads processed in Central Europe. In 2002 about 28 t were collected from the wild (Kathe *et al*., 2004). Arnica montana occurs in Nardus stricta grasslands on siliceous soils in mountain areas. This habitat type (Code 6230) is listed in the EU-FFH-directive (92/43) and the species Arnica montana is listed in Annex V (92/43).
Agriculture formed traditional rural landscapes. Highly diverse and traditionally managed meadows can still be found in the Apuseni Mountains (Transylvania, Romania). In 2001 and 2002 (http://www.proiect-apuseni.org/) the habitats of *Arnica montana* were characterized by species composition and mapped in a test area of 47.9 km^2 (Michler, 2005). The habitats are species rich with a total of 143 species identified (Michler and Reif, 2003). The habitats are threatened by conversion to more intensive agriculture. The maintenance of *Arnica* populations is thus closely bound to traditional farming systems. It is thought that the actual low financial returns from collecting *Arnica* flower heads (about 0.50 € per kg fresh weight) and low productivity in hay might be a disincentive in the future to maintaining *Arnica* habitats (Michler and Reif, 2003). If the farmers think economically, they will fertilize the habitats to increase the production or give up management and the habitats turn into fallows. Both scenarios lead to a loss of species, habitats and landscape diversity. In this study, the habitats were inventoried from the conservation point of view and the productivity was determined in the agriculture sense.

Materials and Methods

The investigation area covers about 80 km^2. In 2004 53 plots one square metre plots were studied intensively. The species present were identified and the cover was measured precisely using a frame of one square metre subdivided into 100 squares of 10 by 10 centimetres. Within the frame, the total biomass of grass and herbs was cut, dried and the dry matter per ha was calculated.
The Shannon-Weaver-diversity index and the evenness (Pielou, 1975) were calculated for each plot. Regressions were calculated between diversity and total biomass and *Arnica* cover, respectively.
The plots were classified based on species composition by standard methods similar to Wildi (1989). The vegetation records were compared with the data in Oberdorfer (1977, 1978, 1983, 1992a, 1992b) by multivariate methods to identify the vegetation type.

Results

The vegetation (Table 1) resembles the *Geo montani-Nardetum strictae* Lüdi 1948 (*Nardion*), with 2 variants with *Vaccinium* species (group 3 and 4, see Table 1), a variant with *Trollius europaeus* and *Gymnadenia conopsea* (group 1) and with transitions to the *Gentiano-Koelerietum pyramidatae* and *Carlino-Caricetum sempervirentis* (the acidophilus wing of the alliance *Mesobromion*, group 2).
The Shannon-Weaver-diversity ranges from 0.55 to 1.37 with a median of 0.97. There are significant differences between the groups. Dry matter ranges from 0.4 to 2.8 t/ha, median 1.1 t/ha. This is typical for extensive mountain meadows. Dry matter is positive correlated with diversity ($y = 0.29 + 1.04x$, $r^2 = 0.33$, $n = 45$) while *Arnica* cover is negatively correlated with diversity ($y = 43 - 31x$, $r^2 = 0.19$, $n = 53$) (Figure 1). *Arnica* cover and productivity are uncorrelated.

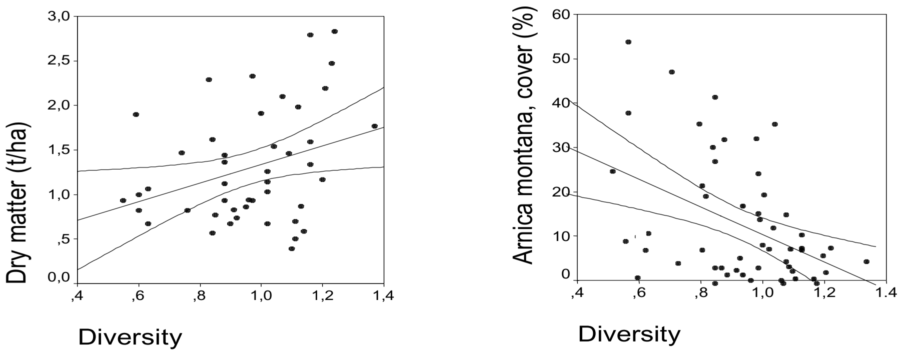

Figure 1. Dry matter is positively correlated with diversity ($y = 0.29 + 1.05x$, $r^2 = 0.33$, $n = 45$) while *Arnica* cover is negatively correlated with diversity ($y = 43 - 31x$, $r^2 = 0.19$, $n = 53$)

Discussion

Arnica cover and biodiversity of the habits is negatively correlated. This could probably be explained by very poor soil conditions where only a few specialised species like *Arnica* can survive. If the soil conditions improve only slightly, dry matter and biodiversity increase

Table 1. Synoptic vegetation table with meadow type and constant / differentiating species *

Meadow types: *Geo montani-Nardetum strictae* Lüdi 1948 (*Nardion*)

1: *Trollius europaeus-Gymnadenia conopsea* variant; 2: transition to *Gentiano-Koelerietum/Carlino-Caricetum sempervirentis* (*Mesobromion*); 3: *Vaccinium* variant with *Viola canina, Ranunculus bulbosus;* 4: *Vaccinium* variant with *Luzula luzuloides*

Meadow type:	1	2	3	4
Number of plots:	5	17	11	20
Mean number of species per m²:	24	26	20	15
Mean diversity:	.94	1.08	1.03	.84
Mean evenness:	68	76	80	71
Constant species:				
Antennaria dioica	4.1	1.2	2.2	2.1
Arnica montana	10.5	8.4	8.3	10.4
Campanula abietina	6.1	6.1	2.0	3.1
Carlina acaulis	4.1	2.2	1.1	1.4
Luzula multiflora	10.1	8.1	6.1	3.1
Nardus stricta	10.2	7.2	8.3	9.4
Scorzonera rosea	8.1	2.2	3.1	4.2
Thymus pulegioides	8.2	7.2	7.2	5.1
Veratrum album	4.1	3.2	1.1	1.2
Veronica chamaedris	2.0	4.1	1.0	1.1
Differentiating species (significant differences between groups):				
Trollius europaeus	10.3	4.3		
Centaurea mollis	8.3	1.1		
Cirsium erisitahles	6.2	1.1		
Gymnadenia conopsea	8.1	5.1		1.1
Plantago media	2.1	3.2		
Anthyllis vulneraria	6.1	4.2		
Cerastium glomeratum	4.0	5.1	1.0	
Lotus corniculatus	2.1	4.2	2.1	
Trifolium repens	6.1	7.1	4.1	1.3
Trifolium pratense	8.1	10.1	6.1	2.2
Centaurea pseudophrygia agg.		6.2	3.2	
Viola declinata	8.1	9.1	3.1	1.1
Stellaria graminea	6.1	8.1	4.1	1.1
Rhinanthus minor	10.1	9.3	5.2	2.1
Plantago lanceolata	4.1	8.1	5.1	
Anthoxanthum odoratum	10.2	10.2	8.1	4.1
Leucanthemum vulgare	6.1	8.1	6.1	1.1
Euphrasia officinalis	8.1	8.1	3.1	1.0
Pimpinella major	4.1	7.1		
Alchemilla vulgaris agg.		6.2		1.0
Crocus vernus	4.1	5.2		3.1
Festuca rubra agg.	2.2	9.3	10.2	6.2
Agrostis capillaris	8.1	7.3	8.2	3.2
Polygala vulgaris	8.1	9.1	7.2	4.1
Potentilla erecta	10.1	9.2	10.3	10.3
Hieracium pilosella	8.1	2.1	7.2	4.2
Viola canina		1.1	5.1	1.1
Ranunculus bulbosus			4.1	
Vaccinium vitis-idaea			5.2	8.2
Deschampsia flexuosa		1.3	9.3	10.3
Vaccinium myrtillus	2.1		5.3	8.3
Veronica officinalis		1.1	6.1	3.1
Melampyrum sylvaticum			5.1	3.2
Danthonia decumbens			5.1	2.2
Carex pallescens		2.0	5.1	7.1
Luzula luzuloides		1.3		7.2

* Notes on the table: Figure in front of the dot: frequency in 10th classes: + = 0–5% frequency; 1 = 5–15% frequency etc. Figure after the dot: square root of mean cover (mean cover = sum of the cover values / frequency): 0 = <.5% cover; 1 ≈ 1% cover; 2 ≈ 4% cover etc; 9 ≈ 80% cover.

because less unspecialised species can survive. The *Arnica* cover decreases, whereas the number of species, and so the biodiversity, increase. However, this is not a linear relationship that can be simply extrapolated. It is very well known and even in the investigation area obvious, that too high a fertilisation rate increases the productivity of those habitats and decreases species richness. *Arnica* is not found on heavily fertilized meadows any more. Moreover, this process seems to be irreversible.

The *Arnica* habitats are diverse, with a wide range of productivity, biodiversity and Arnica cover and species composition (Table 1, Figure 1). To provide more information about this ecosystem additional information is needed on management, differences in soil, altitude, and nutrient regime. Differences between habitat types can be studied, enlarging the sample size, too.

Conclusions

From a conservation point of view it is a stiff challenge to find information about the management and environmental conditions which determine *Arnica* habitats. This knowledge is already nearly lost in western European countries. *Arnica* flower heads collected from the wild should continue to be a valuable resource for future generations to prepare medicines. To ensure this, we need to know which environmental conditions enhance *Arnica* flowering. From the socio-economic point of view, a compensation scheme related to the potential productivity of the threatened habitats needs to be developed. Further investigations during the next 2 years will reveal more details (Michler *et al*., 2004; http://www.arnica-montana. ro/).

Acknowledgements

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Butterfly diversity in Swiss grasslands: respective impacts of low-input management, landscape features and region

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Abstract

In order to enhance agro-biodiversity, Swiss farmers have to convert 7% of the arable land into low-input habitats, namely ecological compensation areas (ECA). This agri-environmental programme is of high scientific interest as it permits to assess and quantify the effects of farming practices at the local and landscape scales. This study aimed at testing the effects of low-input management of grassland on butterfly diversity at the local and the landscape scale in three Swiss farming regions. Low input grasslands did not have higher butterfly diversity than intensive grasslands, despite higher species richness in one year. However, butterfly assemblages varied according to the landscape pattern, namely the amount of low-input habitats, intensive grasslands, crops and forest in the surrounding landscape, and to the regional localisation. Regional differences can be explained by the type and intensity of agricultural production and by landscape features at the regional scale. Recommendations for further development and regionalization of the Swiss ECA scheme are derived.

Keywords: low-input grasslands, agri-environmental scheme, butterfly diversity, landscape features

Introduction

Butterflies are good indicators for biodiversity in agricultural landscapes. They require a combination of different types of habitats (Ouin *et al*, 2004) and some butterflies can be considered as ‘flagship species’ as they are perceived by the wider public. Butterflies are one of the species groups which suffered from agriculture intensification. They are affected by intensive or badly-timed farming practices (pesticides, mowing, fertilisation) (Oates, 1995) and by the reduction and spatial isolation of habitats at the landscape scale (Wettstein and Schmid, 1999). In Switzerland, 7% of farmland is converted into ecological compensation areas (ECA), low-input grasslands making up the major part of ECA. In order to halt the loss of agro-biodiversity, ECA are submitted to restricted fertilisation and pesticide use, and to late mowing. This agri-environmental programme can be regarded as a real landscape restoration experiment at a large scale and permits to assess the effects of farming practices at both local and landscape scales. Identifying the scales at which species respond to low-input management is crucial as it will determine the appropriate scales for establishing management schemes. This study aimed at assessing the effect of low-input grasslands on butterflies in three regions of the Swiss Plateau. The questions we wanted to answer were: Does low-input grasslands have higher butterfly diversity than intensive ones? Does the amount of low-input grasslands at the landscape scale affect butterfly diversity? What are the respective impacts of low-input management at local scale, landscape characteristics and regional localisation?

Materials and Methods

The study was conducted in three 7-8km² regions of the Swiss Plateau. Farming systems consist in mixed cattle-crop production in region 1, milk-cattle production in region 2 and cash-crop production in region 3. The three regions also have different landscape pattern (Table 1): region 1 is characterised by a mixture of crops and grasslands (4% of low-input grasslands), region 2 is characterised by many crops and a few grasslands (1% of low-input grasslands), whereas region 3 has more grasslands (3% of low-input grasslands) and traditional orchards.

Table 1. Proportion of area covered by grasslands, orchards, crops, forest and other land-uses in the three studied regions

Land-use	Region 1	Region 2	Region 3
Grasslands (%)	26.5	7.3	48.9
Traditional orchards (%)	1.5	0.0	8.4
Crops (%)	38.4	52.4	18.1
Forest (%)	27.3	25.1	18.5
Others (%)	6.4	15.2	6.0

During summers 2000 and 2002, butterflies were recorded in 21 low-input grasslands (LIG) and 16 intensive grasslands (INTG) in region 1, in 14 LIG and 12 INTG in region 2 and in 21 LIG and 20 INTG in region 3. Landscape characteristics were described using Geographic Information Systems (GIS). Several landscape descriptors were calculated on land-use maps: (i) the percentage of the different ECA types (low-input grasslands, traditional orchards, flower strips, hedgerows), of crops and of forest in 200m buffers around sampled grasslands and (ii) the Euclidian distance from sampled grasslands to the nearest forest edge, as a measure of grassland isolation from (semi-)natural habitats. The effects of management intensity (low-input vs. intensive), landscape descriptors and region were tested on the species richness using analysis of covariance (ANCOVA). Redundancy analysis (RDA) and partial RDA were used to test the effects of environmental variables on butterfly species assemblages (Ter Braak, 1996). The length of the environmental gradient was short, suggesting a linear response of species to environmental variables. Redundancy analysis is a linear and constrained ordination method which is appropriate in this context. Selection of significant variables was first performed in RDA using Monte-Carlo permutations. A hierarchy of management, landscape and regional variables was then established with a partial RDA: the variance explained by each variable and its significance (Monte Carlo permutations) was obtained after eliminating the variance due to the other variables, which were used as covariables (partial variables).

Results and Discussion

Forty one butterfly species corresponding to 7,314 individuals were observed in the three regions in 2000 and 2002. Butterfly species richness was influenced by management intensity in 2002 (ANCOVA, $P = 0.001$) but not in 2000 (ANCOVA, $P > 0.05$): low-input grasslands had higher numbers of butterfly species than intensive grasslands in 2002. None of the landscape descriptors did affect significantly the number of butterfly species, either in 2000 or 2002 (ANCOVA, 2000 and 2002: $P > 0.05$). Butterfly species richness was higher in region 1 than in region 2 and 3 (ANCOVA, 2000: $P < 0.001$, 2002: $P < 0.001$).

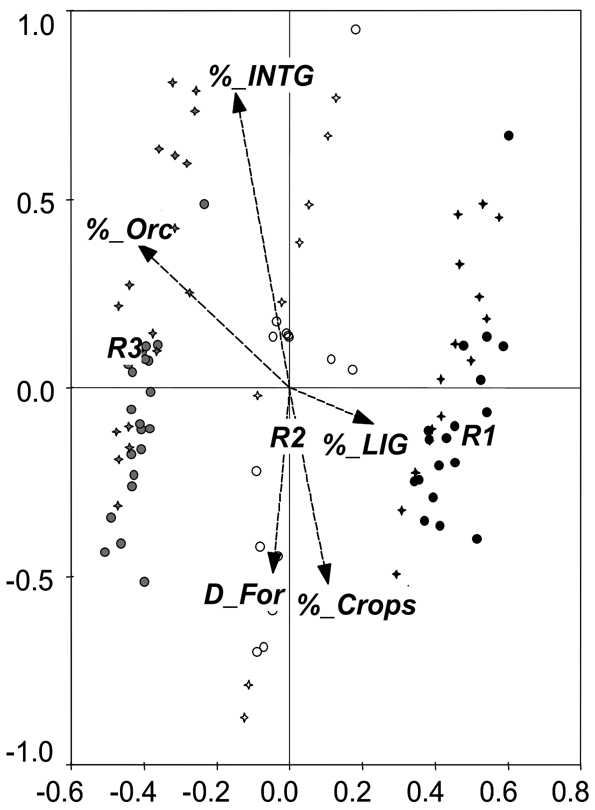

Figure 1. RDA ordination diagram of grasslands based on the butterfly assemblages in 2000 (axes 1 and 2). Significant environmental factors are represented by their centroid on the diagram: R1 = region 1, R2 = region 2, R3 = region 3, D_For = distance to the nearest forest, P_For = percentage of forest (200 m), P_LIG = percentage of low-input grasslands (200 m), P_Orc = percentage of orchards (200 m), P_INTG = percentage of intensive grasslands (200 m), P_Crop = percentage of crops (200 m). Sampled grasslands are represented according to their management and regional localisation: circles = low-input grasslands, stars = intensive grasslands; black symbols = region 1, empty symbols = region 2, grey symbols = region 3

Environmental variables explained 40.2% and 48.6% of the variation in butterfly assemblages in 2000 and 2002 respectively (RDA, Mont-Carlo permutations, P = 0.002). After elimination of interactions between variables in partial RDA, the greatest part of variance of butterfly assemblages was explained by regional localisation (29.5% in 2000 and 2002; Monte-Carlo permutations, P = 0.002). Landscape characteristics explained a lower but significant part of variance (8.5% in 2000 and 7% in 2002; Monte-Carlo permutations, P = 0.002). Butterfly assemblages were not significantly influenced by grassland management (1.9% of variance in 2000 and 0.9% in 2002; Monte-Carlo permutations, P > 0.05).

Figure 1 illustrates the results of RDA performed with significant variables in 2000. The first RDA axis expressed the influences of region and landscape pattern around grasslands. Along this axis, grasslands were differentiated into three groups according to their regional localisation. Axis 1 also differentiated grasslands surrounded by low-input grasslands (200 m radius) from grasslands surrounded by many orchards (200 m radius). This effect of the landscape characteristics along first RDA axis reflects partly the differences between

regions 1 and 3 in the amount of traditional orchards (higher in region 3) and low-input grasslands (higher in region 1).
The second RDA axis was associated with an effect of the landscape characteristics: grasslands embedded in cropped areas and far from forest edges were opposed to grasslands surrounded by many intensive grasslands. The RDA diagram in 2002 showed similar results and is not presented.

Conclusion

Management intensity did not influence the composition of butterfly assemblages in grasslands, although the number of butterfly species was higher in low-input grasslands in one year. However, species assemblages were influenced by the amount of low-input grasslands at the landscape and regional scales. They were also dependant on the amount of crops vs. intensive grasslands in the surrounding landscape. The three regions had different sets of species. Regional differences can be explained by the type of agriculture production and by landscape characteristics at the regional scale, but might also be linked to regional differences in abiotic conditions. The results suggest that the ecological compensation programme should not only focus on low-input management at the local scale but should also promote a connected network of low-input habitats at the landscape and regional scale.

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Temporal trends of arthropod diversity in conventional and low-input meadows

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Abstract

In Switzerland, efforts have been made to reduce the negative impact of intensive management in grassland ecosystems on biodiversity by introducing low-input meadows within an agri-environmental scheme. The management of low-input meadows is regulated in order to achieve environmental goals: restrictions in fertilisation, prescribed dates for mowing. This paper aims to compare temporal trends in species composition of spider, carabid beetle and butterfly communities in low-input compared with intensive meadows in two regions in Switzerland 1997–2004. For the three taxa, significantly different communities were found in the low-input and intensive meadows. Temporal trends differed between the taxa and depended on the region.

Keywords: agri-environmental scheme, low-input meadow, biodiversity, arthropods, temporal trend, principal response curve

Introduction

In the early 1990s the growing costs for the regulation of agricultural markets and increased awareness of environmental damage caused by agriculture led to the introduction of agri-environmental programmes in Europe. In Switzerland, from 1993 onwards, farmers had to increasingly provide ecological services in order to qualify for direct payments and additional incentives were given for specific measures. One of these measures was introduction of ecological compensation areas (ECA) within the utilised agricultural area (UAA) of the entire country. The Swiss agri-environmental programme requires that participating farmers have to convert 7% of their farmland to ECA. The range of ECA encompasses traditional landscape elements as well as new types of biotopes designed for the purpose of enriching the agricultural landscape. The management of ECA is regulated in order to achieve environmental goals (restrictions in fertilisation, pesticide use, prescribed dates for mowing of meadows, etc.). Agricultural management must be continued (no abandonment). For most types of ECA farmers have to commit themselves for at least 6 years. The main purpose of ECA is to stabilise and enhance populations of wild animals and plant species in agriculture (Forni *et al.*, 1999).

This paper aims to compare species composition of spider, carabid beetle and butterfly assemblages in extensively used and low-input meadows (grassland ECA types), and intensively used meadows in two regions of the Swiss plateau, over time. Because species richness of the communities under these different management regimes has not been found to be significantly different from each other over time, we focussed our analysis on species composition.

Regions, sampling methods

The study was carried out in 2 regions of the central Swiss Plateau: region 1, Nuvilly, 30 km W of Fribourg, altitude 580–720 m and region 2, Ruswil, 20 km NW of Lucerne, altitude 650–800 m.

Region 1 (515 hectares) consists of grassland (37%), arable land (55%), forests (6%). Three grassland ECA types, usually small areas of approx. 400 m^2, can be found in this region, namely extensively used meadows (EUM, no fertilisation, late mowing), low-input meadows (LIM, restricted fertilisation, late mowing), and meadows in traditional orchards with standard fruit trees (TO, considered as intensively used in this study because fertilisation and mowing are not restricted). One intensively managed grassland type is considered in this region, namely permanent intensive meadows (PIM).

Region 2 (885 hectares) consists of grassland (59%), arable land (15%) and forests (17%). In region 2, the same ECA types occur and leys (seeded meadows, SM) were found and added to the intensively managed grasslands.

Spiders, carabid beetles in 1997–2003 (3 and 4 sampling years in region 1 and 2, respectively) and butterflies in 2000–2004 (3 sampling years in both regions) were recorded in 13 EUM, 3 LIM, 7 TO and 5 PIM in region 1, and in 10 EUM, 7 LIM, 7 TO, 3 PIM and 2 SM in region 2. Details about spider and carabid beetle collections, and butterfly observations are presented in Jeanneret *et al.* (2003).

Analysis of the management intensity impact over time was carried out on the species assemblages with Principal Response Curve (PRC, Van den Brink and Ter Braak, 1998). This multivariate method for the analysis of repeated measurement designs is based on redundancy analysis (RDA) and partial RDA (Ter Braak, 1996). It allows to focus on the time-dependent treatment effects. In RDA, the significance of time-dependent treatment effect is assessed by Monte Carlo testing (bootstrapping). In our study, treatments encompass the above described grassland types.

Results

The PRC analysis indicates for the spider and carabid beetle assemblages that the overall variation among the grassland types is higher than that among sampling years in both regions (Table 1). On the contrary, in both regions, the sampling year is more important for butterfly assemblages than the grassland type.

Table 1. Percentages of the total variance that can be attributed to time and grassland type for spider, carabid beetle and butterfly assemblages in two regions. The grassland type component includes the interaction between type and time. The remaining fraction of the variance is residual

Data set	% of variance accounted for by			
	time		grassland type	
	region 1	region 2	region 1	region 2
Spiders	7	12	17	17
Carabid beetles	5	7	16	19
Butterflies	14	12	11	11

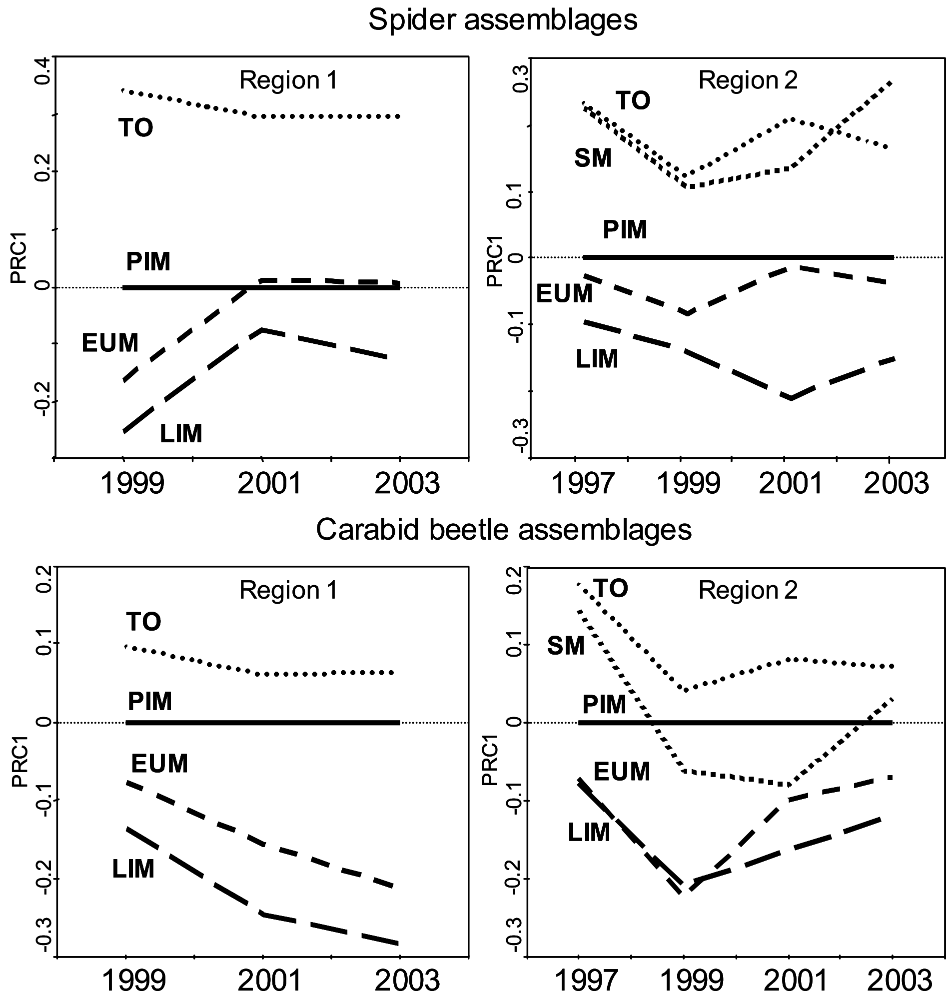

Figure 1. Principal Response Curves (PRC) for spider and carabid beetle assemblages in region 1 and 2, indicating the changes over time in extensively used meadows (EUM), low-input meadows (LIM), traditional orchards (TO), permanent intensive meadows (PIM) and seeded meadows (SM). PIM is set as reference. PRC were tested with Monte Carlo permutations

PRC diagrams presented in Figure 1 (for spider and carabid beetle assemblages only) were significant as tested by Monte Carlo permutations indicating that there is a significant effect of the grassland types depending on time. Figure 1 shows that in the first year of investigation (1999 and 1997 in region 1 and 2, respectively) high differences among spider and carabid beetle assemblages already existed between the grassland types (the same pattern was indicated by butterfly assemblages as well). Grassland ECA types (EUM and LIM) show distinctive assemblages for both organisms compared to intensive managed ones, PIM (reference) and TO in region 1, and to PIM, TO and SM in region 2. These initial differences are higher by spider than by carabid beetle assemblages.

Spider assemblages of EUM and LIM come close to those of PIM in region 1 while start-points (1997) and end-points (2003) are on the same level in region 2 indicating only small temporal trend. In contrast, carabid beetle assemblages of ECA types in region 1 markedly differenciate from PIM and TO over time while in region 2 they come back to the start level after a change in 1999. In addition, carabid beetle assemblages of TO and SM come close to those of PIM over time in region 2.

Discussion

The analysis shows that management intensity (grassland type) has a significant influence on spider, carabid beetle and butterfly assemblages in both regions. Assemblages of extensively used and low-input meadows (EUM and LIM) differ significantly from those of the permanent intensive (PIM), seeded meadows (SM) and traditional orchards (TO). These differences can be explained by the impact of the management on the habitat structure of the meadows.
The PRC method gives immediately discernible information on how biological communities develop in the grassland types over time. Spider and carabid beetle assemblages give different response depending on the region. Spiders show an evolution of the grassland ECA types (EUM and LIM) toward the permanent intensive meadows (PIM) in region 1 and stay stable in region 2 while carabid beetles demonstrate a high differenciation of the meadow types over time in region 1 but not in region 2. The differences between the two regions in terms of land use, landscape and species pool will be analysed to explain the different reactions. Furthermore, the 7, respectively 5 year periods are maybe too short to show clear trends of the impact of the management.

Conclusions

Our study showed that management of grassland has an impact on arthropods so that grassland ECA types and intensive meadows have different spider, carabid beetle and butterfly assemblages. Nevertheless, the responses of the arthropods to the grassland types and the trends over time depend on the taxa and the region. Consequently, the impact of the management on arthropods in grassland ecosystems has to be investigated on several organisms, in several regions and over a large period.

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Intertolerance and productivity of crested wheatgrass (*Agropyron cristatum* L.) in pasture mixtures with white clover

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Abstract

Finding more suitable and productive grass component for white clover pasture mixtures is a significant problem for Bulgarian pasture management. Taking account of permanent climate change, the introduction of new or not very popular species is an approach to find more sustainable productive pasture swards. Crested wheatgrass is a perennial drought - resistant mesophyte grass that has higher forage production during the hot and dry vegetation period. It was tested as a component in binary mixtures with white clover in order to determine its suitability and productivity compared to ryegrass. Results of botanical composition and dry matter from 2001 to 2004 showed that the mixtures with crested wheatgrass had more legume with higher dry matter yield.

Keywords: wheatgrass, white clover, pasture mixture, dry matter yield.

Introduction

During recent decades at our latitude lasting changes have been observed in climatic conditions, mainly expressed as long droughts in spring and summer (Barton and Dracup, 2000). That has a negative influence on the productivity of the herbaceous forage crops already confirmed in practice, mainly in pasture swards.

It is necessary to carry out research on the adaptibility of new herbaceous forage species and varieties to unfavourable abiotic factors (Barton and Dracup, 2000; White *et al*., 2001).

Interest in forage production of wheatgrass, a drought resistant species of the mesophyte group, has recently been increasing greatly (White, 1983; Shamov, 1995; Yancheva and Shamov, 1996; Radeva *et al*., 2003). Its interaction with white clover as a grass component in pasture mixtures and its productivity have not been studied.

The objective of this experiment was to study the productivity and interspecies relations of wheatgrass and white clover in pasture swards for regions of a typical moderate climate.

Materials and Methods

During the period 2001–2004 a field trial was carried out near Pleven in the Central North Bulgaria on leached chernozem soil without irrigation. Three pure swards of white clover (cv. Debyut), crested wheatgrass (local population) and ryegrass (cv. Merrety) were tested. The binary mixtures between the clover and grasses, and a mixture of all species were also tested. The legume and grass component ratio was 1:1. The crops were sown in early autumn of 2001. The experiment included four replicates in complete randomized blocks. The plot size was 2m × 5m. In order to simulate a pasture management schedule, the swards were cut after reaching 20 cm. Three cuts were taken at 5 cm height from each plot in 2002 and four in 2003 and 2004. Dry matter yields were recorded and botanical composition assessed, determining the content of sown species and weeds in the harvest yield.

Fertilization was used as a background according to available P and K that would favour clover rather than grass components in the mixtures. Nitrogen fertilizer (50 kg ha^{-1}) was applied once in the early spring of the first year in order to stimulate all species at the start of growth. Software programme SPSS for Windows 2000 was used to calculate LSD.

Results and Discussion

The contribution of the studied species depended on cut number and sward type (Figure 1). On average for the period the proportion of white clover in the pure stand was slightly above 50% in the first, second and fourth cut and over 80% in the third cut. In the mixture with wheatgrass the clover content was approximately 12 to 16% in the first, third and fourth cut and considerably higher in the second cut at 32%. Its content in the mixture with ryegrass and in that with two grass components was similar, but the clover proportion was twice as small in the respective cuts and even three times as small in the sward of the third cut. The weed infestation in these two mixtures was approximately equal. Therefore wheatgrass is less aggressive than ryegrass and coexists with clover better which was confirmed by its greater proportion in the sward.

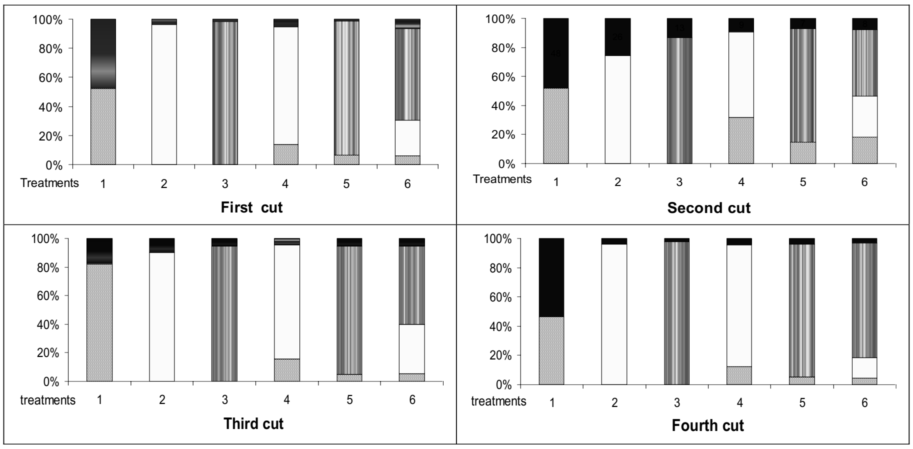

Figure 1. Botanical composition of the swards average for the period (2002–2004)

Grass species predominated in all swards but their proportion decreased considerably in the second cut. In the binary mixtures with clover, the content of grass was higher with ryegrass than wheatgrass. Therefore ryegrass is a more aggressive species than wheatgrass and decreased the white clover proportion in the mixture considerably. In the triple mixture ryegrass predominated in the sward at all cuts and its proportion was smallest in the second cut, i.e. 46%, and greatest in the fourth cut, i.e. 78%. The wheatgrass contribution was considerably smaller than that of ryegrass. A small increase in its proportion was found at the expense of ryegrass (28 and 34%) in the second and third cuts formed during the warm and dry period of the summer months. In the sward of the fourth cut formed during the moister and cooler part of the growing season the wheatgrass proportion was only 14%.

The dry mass yield depended on the species in the studied tested swards. The cut number (Table 1) and the stand age (Table 2) exerted influence on the differences in the productivity.

In all tested swards the dry mass yield was highest in the first cut and decreased with advance in the cut number (Table 1). There were no significant differences between yields at the first cut. Pure clover was an exception because of its lower productivity during the first year (Table 2). Higher yields were recorded from the swards which had predominantly ryegrass (treatments 3, 5 and 6). Significant differences were found in the second and third cuts formed during the warmer and dry period. The swards where wheatgrass predominated, yields were higher in the fourth cut from the swards which were predominantly ryegrass.

Table 1. Average dry matter yields at each cut and annual total for the period 2002–2004, kg ha^{-1}

Treatments / Cuts		I	II	III	IV	Total
1	White clover	2,108	1,768	1,765	236	5,877
2	Wheatgrass	2,780	1,590	1,249	427	6,045
3	Ryegrass	2,896	1,150	971	554	5,571
4	White clover + Wheatgrass	2,609	1,674	1,544	430	6,256
5	White clover + Ryegrass	2,942	1,237	1,176	573	5,927
6	White clover + Wheatgrass + Ryegrass	3,054	1,242	1,184	558	6,038
	Average	2,731	1,443	1,315	463	5,952
	LSD $_{5\%}$	418	266	196	123	

During the first year the lowest yield was obtained from pure clover stand (Table 2). Higher yields were recorded in the swards with ryegrass predominance as compared to those with wheatgrass and highest yield was observed in the three-component mixture (treatment 6). Ryegrass has a greater rate of development than wheatgrass which explained the results obtained (Chakarov and Dimitrova, 2003; Radeva *et al*., 2003). During the second year the yields from the swards with wheatgrass predominance (treatments 2 and 4) increased considerably and exceeded those from the corresponding swards with ryegrass (treatments 3 and 5). The yield obtained from pure ryegrass remained the same but the yields from the mixture of ryegrass and white clover, as well as from the three-component mixture decreased.

During the third year in all swards the yields decreased except for pure white clover. The yields obtained from the swards which were predominantly wheatgrass were highest (treatments 2 and 4) and significantly exceeded those from the swards with ryegrass predominance (treatments 3 and 5). Lowest yield was obtained from the three-component mixture (treatment 6). On average for the period the yield obtained from the pure wheatgrass sward was higher than that from pure ryegrass. There was a trend to higher dry mass productivity from the mixture of wheatgrass and white clover.

Table 2. Average annual dry matter yield for the period 2002–2004, kg ha^{-1}

Treatments / Years		First	Second	Third	Average
1	White clover	2,850	7,207	7,574	5,877
2	Wheatgrass	5,796	6,719	5,618	6,045
3	Ryegrass	5,846	5,866	5,003	5,571
4	White clover + Wheatgrass	5,910	7,046	5,812	6,256
5	White clover + Ryegrass	6,856	5,853	5,073	5,927
6	White clover + Wheatgrass + Ryegrass	7,184	6,628	4,300	6,038
	Average	5,740	6,553	5,563	5,952
	LSD $_{5\%}$	225	833	656	514

Conclusions

Wheatgrass was found to be a suitable grass component for white clover in pasture swards. The contribution of white clover to a mixture with wheatgrass was two times higher than that in a mixture with perennial ryegrass.
On average for three years the dry mass yields from the second and third cut of pure wheatgrass and its mixture with white clover was 28 to 38% higher than those from pure ryegrass and its mixture with white clover.
During the second and third year of the stand the dry mass yields from the pure wheatgrass swards and its mixture with white clover were by 12 to 20% higher than those from pure ryegrass and its mixture with white clover.

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Biodiversity protection of bog meadows by agriculture and forestry farms

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Abstract

Bog grasslands have high natural, landscape values and reach a degree of biodiversity, which is unparalleled in Western Europe. More recently because of the low nutritive value of the resulting forages, they have not been cut which has led to their overgrowing. The aim of this study was to improve the palatability and digestibility of bog forage through ensiling in big bales. The study was carried out in 2002 and 2003. Bog meadow sward composed of 70–80% of sedges was taken for ensiling. Part of the herbage was ensiled with added inoculum (LAB + enzyme). During the winter period, the resulting silages were tested and compared with the nutritive value of hay from bog herbage and with silage from cultivated grasses using 32 heifers with mean weight of 322 kg in 2002 and 303 kg in 2003, divided into 4 feeding groups. These groups were: group I – fed with sedge silage, group II – sedge silage supplemented with Polmazym, group III – hay of sedges and group IV – silage from cultivated meadow. Apart from the tested feeds the heifers also received 1.5 kg of concentrate each. The feeding experiment lasted for 40 and 63.5 days. The following body gains were obtained in successive groups: 0.575, 0.695, 0.385, 0.717 kg in 2002 and 0.690, 0.048, 0.367, 0.813 kg in 2003. The silages, and particularly silage plus inoculum, improved the nutritive value and intake of forage compared to hay, and were similar to the nutritive value of silage made from cultivated meadow. The daily intake by heifers was 7.47, 8.30, 5.94, 7.81 kg of DM per head (2002) and 7.66, 8.82, 6.21 and 9.58 kg of DM (2003) for successive groups of animals, respectively. It was noted that the sedge herbage silage was also eaten by wild animals in the forest.

Keywords: bog grasslands biodiversity, silage, hay, nutritive value, gain of heifers

Introduction

In the last few decades a significant area of bog meadows in Europe and in Poland has undergone irreversible, unfavourable changes as a result of river regulation and drainage due to agricultural intensification and urbanization. A few isolated areas have been protected due to their unique natural and landscape value. These are places with rare plant and bird species. They are also natural water resources. Belonging to the group of wetlands they are subject of many international projects and conventions relating to environmental protection (Dembek *et al.,* 1999; Tederko, 1999). In Poland, the biggest area of bog meadows is the Valley of Narew River and its tributary, Biebrza River. It is the largest lowland river in Europe, which has remained in an almost completely natural state. The most precious are communities of *Molinion* alliance of wet meadows, *Magnocaricion* of flooded meadows, also *Calthion* alliance from more dry meadows with abundance of low sedges (Oświt, 1991; Oświt 2000; Wasilewski, 2002). Bog meadows were mown extensively for hay and used mostly for horse feeding. Because of the high silica content and structural fibre cattle are reluctant to eat it (Denisiuk, 1980; Moraczewski, 1996; Nowiński, 1966). Recently, this agricultural use of bog areas has been abandoned and bog meadows have started to disappear. They have become overgrown by the natural regeneration of trees and shrubs and developed into coppice communities. This study was aimed to find ways of improving the palatability and nutritive value of herbage through ensiling by using rolling up presses and to evaluate the possibility of sedge silages for use in agriculture and forest farms.

Materials and Methods

The study in the Experimental Station of IMUZ in Biebrza in Podlaskie province was carried out during 2002 and 2003. Vegetation was harvested from two bog meadows situated in and near the area of Biebrza National Park. 70% of the vegetation of *Calthion* alliance consisted of low sedges: *Carex panicea* (59%), *Carex oederi* (6%), *Carex fusca* (5%) (meadow I); 80% of the vegetation of *Magnocaricion* alliance from a flooded meadow consisted of sedges, mostly *Carex gracilis* (meadow II). In 2002 the meadows were cut in the middle of June and in 2003 at the beginning of July. After cutting, the herbage from both meadows was pre-wilted in situ to 500 g dry matter (DM) kg^{-1}. Herbage was harvested with the rolling up press. Half of ensiled material was inoculated during the harvest with Polmazym containing lactic acid bacteria and enzymes at a rate of 1 l t^{-1} of herbage. For comparison, 80% of the herbage from the cultivated meadow containedgrasses: *Poa pratensis* (40%), *Dactylis glomerata* (14%), *Phleum pratense* (7%), *Alopecurus pratensis* (6%), *Festuca rubra* (6%), other species (7%), the remaining 20% were herbs and weeds. At the same time hay was also made from sedge herbage from the same bog meadows. The hay was harvested after 4–5 days of drying on the surface of the meadow.

During the winter period different forages were fed to 32 heifers aged between 18–23 months with mean body weight of 322 kg in 2002 and 303 kg in 2003. These were divided into 4 feeding groups: group I – fed with sedge silage, group II – sedge silage supplemented with Polmazym, group III – hay of sedges and group IV – silage from cultivated meadow. The feeding experiment in 2002 lasted for 40 days and 63.5 days in 2003. Animals were fed as a group "*ad libitum*". The forages were offered in amounts that only just exceeded the standard rates (9–10 kg of DM per head per day). Feeds were given two times a day and refusals were recorded. Along with the forages the animals received 1.5 kg concentrate per head and day. To verify the zero hypotheses on body gain of animals the Fisher-Snedecor F test was used. In a separate trial, the silage intake by wild animals was recorded in the winter months. These animals were fed in their usual feeding places in forests close to meadows from where the herbage had been taken.

Results

The quality of silage prepared from sedge herbage varied between years especially due to different level of DM in the herbage before the harvest. Good weather conditions during cutting and harvesting in 2002 facilitated pre-wilting to the correct moisture content and produced very good silages according to the Flieg-Zimmer scale (Norma Branżowa, 1974). No butyric acid was found and the content of lactic acid in the fresh silage prepared from sedge herbage, both with and without Polmazym, was similar to that in silage made from cultivated meadow sward. However, rainfall in 2003 and inadequate pre-wilting of some parts of the herbage on thicker swaths, produced some silage bales of low quality. The butyric acid and greater quantities of acetic acid, especially in silage made without the Polmazym addition are shown in Table 1.

Table 1. Chemical evaluation of the silages

Year	2002			2003		
Type of silage	sedge	sedge + Polmazym	cultivated meadow	sedge	sedge + Polmazym	cultivated meadow
DM (g kg^{-1})	553.7	523.7	661.9	439.6	496.5	511.8
pH	5.00	4.90	5.60	4.90	4.70	5.10
Lactic acid (g kg^{-1} FM)	2.70	2.67	2.79	2.03	2.62	2.93
Acetic acid (g kg^{-1} FM)	0.24	0.33	0.22	0.73	0.46	0.35
Butyric acid (g kg^{-1} FM)	0.00	0.00	0.00	0.11	0.06	0.00
Sum of acids	2.94	3.00	3.01	2.88	3.14	3.28
Evaluation acc. to Flieg-Zimmer scale	very good	very good	very good	good	good	very good

Silage prepared from sedge vegetation contained significantly more crude protein than hay prepared from the same type of vegetation. Also the content of crude fat and phosphorus was higher and crude fibre lower. The nutritive value of feeds was significantly improved by ensiling. The silage made with addition of Polmazym had higher nutritive value than control silage (without additives). They had higher phosphorus (2002 and 2003) and crude protein (2002) contents. The phosphorus content both in the hay and in sedge silage was significantly lower than in the silage from cultivated meadow (Table 2).

Table 2. Nutritive value of tested feeds

Year	2002				2003			
Feeding groups	I	II	III	IV	I	II	III	IV
Content in DM (g kg^{-1})of:								
Crude protein	151.0	186.3	134.8	190.7	150.1	146.8	131.4	199.7
Crude fibre	229.1	257.3	323.3	286.6	343.0	332.0	399.1	321.9
Crude fat	37.5	37.6	35.6	37.9	–	–	–	–
Phosphorus	2.4	2.7	2.3	3.4	3.6	4.4	2.5	6.5
Daily gains of animals (g head^{-1})	575ab	695a	384b	717a	690a	748a	367b	813a
Daily intake(kg head^{-1}):								
Silage	7.47	8.30	5.94	7.81	7.66	8.82	6.21	9.58
Concentrate	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50

According to the literature (Denisiuk, 1980), in many cases the sedge vegetation contains more vitamins, nutritive components and some micronutrients than the grass meadows herbage which is thought to be the best. The sedge herbage is characterized by higher fat and lower crude fibre contents than grasses. Almost all sedges are rich sources of vitamins A and C. They contain also more copper and cobalt than grasses.

Results from the feeding experiments (Table 2) in both years were similar and showed that animals receiving the sedge silage achieved higher liveweight gains than animals fed with the sedge hay. Although liveweight gains were lower on the sedge silages than on the cultivated meadow silages, the differences were not significant. The results of animal performance in this experiment confirmed the high nutritive value of sedge herbage. Animals receiving the sedge silage with added Polmazym achieved higher liveweight gains than animals fed with the control silage (without additive), but the differences were not significant. Liveweight gains were positively correlated with the nutritive value of feeds and the level of intake. The animals ate more fodder in the form of silage than hay. Intake of the silage with additive was

higher than silage without additive and was similar to the silage from cultivated meadow (Table 2).
Simultaneously with testing these ensiled feeds on heifers, observations of the intake of sedge silage by wild animals were also carried out. It was observed in 2002 over a 40 day period that the wild animals ate four silage bales placed in two feeding places. The most often common animal was *Capreolus capreolus.* In 2003 in the places crossed by wild animals, close to six different feeding places six bales were offered. One from bales was almost untouched and the remaining bales were eaten within approximately 50 days. From the observation of trails and animal excrements it was inferred that the silage was eaten by hares, roedeer, wild pigs and stags. These animals were also seen near the offered feed.

Conclusions

The quality and nutritive value of silage and liveweight gains of animals in two years demonstrated that ensiling of sedge herbage was a better method of feed conservation than haymaking. Well-prepared silage from sedge herbage had a value similar to that of feeds from cultivated meadow grasses and was suitable for feeding farm animals. The addition of Polmazym to ensiled sedge herbage significantly improved the nutritive value of silage. Feeds made of sedge herbage contained lower phosphorus content. Silage of sedge herbage was also eaten by wild animals but the consumption of this type of feed was low.

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Spatial variation of grazing effects in cooperatively used pastures in the pre-Alpine region of Southern Germany

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Abstract

In the pre-Alpine region of Bavaria (Southern Germany) grazing effects were investigated in eight cooperatively used pastures. Since medieval times these areas have been used as low intensity pasturing and therefore are characterized by a large diversity of plants and animals, especially in the integrated fens and bogs areas.

It is shown that cattle clearly prefers grassland on mineral soil (*Lolio-Cynosuretum*), whereas open terrain on boggy ground, contributes far less to feed supply. In general grazing intensity declines with increasing soil moisture. Under moist or wet conditions grassland vegetation is influenced in a more dynamic way compared with the more productive and drier areas.

Since shrubs and trees are hardly affected by cattle, it is concluded that the integrated peatlands will not be maintained under the current management. Semi-open and open fens or bogs in these pastures are a result of coexistence of different land-use systems (litter and fodder production, collecting of firewood, felling of trees) in the past. Grazing should therefore be combined with mechanical methods to maintain the open nature of the peatlands.

Keywords: grazing effects, wetland, nature conservation

Introduction

The investigation site, east of the river Lech (Southern Bavaria), contains large areas of heterogeneous grassland and is traditionally used cooperatively as pasture for young cattle. This landscape is dominated by glacial impact and therefore is characterized by a mosaic of areas with different soil types (mineral soils, calcareous fens, transitional and peat bogs) and levels of soil humidity. Thus, there are very different vegetation types ranging from wetlands to very productive pastures based on *Lolium perenne.* Some areas are covered by shrubs and trees and they are all part of a single feedlot with the possibility for selective grazing. Due to different conditions these areas are habitats for many plant species and favour biodiversity.

The goal of this study was to investigate the impact of the cattle on the different vegetation types at large scales by observing the intensity of grazing and trampling to provide basic data needed for an estimation of the long term effects. The ultimate goal is an ability to preserve an open landscape through the present pasture management.

Materials and Methods

The research was carried out on eight pasture systems (permanent or rotational grazing) during the year 2000. The climate is characterized by an annual precipitation of 1382 mm and a mean annual temperature of 6.8 °C. The total area investigated was 378 ha. The pastures were grazed by growing cattle with a mean stocking rate of 1.3 livestock units ha^{-1} (1 livestock unit = 500 kg liveweight). For further details see Table 1.

Three times during the growing season the grazing impact was visually rated using 4 classes (Table 2). A vegetation map of the pastures (for plant communities see Table 3) was used (Lederbogen *et al*., 2004) as the basis for the investigations.

Table 1. Specification of the investigated pastures

Pasture	I	II	III	IV	V	VI	VII	VIII	total
Area (ha)	51	14	36	12	111	33	68	53	378
Proportion covered by fens and bogs (%)	58	11	8	45	3	12	17	20	18
Proportion covered by trees and shrubs (%)	35	43	33	58	35	45	18	45	35
Grazing period (days)	132	147	145	118	147	153	190	147	147
Mean stocking rate (livestock units ha^{-1})	0.5	0.9	1.0	1.5	1.4	1.5	1.3	2.0	1.3

Table 2. Classification levels for impact of grazing animals on the vegetation

Level of impact	Grazing intensity (herbaceaous plants)	Trampling
Without	all plants unaffected	without trampling
Low	≤ $^1/_3$ of the vegetation grazed to 5–10 cm	damaged sward area ≤10%
Middle	>$^1/_3$ to ≤$^2/_3$ of the vegetation grazed to 5–10 cm	damaged sward area >10 to ≤25%
High	more than $^2/_3$ of the vegetation grazed to 5–10 cm	damaged sward area >25%
Impact on trees and shrubs: Percentage of damaged shoot tips in classes: 0, >0–1, >1–5, >5–10, >10–20, >20–35, >35–50, >50–100%		

Results

From about 243 ha open land (without trees and shrubs, available for grazing) only 198 ha were substantially grazed (level of impact ≥ middle). As expected nearly all of the productive areas (*Lolio-Cynosuretum*) were intensively used (Table 3), whereas the areas with trees and the bogs (*Spahgnion magellanici*) are relatively unimportant for feeding. Calcareous fens and mineral soils with higher moisture showed an intermediate level of use.

The trampling intensity shows, that nearly all areas were visited by the cattle and only 24 ha (mostly bogs) are uninfluenced. Soil carrying capacity and weather conditions had more effect on visible footprints then the intensity of grazing. Therefore, the highest impact was found in the wet dips and ditches or in the shrub and alluvial forests used for shelter. A low impact was observed on the productive areas.

Influence of the cattle on woody plants was low (Fig. 1). Conifers were almost unaffected. Deciduous trees were damaged more, although more than 85% of them had less than 10% of shoot tips damaged. This influence is too little to inhibit future afforestation.

Discussion

Heterogeneous feedlots enable pasturing animals to select preferred plants and vegetation types. Therefore the grazing intensity was closely related to the presence of preferred species in the pasture. In systems with freely accessible dry and wet zones, there was a declining grazing intensity with increasing soil moisture. This effect was also found in similar investigations by Benn and Holsten (2002). At the beginning of the pasturing period, there was enough feed supply in mineral soil areas where more preferred plants are growing and so there was no reason for the animals to graze in the fens and bogs (Wagner *et al.*, 2004). In autumn, when plant growth decreases, the fodder quality of the wet areas, mostly dominated by *Carex* species, was too low (high crude fibre content, low energy and phosphorus concentration) and was therefore despised by the animals.

Table 3. Impact of pasturing animals at different plant communities

Plant communities	Total area (ha)	Impact by animals (% of total area)							
		Grazing intensity				Trampling intensity			
		without	Low	middle	high	without	low	middle	high
Mineral soils									
Lolio-Cynosuretum productive areas	150	0	1	12	87	0	88	12	0
Lolio-Cynosuretum lotetosum uliginosi regions with high soil humidity	38	8	32	52	8	2	65	28	5
Artemisietea vulgaris areas with nitrogen accumulation via faeces	1	7	7	29	57	0	83	17	0
Agropyro-Rumicion dips and ditches	4	2	30	56	12	0	40	33	27
Fens and bogs									
Caricetalia davallianae calcareous fens	53	27	33	23	17	5	80	13	2
Sphagnion magellanici transitional bogs and peat bogs	15	78	19	3	0	51	35	14	0
Woodlands									
Alnetalia glutinosae, *Alno-Ulmion* alluvial forests	23	64	31	5	0	10	34	35	21
Galio odorati-Fagenion woods mostly dominated by *Picea abies*	80	54	38	6	2	10	78	10	2
Berberidion shrubberies	8	10	33	23	34	9	32	38	21

The use of fences to restrict free selection by animals will be needed when the aim is to have more grazing activity in the fens and bogs. There is however no real interest from the farmers for this arrangement, because of the low liveweight gain due to low feed quality and problems with endo-parasites associated with this system. For farmers this option will only be of interest with profitable subsidies.

The present results demonstrate that it is not possible to maintain the open nature of the fens and bogs with free ranging cattle. The influence of cattle on woody plants is very low (Bunzel-Drüke *et al.*, 1999). Because cattle are grazers, as opposed to browers, they cannot prevent the herbaceous vegetation being invaded from adjacent groves. It was observed, that sometimes pasturing even stimulates the growth of young trees by defoliation of the herbaceous plants and so restriction of the competition.

Therefore it is suggested that this characteristic landscape is not only an effect of grazing by animals in the past. There are other influences that help to maintain the largely open nature of the fens and bogs in the rangeland (Wagner *et al.*, 2004). Formerly those parts of the pastures were also used for the production of litter in a region without cultivation of grain. Today no litter is needed for modern stables and so the remaining growth is not any longer cut in late summer. Additionally in the past there was use of young trees as firewood and therefore these activities were very important to keep this man-made environment.

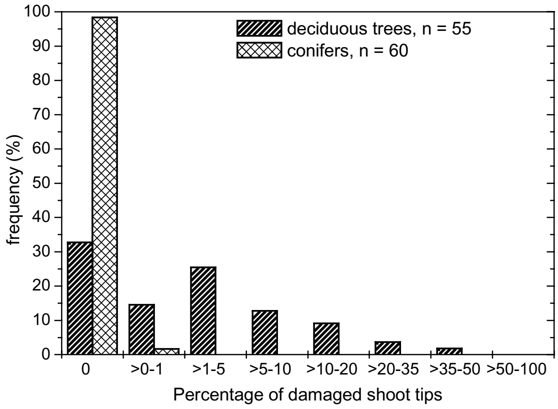

Figure 1. Impact of pasturing animals on woody plants

The structural change in European agriculture will also influence the traditional use of these pastures. Reduction of the number of milking cows and the resultant redundancy of grasslands will reduce the interest in using such marginal areas for young cattle. In addition, the feed quality is limited and often not adequate for the requirements of modern highly selected heifers. The possibility of maintaining this rangeland in the traditional state by other livestock farming systems, like suckler cows or bullocks, depends on the economic conditions. Mechanisms will be needed to promote animal husbandry and additionally for actions like mowing and cutting trees to maintain these areas for nature conservation.

Conclusion

In systems with freely accessible dry and wet zones the integrated peatlands will not be maintained under the current management, since shrubs and trees are hardly affected by grazing cattle. Semi-open and open fens or bogs are more a result of coexistence of different land-use systems and the associated impact on the vegetation in the past. Grazing should therefore be combined with mechanical methods to maintain the diversity of the peatlands.

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Effect of low-rate N application and cutting frequency on botanical composition of short-term natural grassland

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Abstract

Species richness and preservation of biodiversity are nowadays very important goals in grassland management. An experiment was established in spring 2002, on short-term natural grassland, to evaluate the effects of low rates of nitrogen (N) application (30, 60 and 80 kg ha^{-1}) and cutting at heading and flowering stage of growth on botanical composition of the sward. Among 43 species, *Holcus lanatus* was dominant in the botanical composition of a two-year old experimental grass sward, but *Erigeron annuus* and *Picris hieracioides* were abundant.
After three years, and, depending on fertilisation and cutting frequency, botanical composition of the sward was changed considerably. Up to 34 different species were found in some plots, but, in the whole experiment field, a total of 64 species. *Holcus lanatus* dissapeared to a great extent. *Erigeron annuus* and *Picris hieracioides* became less abundant. *Dactylis glomerata* and *Arrhenatherum elatius* increased their portion in the sward. *Plantago lanceolata*, *Achilea millefoliun, Prunella vulgaris* and *Ajuga reptans* became invasive species.

Keywords: grassland, botanical composition, N fertilisation

Introduction

Bosnia and Herzegovina grasslands are well known for a considerable species richness. That is because of various climate and soil conditions, as well as extensive grassland management systems. However, the number of plant species is reduced in cases when grasslands have been abandoned on a long term basis (Alibegovic-Grbic *et al.,* 2002). This reduction is also noted when arable lands have been abandoned (Mrfat-Vukelic *et al.,* 1998). It is well known that such types of grassland show a lesser degree of productivity and produce forage of low quality.
The objective of this study was to evaluate the effects of low-rates of nitrogen (N) application (30, 60 and 80 kg ha^{-1}) and cutting at heading and flowering stage of growth on forage yield and forage quality (Alibegovic-Grbic *et al.,* 2004), as well as on botanical composition of the sward.

Materials and Methods

The experiment was carried out during the period 2002–2004 on a two-year old grass sward, which followed barley for seed. We observed the influence of three levels of nitrogen fertilization and harvesting at two stages of plant growth on forage yield, forage quality, and botanical composition of the sward. The trial was located in Gracanica's hilly region, at Vina (300 m a.s.l), with an average annual precipitation of 870 mm and average annual temperature of 10.6 °C. The soil characteristics were as follows: pH-6.1 (in KCl), P-6.4 and K-13.2 mg and N-260 mg in 100 g of soil.
The field experimental design was with random-blocks of four replications per block. Plot

size was 6 m[2]. Nitrogen fertilizer was applied early in the spring, with four treatments: 30 (N30), 60 (N60), 80 (N80) kg N ha^{-1} and zero N (N0, control). The swards were harvested in two stages of plant growth: heading and flowering. Botanical composition was recorded using the Braun-Blanquet method.

Results and Discussion

More than a half of the initial botanical species present were typical for arable land or barley fields (*Agropyron repens, Lolium multiflorum, Vicia hirsute, Lathyrus aphaca, Myosotis arvensis, Matricaria chamomilla, Viola arvensis, Euphorbia exigua*,…) (Table 1). However, the most abundant were species (*Holcus lanatus, Erigeron annuus and Picris hieracioides)*, were rather more typical of the botanical composition of grasslands. The reason for this is probably the spreading of seeds from adjacent permanent grassland sites due to late cutting and easiness of seed movement.

Table 1. Botanical composition of the sward (2002–2004)

Species	2002	2003	2004
1	2	3	4
Holcus lanatus	3.4	3.3	2.2
Agropyron repens	1.3	1.3	+.2
Lolium multiflorum	+.1	+.1	+.1
Dactylis glomerata	+.1	+.1	+.2
Anthoxanthum odoratum	+.1	+.1	+.1
Lolium perenne	+.1	+.1	+.2
Poa pratensis	+.1	+.1	+.1
Poa trivialis	+.1	+.1	+.1
Poa angustifolia	.	+.1	+.1
Poa annua	.	.	+.1
Agrostis vulgaris	.	.	+.1
Arrhenatherum elatius	.	+.1	+.1
Bromus sterilis	+.1	.	.
Bromus erectus	+.1	+.1	+.1
Cynodon dactylon	.	.	+.1
Festuca pratensis	+.1	+.1	+.1
Setaria viridis	.	.	+.1
Trifolium pratense	+.1	+.1	+.1
Trifolium repens	+.1	+.1	+.1
Lotus corniculatus	+.1	+.1	+.1
Medicago sativa	.	+.1	+.1
Trifolium campestre	.	.	+.1
Vicia hirsuta	+.1	+.1	+.1
Lathyrus aphaca	+.1	+.1	+.1
Erigeron annuus	3.3	2.3	1.3
Picris hieracioides	2.3	1.3	+.1
Cirsium arvense	+.1	+.1	.
Myosotis arvensis	+.1	.	+.1
Filipendula vulgaris	+.1	+.1	1.2
Rumex crispus	+.1	+.1	+.1
Rumex obtusifolius	.	+.1	+.1
Rumex acetosa	+.1	+.1	+.1
Symphytum officinale	+.2	+.2	+.1

1	2	3	4
Galium cruciata	+.1	+.1	+.1
Silene vulgaris	+.1	.	.
Campanula patula	+.1	+.1	+.1
Veronica chamaedrys	+.1	.	.
Convolvulus arvensis	+.1	+.1	+.1
Euphorbia exigua	+.1	+.1	+.1
Mentha longifolia	+.2	+.1	+.1
Chrysanthemum leucanthemum	+.1	+.2	+.2
Scrophularia nodosa	.	.	+.1
Plantago lanceolata	+.1	+.2	1.3
Plantago media	.	+.1	+.1
Geranium dissectum	+.1	+.1	+.1
Veronica hederifolia	.	.	+.1
Viola odorata	+.1	+.2	+.2
Viola tricolor	.	.	+.1
Viola arvensis	.	+.1	+.1
Potentila anglica	.	+.1	+.1
Achillea millefolium	+.1	+.1	1.3
Bellis perennis	+.1	+.1	+.1
Glechoma hederacea	+.1	+.1	+.2
Laminum purpureum	.	+.1	.
Allium vineale	.	.	+.1
Ajuga reptans	+.1	+.1	1.3
Ranunculus tuberosus	+.1	+.1	+.1
Rumex acetosella	+.1	+.1	+.1
Prunella vulgaris	+.1	1.2	1.3
Taraxacum officinale	.	.	+.1
Ttlaspi perfoliatum	+.1	+.1	+.1
Anthemis austriaca	.	.	+.1
Matricaria chamomilla	.	+.1	+.1
Daucus carota	.	+.1	+.1
Arabis hirsuta	.	+.1	+.1
Galium molugo	.	+.1	+.1
Pastinaca sativa	.	+.1	+.1
Ornithogalum umbellatum	.	+.1	+.1
Lepidium campestre	.	.	+.1

After the three year experiment botanical composition of the sward was changed considerably. Instead of 43 at the begining, 64 species were found in the third year of research. *Holcus lanatus* disappeared to a great extent; *Erigeron annuus* and *Picris hieracioides* became less abundant. Some of the species (*Bromus sterilis, Silene vulgaris, Veronica chamaedrys*) disappeared. The portion of the others in the sward (*Dactylis glomerata* and *Arrhenatherum elatius*) was increased, or became invasive (*Plantago lanceolata*, *Achilea millefoliun, Prunella vulgaris* and *Ajuga reptans*). Up to 34 species could be found in single plots.

As a result of N application, the percentage of grasses in the sward was increased (Table 2) in comparison to (zero N). The application of N80 increased the portion of grasses to 63.75; 79.00 and 68.75% in comprison to zero N (48.00; 40.50 and 25.75%, respectively). The portion of legumes was increased to a small extent by application N30 or zero N and decreased by application N60 or N80.

Cutting frequency indicated more empty space or less plant density in the sward then when the sward was less frequently cut. Late cutting had some positive effect on the portion of species from «other» group (herbs and weeds).

Table 2. Effect of N application on portion (percentage) of various groups in the sward

N Application	2002			2003			2004		
	Grasses	Legumes	Other	Grasses	Legumes	Other	Grasses	Legumes	Other
N0	48.00	2.50	49.50	40.50	7.00	52.50	25.75	3.00	71.25
N30	56.75	2.00	41.25	51.50	5.00	44.00	34.25	2.75	63.00
N60	58.75	3.75	37.50	71.50	2.00	26,25	39.75	2.50	57.75
N80	63.75	3.75	33.75	79.00	1.00	20.00	68.75	2,25	29.00

Conclusions

Botanical composition of short-term grassland followed by cessation of arable crop production is very unstable. Changes were influenced by N application, cutting frequency, but also by weather conditions.

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Mill waste-water and olive pomace compost as amendments on rye-grass cropped in a lysimeters

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Abstract

Olive Waste Water (OWW) presents chemical properties that could improve soil fertility and plant production. Furthermore, the organic fertilization could increase the efficient use of nitrogen (N) by avoiding surplus mineral N in the soil. Therefore, a two-year experiment (2001–2002) was carried out in a Mediterranean environment (Rutigliano, Bari – South Italy) to study the effects of applying untreated OWW treated OWW and olive pomace compost as soil amendments on both rye-grass growth and soil characteristics. Lysimeters were used to isolate treatments and growth parameters (Leaf Area Index, fresh and dry weight), plant N status (SPAD readings), leaf N uptake of the rye-grass and chemical soil characteristics were determined. The results of this research show that the highest untreated OWW application increased growth parameters, indicating the possible use of OWW as an amendment to rye-grass swards. A significant increase of total and extracted organic carbon and no accumulation of heavy metals in the soil were found at the end of the experiment. Furthermore, the N content in OWW was used by rye-grass for plant growth which increased N uptake and consequently dry matter accumulation.

Keywords: rye-grass, olive waste waters, yield and growth parameters, soil characteristics

Introduction

In the Apulia region (Southern Italy), there is a large amount of olive waste water (OWW), which comes from the olive oil extraction process. Disposal of this waste product cause problems for the producers as previous research indicated that OWW, spread on the soil, could increase pollution risks due to the presence of phenol compounds snd other pollutants (Aldrich *et al*., 1992). However, OWW presents chemical properties (organic carbon, nitrogen, potassium and phosphorus contents) that can increase soil fertility (Tomati and Galli, 1992; Papini *et al.*, 2000) and yield production, due to its fertilising value as suggested by Briccoli Bati and Lombardo (1990) and by Ben Rouina *et al.* (1999). Moreover, OWW could improve physical properties, organic matter, available P and exchangeable K content of soil as reported by Ferri *et al.* (2000).

Therefore, the objective of this research was to study the possible use of OWW and olive pomace compost as soil additives on rye-grass yield and soil characteristics.

Materials and Methods

The research was carried out in the Experimental Farm 'Agostinelli' at Rutigliano (41°01´ of latitude, 4°39´ longitude, 112 m a.s.l.) in an apparatus for measuring percolation and leaching losses (lysimeter). The lysimeters presented the following characteristics: height = 128 cm, diameter = 112 cm, area = 0.985 m^2 and were filled with soil before the experiment. The main soil characteristics are the followings: total N = 0.136%; available P = 21.5 mg kg^{-1}; exchangeable K = 248 mg kg^{-1}; pH = 7.54. The rye-grass (*Lolium perenne* L. cv "Barvestra") was grown in a completely randomised experimental design with three replications for two years (2001 and 2002).

Table 1. List of treatments

Year	Treatments	Kg N ha^{-1}
2001	untreated control (contr)	0
	50 of OWW (50ref)	80
	olive pomace compost (120com)	120
	200 of OWW (200ref)	200
	200 of OWW with MnOx catalyser (200cat)	200
2002	untreated control (contr)	0
	80 of OWW (80ref)	80
	olive pomace compost (120com)	120
	320 of OWW (320ref)	320
	320 of OWW with MnOx catalyser (320cat)	320

During rye-grass growth cycles shoots were harvested at 0.5 m from the soil level to minimise soil contamination; 5 cuttings were made in 2001 and 13 in 2002. In both years fresh weight, dry weight (48 h at 70 °C), total N content of the plants (Fison CHN elemental analyser mod. EA 1108) and total N uptake (N content x biomass dry weight) were determined. At each sampling, Leaf Area Index (LAI) and SPAD readings (a rapid and non destructive estimate of leaf greenness determined by a portable chlorophyll-meter) were recorded. SPAD readings were measured at mid-length on the fully expanded leaf from approximately 10 randomly selected plants from each lysimeter. Finally, nitrogen utilisation efficiency (NUE in kg kg^{-1}) as a ratio of dry weight to total N uptake was calculated, according to Delogu *et al.* (1998).
At the beginning (t0) and at the end (tf) of the cropping cycles, the total organic carbon (TOC), extracted total organic (TEC) and heavy metals (Cu, Ni, Zn and Pb) were determined.
Statistic analysis was carried out using the SAS system (SAS Institute, 1990). Treatments effects were tested using analysis of the variance and means were compared using Duncan's Multiple Range Test.

Results

The untreated OWW chemical characteristics are presented in table 2. The OWW obtained by centrifuge method presented lower values of total carbon, phenol composts and heavy metals due to different extraction methods.
Yield and growth parameters of rye-grass in the lysimeters are reported in table 3. Significant differences in yields and N uptake were found between 2001 and 2002 years. In the first year (2001) significant decreases in dry weight of the rye-grass were found compared to controls (409.8, 395.6 and 340.4 g $lysimeter^{-1}$, for contr, 50ref and 120com respectively). However, in 2002, the highest yield performance was recorded in the 320ref treatment (69.9% of increase of dry weight in respect to contr treatment).

Table 2. Chemical characteristics of olive waste water

	pH	Total N g l^{-1}	Total carbon mg l^{-1}	C/N	Phenol compost mg l^{-1}	Zn mg l^{-1}	Cu mg l^{-1}	Ni mg l^{-1}	Pb mg l^{-1}
Press system	4.36	1.59	43.28	20.3	20260	7.05	0.32	2.64	8.05
Centrifuge system	5.11	1.59	15.36	9.7	5020	3.75	1.99	0.05	1.54

Table 3. Yield and growth parameters of rye-grass cropped in a controlled environment

Year	Treatments	Fresh weight (g lysimeter^{-1})		Dry weight (g lysimeter^{-1})		LAI		SPAD readings		N uptake (kg ha^{-1})		NUE (kg kg^{-1})	
2001	50ref	2776.5	ab	395.6	a	7.7	ab	37.6	b	153.6	ab	25.8	c
	200ref	2453.2	b	371.3	ab	6.7	b	38.1	a	79.3	bc	46.8	b
	200cat	2804.7	ab	388.5	ab	7.5	ab	38.5	a	39.9	c	97.5	a
	120com	2330.6	b	340.4	b	6.4	b	37.6	b	134.4	ab	25.3	c
	contr	3029.1	a	409.8	a	8.2	a	38.5	a	174.5	a	23.5	c
2002	80ref	4019.7	ab	848.1	ab	10.6	ab	38.7	a	222.7	ab	38.0	ab
	320ref	4643.3	a	926.0	a	12.0	a	38.4	a	248.7	a	37.7	b
	320cat	3619.0	ac	776.1	ab	9.3	ac	38.0	a	197.3	ab	39.4	a
	120com	3004.8	bc	664.3	ab	8.0	bc	38.2	a	172.4	ab	38.6	ab
	contr	2571.6	c	545.0	b	6.5	c	35.9	b	144.2	b	37.8	b
mean	2001	2678.8	b	381.1	b	7.3	b	38.1		116.3	b	43.8	a
	2002	3571.7	a	751.9	a	9.3	a	37.8		197.1	a	38.3	b

Values in a row followed by different letter are significantly different according to DMRT at $P < 0.05$

Figure 1, present the TOC and TEC at the beginning (t0), and at the end of the experiment (tf). Significant increases were found for TOC in 80ref, 320ref and 120com, and for TEC in 320ref, 320cat and 120com treatments. No accumulation of heavy metals (Cu, Ni, Zn and Pb) was recorded in the soil at the end of the experiment (Table 4).

Discussion

The decrease of cumulative dry weight in rye-grass recorded in 2001 was probably due to the temporary immobilisation of the N (high C/N ratio) (Table 2) and to the elevated organic N of the 120com treatment (120 kg ha^{-1}), according with Bonari and Ceccarini (1994). The 50ref treatment showed similar values to the contr (fresh, dry weight and LAI) indicating that the presence of polyphenolic compounds in the waste water, although reducing the biological activity of soil bacteria, did not influence productive performances (Aldrich *et at.*, 1992). In the second year the highest yields and N uptake were found in 320ref and this indicates the possible use of OWW as an amendment to rye-grass swards. Therefore, it is a valid method to sustain yield and to distribute mineral elements to the plants (Papini *et al.*, 2000). Furthermore, the results show that for these treatments, soil organic carbon was increased without any pollution risks.

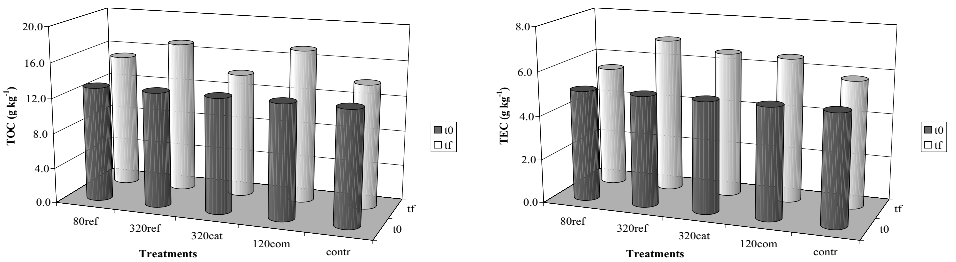

Figure 1. Total (TOC) and extracted organic carbon (TEC) at the beginning (t0), and at the end of experiment (tf)

Table 4. Heavy metals in the soil at the beginning (t0) and at the end of experiment (tf)

		Cu	Ni	Zn	Pb
t0		1.3	2.1	2.7	1.8
tf	80ref	31.73	47.6	70.1	42.3
	320ref	32.8	51.5	72.0	46.1
	320cat	34.5	46.4	63.1	46.8
	120com	32.4	47.6	63.0	43.9
	contr	32.7	54.2	65.0	42.7
	mean	33.1	49.4	66.6	44.4

Finally, the N content in OWW (Table 2) was used by rye-grass plants to increase N uptake (Table 3), which is an important parameter for plant growth.

Conclusions

The results obtained show the potential of olive waste water and olive pomace compost as soil amendments. In fact, the amendment function could be more important than the nutritional function in some area of Southern Italy characterized by elevated mineralization. Furthermore, the application of these residues did not seem to point to a potential risk for the agro-system.

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An investigation of the basic morphological and agronomic traits of *Trifolium pannonicum* L. from the wild flora of Serbia

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Abstract

The results of a study of the morphological and quality traits of the wild species, *T. pannonicum* L., which is widespread in Serbia's natural grasslands, are presented. Seed of *T. pannonicum* populations was collected from five natural grasslands localities at 500–1100 m a.s.l. Plants were grown in a nursery and green mass yield per plant, plant height, number of tillers per plant and numbers of internodes on the main stem were determined. Dry matter yield per plant varied from 20 g to 250 g and the percentage of leaf in the total yield was in the range of 26–34%. Plant height was between 30 and 70 cm. There was high variability of investigated traits, between single plants within populations as well as between populations. Crude protein, crude cellulose and ash were determined when plants were at the stage of onset of flowering. All examined parameters depended significantly on the population.

Keywords: clovers, morphological traits, *T. pannonicum* L., quality, variability

Introduction

The genus *Trifolium* includes about 250 species out of which only a small number is studied intensively since only 10 to 15 species have high economic value. The majority of this species (150–160) originates from Euro-Asian centres of diversity i.e. from the Mediterranean region, while other species originate from American and African centres of diversity (Taylor, 1980). The economic important species in Serbia of genus *Trifolium* are red clover and white clover, while other species are part of the wild flora. In the Global Compendium of Weeds *Trifolium alopecuroides* Pers is a synonym for *Trifolium pannonicum* L. and its common name is Hungarian clover. In the natural grasslands of Serbia (1.62 million hectares) about 50 species of clover were found up to 2000 m a.s.l. *Trifolium pannonicum* L. represents one of the wild species. This species grows in mountain regions – areas of natural grasslands and pastures and thin forest up to 1800 m a.s.l. (Cincovic, 1982). Although *T. pannonicum* is not cultivated, its presence in grasslands imposes a need for investigation due to its high quality and in order to conserve biodiversity.

Materials and Methods

The seeds of *Trifolium pannonicum* L. populations were collected in August 2002 from five localities: Duga Poljana (1100 m), Rajac (850 m), Crni Vrh (750 m), Kosjeric (800 m) and Kopaonik (1100 m a.s.l.). The trial was set up on the experimental field of the Centre for Forage Crops, Krusevac at 150 m a.s.l. From all populations, 20 individual plants were investigated at the first cut. At the beginning of flowering, the plants were cut and green mass yield per plant (GMY), plant height, number of tillers per plant and internodes number on main stem were determined. The ratio of leaf, stem and flower mass in total biomass was also determined. The plant parts were separately analyzed for crude protein, crude cellulose and ash contents. The quality parameters for the whole plant were calculated according to their ratios in total yield. The total nitrogen was determinated automatically on Kjeltec auto system 1030. Crude protein content (CPC) was obtained by multiplication of total nitrogen by 6.25. Crude fibre content (CCC) was determined according to the Weende method, and ash content by dry ashing at 550 °C. The average values, variance and coefficient of variation were calculated and significance of differences was tested by LSD test.

Results and Discussion

The results for the basic morphological characteristics of investigated populations of *T. pannonicum* L. are shown in Table 1. Variability of individual plants for all investigated features was very high as was shown by the high coefficients of variation. The highest coefficients of variation were found for green mass yield per plant and number of tillers, while the variability of plant height and internodes number was significantly lower. The population, Rajac, showed the highest GMY. The others, except the population Kopaonik, had significantly lower GMY per plant. Coefficients of variation for plant height, as the main competitive ability parameter, were from 10.1% for population, D. Poljana, to 14.8% for population Rajac. The highest plant height was for population Kopaonik (52.66 cm), while the lowest height was in population D. Poljana (37.83 cm). Variability in number of tillers in all investigated populations was very high. There were no significant differences between populations for this trait. The lowest variability was obtained for the number of internodes. The population, Rajac, had the highest number of internodes (4.89) which was correlated with the highest plant height of this population. *T. pannonicum* L. had significantly lower values for all investigated traits in comparison to red clover populations, i.e. cultivars (Lugic, 1999). However, variability of individual plants in all investigated populations of *T. pannonicum* L. was higher. Such tendencies could be explained due to the fact that there was no breeding in this wild population in comparison to red clover where breeding programs have existed for a long time.

Table 1. Average values and coeficients of variation for investigated traits

Population		Green Mass Yield (per plant)		Plant height		Tillers		Internodes	
		(g)	CV %	cm	CV %	Number	CV %	Number	CV %
Duga Poljana		49.40	24.60	37.83	10.12	21.50	26.51	3.66	9.22
Rajac		112.65	26.12	53.17	14.84	22.67	27.32	4.89	10.15
Crni Vrh		82.01	23.47	43.00	12.23	20.38	23.12	4.31	8.97
Kosjeric		56.82	25.33	38.00	10.38	24.20	25.96	3.80	11.37
Kopaonik		105.73	27.43	52.66	12.46	20.33	27.45	4.33	12.17
LSD	0.05	8.66		4.26		4.73		1.12	
	0.01	14.23		6.36		7.11		1.47	

Stem was the main component of the green mass yield per plant (42.2–49.4%) in all investigated genotypes (Table 2). Leaf ranged from 26.6% in population Rajac to 34.1% in population Crni Vrh. Due to remarkable size of flower head and appearance of generative organs in almost all tillers, the proportion of flower in total green mass yield was very high. In all populations the leaf had the highest ash content (110.50–164.6 g kg^{-1} DM), while stem had the lowest content (65.10–72.50 g kg^{-1} DM). The influence of population, i.e. genotype, on ash content in all plant parts was significant. The population, Crni Vrh, had the highest ash content and also the highest leaf proportion in total green mass yield. The population, Kosjeric, had the lowest content of this parameter. Ash content of all *T. pannonicum* L. plants were similar to the results of red clover in the first cut, but lower compare to the bud stage and beginning of flowering stage of white clover in the first and second cuts (Ignjatovic, 2002). Crude protein (CP) content mostly varied depending on part of plant. Content of CP in leaf was up to 209.7 g kg^{-1} DM, while it was only from 86.70 g kg^{-1} DM to 99.10 g kg^{-1} DM in stem. The highest CP content in the whole plant was in the Kosjeric population (145.60 g kg^{-1} DM) while the lowest CPC was in the Duga Poljana population (138.00 g kg^{-1} DM).

Table 2. Quality parameters in leaf, stem and flower of investigated populations

Population	Part of plant	Portion in total yield (%)	Ash (g kg^{-1} DM)	CPC (g kg^{-1} DM)	CCC (g kg^{-1} DM)
Duga Poljana	Leaf	28.94	135.20	208.80	190.20
	Stem	44.48	72.50	99.10	377.80
	Flower	26.58	99.10	171.00	319.50
	Whole plant		97.60	138.00	307.90
Rajac	Leaf	26.06	131.80	209.70	187.90
	Stem	49.37	65.10	94.80	415.00
	Flower	24.57	86.10	168.80	325.20
	Whole plant		87.50	142.90	333.80
Crni Vrh	Leaf	34.10	164.60	187.80	195.70
	Stem	45.09	73.90	86.70	409.80
	Flower	20.81	108.00	177.70	306.30
	Whole plant		111.90	140.10	315.20
Kosjeric	Leaf	29.94	110.50	209.10	200.70
	Stem	42.19	67.80	90.40	388.90
	Flower	27.87	78.20	161.00	316.70
	Whole plant		83.50	145.60	312.50
Kopaonik	Leaf	29.84	130.00	197.90	157.10
	Stem	47.09	71.20	92.60	386.30
	Flower	23.11	83.40	171.20	306.70
	Whole plant		91.60	142.20	299.70

These results are in agreement with results for alsike clover, crimson clover, hop clover and red clover in the full bloom stage, while they are significantly lower than the CP content of white clover. Investigated populations of *T. pannonicum* L. had a higher CP content than grasses in full bloom stage and at the mature stage (Essig, 1985).

The highest crude fiber (CF) content was in the stem of all populations and it was up to 415.6 g kg^{-1} DM, while the lowest CF content was in the leaf (157.1–200.1 g kg^{-1} DM). Population significantly influenced CF content and the highest value of CF content in the whole plant was in Rajac population (333.7 g kg^{-1} DM). These values are significantly higher than the CF content in other cultivated legumes (red clover, white clover, alfalfa) in early bud stage and in the beginning of flowering according to Beyer *et al*. (1978). Ignjatovic (2000) indicated that CP content decrease significantly with maturity in red and white clover, while the CF content increased at the first cut, from the early bud stage to the full bloom stage (up to 253.30 g kg^{-1} DM).

Conclusion

Variability of individual plants for all investigated traits in all populations of *T. pannonicum* L. was very high. The influence of genotypes, i.e. populations, on investigated traits was also significant. The largest differences among investigated populations were for the green mass yield per plant and plant height. The Rajac population had the highest GMY per plant, plant height and number of internodes. A high variability of populations for leaf, stem and flower, and a high proportion of flower in the total biomass yield per plant were found.
Lower CP contents and higher CF contents compared to cultivated perennial legumes indicated a lower nutritive value of this wild species. The high presence of this species in natural grasslands and pastures in extreme climatic and edaphic conditions of mountain regions can have a positive influence on the biomass quality. Further investigations of these species are necessary, not only from the point of view of quality, but in order to conserve biodiversity.

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Persistency of *Trifolium repens* and sward productivity in low-input pasture on peat-muck soil

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Abstract

The grazing studies were conducted in two experiments established in 1996. The main purpose of the investigations, carried out in the years 2000–2003 was to determine the persistency of *Trifolium repens* cultivars in two sward types on a peat-muck soil. The main grass component in experiment A was *Poa pratensis* and in experiment B – *Lolium perenne*. Apart from these species, grass/clover mixtures contained *Phleum pratense* and *Dactylis glomerata*. A grass sward composed of these species was treated as a control. The swards were fertilized with 40 kg N, 35 kg P and 100 kg K ha^{-1} year^{-1}. Mean dry matter yields in the study period ranged between 9–11 t ha^{-1}. Sward with *Lolium perenne* usually yielded less than the sward with *Poa pratensis*. White clover still made an important contribution to the sward after seven years of pasture management. The content of white clover in the herbage depended on cultivar and the type of grass species in the sward. *Poa pratensis*, being a less aggressive species, ensured the maintenance of *Trifolium repens* in the sward better than *Lolium perenne*. Among the white clover cultivars studied Romena was the most persistent in the pasture under organic soil conditions.

Key words: persistency of *Trifolium repens*, peat-muck soil, sward type, productivity

Introduction

It is generally known that *Trifolium repens* is an essential component of sustainable farming systems, because of its potential to fix nitrogen, and its ability to persist under grazing and to improve soil quality. Growing in a pasture it also supplies associated grasses with N as a result of the mineralization of accumulated organic N in the soil (Mallarino *et al.*, 1990). Thus, presence of clover in the grass sward reduces the need for N fertilizer (Younie *et al.*, 1995), but higher availability of N for grasses can adversely affect clover persistency. White clover is not a typical grassland species on peat-muck soils. However, its introduction into a sward in a post-boggy (peatland after dewatering used as a meadow) habitat is beneficial, due to an increase in floristic diversity. White clover spreads through the sward by branching stolons and in that way can protect an organic soil surface when some species disappear after harsh winters (Warda and Krzywiec, 1998). To be beneficial the species in *Trifolium repens*-based pastures need to be persistent for more than four or five years. Thus, the main purpose of these studies was to determine the persistency of *Trifolium repens* cultivars in two sward types and their productivity on peat-muck soil, after seven years of management as a pasture.

Materials and Methods

The grazing studies were conducted in the years 2000–2003 in two experiments, established on a peat-muck soil (MtII – middle decayed peat) in 1996 (Krzywiec, 2000). A randomised block design with four replications was used. Six Polish cultivars of *Trifolium repens*, a mixture of these cultivars and cv. Alice were included to the sown mixtures. The main grass component (35%) of the mixtures with *Trifolium repens* (35%) in experiment A was *Poa pratensis* and in experiment B – *Lolium perenne*. Apart from these species, grass/clover mixtures contained *Phleum pratense* (20%) and *Dactylis glomerata* (10%). Swards composed only of these grasses were used as a control. The swards were fertilized with 40 kg N, 35 kg P and 100 kg K ha^{-1} $year^{-1}$ and grazed rotationally with Limousine cattle four times during the grazing season. The pre-grazing SSH (sward surface height) was 23 (±2) cm. The sward was grazed down to an average height of 6 cm. The lowest values of average monthly air temperature were observed in December 2001 and also in December 2002-February 2003 when minimum air temperatures reached below –25 °C. Dry matter yields were determined using sward-cutting techniques. Samples of herbage were botanically analysed by manual separation and expressed on a weight basis. Data were subjected to analysis of variance. Tukey's test was used for statistical comparison.

Results

Trifolium repens still made an important contribution to the sward after seven years of pasture management. Conditions for white clover development and persistency were better, but not significantly so, in the sward with *Poa pratensis* than the sward with *Lolium perenne* (Table 1). Differences in the maintenance of cultivars of *Trifolium repens* in the swards were significant. Among the cultivars studied, the large-leaved Romena was the most persistent in the pasture under organic soil conditions. Its average content in the sward with *Poa pratensis* exceeded 35% (22.2–47.9%) and was significantly higher than some other cultivars (Anda, Armena, Astra and Alice).

Table 1. Mean content of *Trifolium repens* (DM %) in pasture depending on sward type and cultivar of white clover, in the years 2000–2003

Treatment	Sward with *Poa pratensis*		Sward with *Lolium perenne*		Mean for the treatment
	ranges in the years	mean	ranges in the years	mean	
Grass(G) + *T. repens* cv. Anda	10.8–33.5	23.9	23.0–30.6	26.9	25.4
G + *T. repens* (*Tr*) cv. Armena	11.9–25.6	20.3	17.3–35.0	24.0	22.2
G + *T. repens* cv. Astra	14.6–26.4	21.1	17.6–26.7	23.0	22.1
G + *T. repens* cv. Rema	17.4–41.9	29.6	20.2–30.0	24.7	27.2
G + *T. repens* cv. Romena	22.2–47.9	35.6	22.7–30.4	27.4	31.5
G + *T. repens* cv. Alice	17.0–36.7	23.4	17.8–24.9	22.3	22.8
G + *T. repens* cv. Santa	17.4–40.3	26.4	15.3–28.2	23.8	25.1
G + *T. repens* Polish cvs mixture	21.1–38.8	29.3	22.1–28.8	24.5	26.9
Mean		26.2		24.6	25.4
$LSD_{0.01}$		9.6		ins.	8.0

Mean dry matter yields in the study period ranged between 9–11 t ha^{-1}. Swards with *Lolium perenne* usually yielded less than those with *Poa pratensis* (Table 2). This was due to swards with *Lolium perenne* being less resistant to harsh winter conditions in 2001/2002 and 2002/2003. The effect of clover cultivars on the yield of the sward was not significant, but the range of yields between the treatments were high during the study period, particularly in the pasture with *Poa pratensis* (A).

Discussion

The type of grass species in the sward and weather conditions (especially air temperatures) in study years had an important effect on the maintenance and productivity of swards with *Trifolium repens*. *Poa pratensis* as a less aggressive species ensured better maintenance of white clover in the sward than *Lolium perenne*. Similar results and observations were also reported by Rogalski and Kryszak (2001). The role of *Trifolium repens* in sward yield was less important under organic soil conditions, where an amount of N comes from mineralization of accumulated organic matter (Sapek and Sapek, 1993). In this habitat, the maintenance of the main grass components was more significant for sward yield. Higher stability of *Poa pratensis* in the pasture during the study period ensured higher dry matter yields than *Lolium perenne*. This has also been confirmed in earlier studies (Baryła and Warda, 1999), on organic soils when *Lolium perenne* was found to be rather susceptible to frost.

Table 2. Productivity of pasture depending on sward type, in the years 2000–2003

Treatment	Sward with *Poa pratensis* DM yield (t ha^{-1})		Sward with *Lolium perenne* DM yield (t ha^{-1})	
	ranges in the years	mean	ranges in the years	mean
Grass(G) + *T. repens* cv. Anda	9.1–11.6	10.3	8.0–10.2	9.4
G + *T. repens* (*Tr*) cv. Armena	8.9–12.2	10.1	8.6–10.0	9.4
G + *T. repens* cv. Astra	8.8–11.4	9.8	9.6–10.0	9.8
G + *T. repens* cv. Rema	9.3–11.8	10.4	7.8–10.0	9.2
G + *T. repens* cv. Romena	9.3–10.7	10.2	8.7–10.5	9.6
G + *T. repens* cv. Alice	8.8–11.5	9.7	9.1–10.1	9.6
G + *T. repens* cv. Santa	9.6–12.4	10.7	9.0–9.9	9.6
G + *T. repens* Polish cvs mixture	9.6–11.9	10.5	8.2–9.3	8.9
Grass sward	8.9–11.5	10.0	9.8–10.7	10.1
Mean for sward type		10.2		9.5
$LSD_{0.01}$ between sward types		0.3		

Conclusions

On peat-muck soil, the type of grass species in the sward and weather conditions during the winters have an important effect on the maintenance and productivity of grass-clover swards. The sward with less aggressive *Poa pratensis* yields higher and ensures better conditions for *Trifolium repens* development and persistency than the sward with *Lolium perenne*. Cultivar of *Trifolium repens* can be one of the factors conditioning persistency of this species in pasture, but its effect on the mixed sward yield is less important under post-boggy habitat.

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The grazing of livestock on coastal grasslands in Estonia

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Abstract

The coastal grasslands in Estonia are traditionally grazed by beef cattle, sheep and horses due to good quality of fodder. The coastal grasslands of the island Hiiumaa were investigated in the years 2001–2004. The main goal of the work was to investigate the grass quality and the impact of grazing on the plant associations. The grass quality from different plant associations was investigated to ascertain if it met the requirements of livestock during the grazing period. Plant material was analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), P, K, Ca and Mg. Digestible DM, DM daily intake, relative feed value and metabolizable energy (ME) content were calculated on the basis of ADF and NDF. The different investigated plant associations showed relatively stable fodder quality throughout the vegetation period but being lower in the plant association dominated by *Phragmites australis*. Relatively higher values were found when analysing the swards in salt areas and in the *Glauco-Juncetum gerardii* plant association. The content of mineral elements (Ca, Mg, K) in hay was satisfactory but the content of P was too low.

Keywords: grass quality, impact of grazing, coastal grasslands

Introduction

Traditionally, coastal meadows have been used for grazing due to the stable quality of feed and good animal performance. The quality of fodder is an important factor for farms using the coastal areas for grazing. The requirements for animals have to be met in order to maintain the high productivity of grazing livestock. Usually the grass from species-rich semi-natural grasslands has lower quality than *Lolium perenne*. The digestibility and feeding value of those forages are often lower than that of *L. perenne*, even at the same stage of maturity or with the same chemical composition (Bruinenberg et *al*., 2002).

In Estonia the reason for diminishment of coastal meadows and the expansion of the stands of the common reed (*Phragmites australis*) is the discontinuation of traditional use of grasslands, namely grazing and cutting. *Phragmites australis* usually produces dense and monocultural stands at the waterline, where species richness is low and it can survive in ungrazed shore meadows, but it suffers from grazing (Tyler, 1969). Because of the reduced output, farmers will probably hesitate to use forages from semi-natural grasslands for their animals. The effect of grazing on plants and soil includes plant defoliation, nutrient removal and redistribution through excreta and mechanical impact on soil and plants through trampling (Vallentine, 1990).

There are not many studies made in Estonia about grass quality and impact of grazing with reference to the coastal grasslands. The aim of the study was to determine the changes in grass quality of different plant associations during the vegetation period.

Materials and Methods

The investigated farm (total area 544 ha) in south-eastern Hiiumaa embraces approximately 400 ha of coastal meadows and the whole area (divided into 3–7 parts) is grazed by horses and beef cattle. The phytomass in each research area was cut in four replications (plots of 6 m^2), weighed and an average sample (1 kg) taken to estimate DM yield. Plant material was analysed for crude protein (CP), acid detergent fibre (ADF), neutral detergent fibre (NDF), P, K,

Ca, Mg. Digestible DM (DDM = 88.90-(0.779*ADF), %), DM daily intake (DMI=120/NDF, % of cattle weight), relative feed value (RFV=(DMI*DDM)/1.29, points) and metabolizable energy (ME) content were calculated on the basis of ADF and NDF (Nutrient Requirements for Dairy Cattle, 2001). Soils were described by digging pits and samples for soil analysis were taken from the humus layer (0–10 cm), oven-dried, and sieved trough a 2 mm sieve. Soil samples were analysed for C according to Tjurin method, N according to Kjeldahl, and P, K, Ca and Mg according to Mehlich-3 (Soil Survey, 1996).
The statistical analysis was performed by using the ANOVA, the Least Significant Difference ($LSD_{0.05}$) and Standard Deviation (SD) being presented.

Results and Discussion

In Estonian coastal grasslands the most widespread plant associations are *Glauco-Juncetum gerardii* and *Festucetum rubrae*. On the investigated salt area the plant association *Salicornietum europaeae* had halophytes like *Salicornia europaea, Honckenya peploides*, *Cakile maritima*, and *Halimione pedunculata* as constituents. The *Phragmitetum australis* plant association has widened its area over the past 50 years. *Phragmites australis* is a species that is sensitive to overgrazing. Over-trampling reduces the share of perennials, the roots or rhizomes of which are seriously damaged or which cannot accumulate food supplies or set seed in time (Palo, 1996). The investigated *Phragmitetum australis* association was influenced by grazing activities, remaining rather sparse and due to that had relatively low productivity reaching 1.9 DM per hectare. The productivity of other investigated plant associations varied remarkably, the lowest value of 0.64 t ha^{-1} being from *Glauco-Juncetum gerardii*. Grazing cattle eat mostly the grasses, as well as many herbs with larger leaves, thus reducing the competition for light, and by damaging the sod layer they create better conditions for germination of seeds. The grazing intensity is quite low and it was not equal on the whole area, depending on the productivity of the meadow. In some places the grazing has not been intensive enough to suppress the spreading of reed.

Table 1. The quality of grass samples taken in mid-June from different plant associations of coastal grasslands

Parameter	*Festucetum rubrae*	*Glauco-Juncetum gerardii*	*Phragmitetum australis*	*Salicornietum europaeae*	$LSD_{0.05}$
CP, %	8.59	9.33	11.79	13.24	4.44
ME, MJ kg^{-1}	9.38	9.92	9.07	13.18	0.88
NDF, %	66.70	63.04	72.65	23.41	6.32
ADF, %	36.57	32.85	38.72	10.24	6.09
DDM, %	60.41	63.31	58.74	80.39	5.04
DMI, %	1.80	1.92	1.66	4.97	0.28
RFV, %	84.50	94.67	75.33	321.67	14.81
Ca, %	0.32	0.48	0.29	0.30	0.28
P, %	0.15	0.09	0.12	0.20	0.05
Mg, %	0.20	0.20	0.11	0.67	0.06
K, %	1.35	1.22	1.70	1.05	0.73

From the investigated plant associations *Salicornietum europaeae* occupied quite small areas and due to late emergency and low productivity its share of cattle diet was not marked although it had the highest quality parameters (Table 1). Salt area plants have very low fibre content (ADF and NDF) and therefore the digestibility and DM intake as well as the RFV are very high. During the vegetation period the digestibility decreased, this being caused by the increasing proportion of cell wall components (cellulose, hemicellulose and lignin) of the grass whereas the proportion of cell contents decreases (Bosch *et al*., 1992). From the other investigated plant associations *Glauco-Juncetum gerardii* showed relatively good quality compared with *Festucetum rubrae* and *Phragmitetum australis* associations. Comparing the plant samples taken in mid-June and August the quality parameters did not change markedly during the vegetation period (Figure 1). The tendency for forage digestibility to rise, or at least not to decline further between July and September, reflects a predominantly vegetative regrowth and the presence of young leaves in the sward. Those areas are important bird areas and so to maintain the biodiversity it is suggested not to harvest the grass before mid-June, since this enables the grasses and meadow birds to reproduce. Cutting semi-natural grasslands in mid to late summer, when most of the grasses are at an advanced state of phenological maturity, means that there will be a high proportion of lignin and structural carbohydrates in the harvested dry matter (Bruinenberg *et al*., 2002)

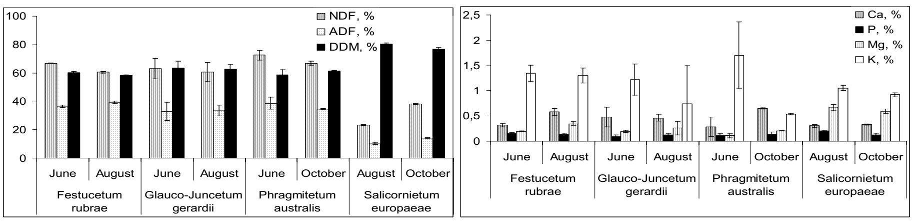

Figure 1. The change of quality parameters during the vegetation period in fodder from different plant associations of coastal grasslands (M±SD).

A decrease in the ME concentration of the consumed herbage will rapidly result in a decline in milk output or animal growth. This reduction may be higher if intake is also reduced, which will probably occur with low-digestible forages. The ME concentration was estimated and had values between 9.07 for *Phragmitetum australis* and 13.24 MJ kg^{-1} DM for *Salicornietum europaeae* though it did not change significantly during the vegetation period.

Besides digestibility and ME concentration of a feed, voluntary intake also determines the feeding value. Voluntary intake is often related to dry-matter digestibility, structural carbohydrate content and breakdown capacity in the rumen (Derrick *et al*., 1993). Intake of forages from semi-natural grasslands is found to be lower than intake from ryegrass and clover swards, mainly attributed to differences in digestibility (Armstrong *et al*., 1986). The lowest DM intake was from *Phragmitetum australis* and it can be due to high NDF (ADF) concentration in fodder and also relatively lower dry-matter digestibility. Intake can also be reduced by low nitrogen content in forage. The seasonal decline in nitrogen is associated with an increase in cell wall constituents in the dry matter (Gill *et al*., 1989).

The content of mineral elements in grass met the requirements of livestock for Ca and Mg and with increasing stage of maturity there was a significant change of those elements, especially in *Festucetum rubrae* and *Phragmitetum australis* communities (Figure 1). Although K content of the herbage cut was adequate for productive ruminant livestock there was a big variance of its content in fodder.

Hays from the coastal grassland communities examined in this study had inadequate P contents to sustain high growth rates in ruminant livestock. Due to high content of Ca the relatively high Ca:P ratio (optimum estimated between 1:1–2:1) of the forage was noteworthy, e.g. 5.3:1, in the by *Glauco-Juncetum gerardii* association. A high ratio can cause deleterious effects on the growth and health of livestock (Tallowin, Jefferson, 1999). The content of P in plants is also related to the content of P in soils. The content of plant available nutrients in the investigated grassland soils was relatively high in K, Na, Ca and Mg but the content of P was low. At the same time low soil P availability appears to be a key factor allowing high species richness to be maintained (Janssens *et al*., 1997).

Conclusions

Throughout the summer digestibility of forages from species-rich coastal grasslands remains low (below 65%) and the quality of fodder does not meet the requirements for high productive milking cows although it is suitable for beef cattle. The quality of grass on coastal meadows is relatively stable and does not vary markedly between plant associations and during maturation in the vegetation period. The biodiversity of coastal grasslands of Estonia is relatively high and distribution of plant species is influenced among other factors by trampling and grazing effects of livestock. Soils are rich in plant available nutrients like Ca, Mg, Na and K but poor in P and this can be one of the restrictive factors of plant growth and low P content in fodder.

Acknowledgements

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Allelopathic effects of grasses and biodiversity of plant communities

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Abstract

One of the least known of biocenosis factors is the allelopathic effect of higher plants. This investigation's results indicate that the phytosociological systems of most plant associations are developed by these properties. Allelopathy could be used so that the agriecosystem biodiversity could be extended. Some investigations need to be performed to get to know the allelopathic mechanisms as well as to separate them from other plant interactions, mainly competition. Field experiments are extremely difficult to carry out, that is why attempts are made to determine these relationships under the laboratory conditions.

To define the operation of an allelopathic factor of various grass species, it was decided to use a density dependent phytotoxicity model. The model is based on the fact that along with acceptor plant density growth, the response to allelopathic compounds decreases, while the negative competition effects increase. A higher growth of acceptor plants accompanying their density increase in a population is discordant with competition rules and is likely to imply the allelopathic background of the changes recorded. These investigations were designed to evaluate the allelopathic properties of grass donors by using extracts of leaves collected at various developmental stages. A tested acceptor species *Ph. pratense* was sown at 10 and 20 seeds per dish density. The study results showed that initial growth and development of acceptor seedlings varied subject to its dish density and a donor species. Poorer growth of *Ph. pratense* in the treatments of lower density proves the allelopathic influence of the grass donors examined.

Keywords: allelopathy, biodiversity, *density dependent phytotoxic* model, grass, resource competition

Introduction

Currently allelopathy belongs to the least known biocenosis factors. It is one of the prerequisites of floristic biodiversity extension in the agriecosystems (Chou Ch., 1999; Rutherford and Powrie, 1993; Smith and Martin,1940). However, the efficient use of allelopathy in agricultural practice requires searching for species and establishing the developmental stages at which the allelopathic substances are released at bioactive concentrations. It is vital to separate allelopathy from other aspects of plant interactions, mainly from competition for environment resources (Chou, 1999). That still remains one of the most significant tasks in researche on plant interference. Allelopathy cannot be considered as a competition element. It does not consist of resource limitation but the biochemical interactions of plants (Chou, 1999). A model "density dependent phytotoxic" is one of the solutions to discriminate competition from allelopathy. The model assumes that the effects harmful for plants depend on their density in a given phytotoxic environment. The plants grown at low density are provided with greater amount of phytotoxins, while at higher density each plant obtains a relatively smaller dose (Weidenhamer, 1996; Thijs *et al*., 1994; Gentle and Duggin, 1997). It is assumed that an increase of acceptor plants growth causes a decrease of their reaction to allelopathic compounds. Growth diminution at low plant density is discordant with competition and may prove the allelopathic influence.

In the investigations with the "density dependent phytotoxic" model application an attempt was made to show the allelopathic impact of *Festuca arundinacea, Lolium multiflorum* and *Lolium perenne* on seed germination and the initial growth and development of *Phleum pratense*.

Materials and Methods

The experiment was carried out in the department of Grassland Science and Green Management. In order to avoid soil and microbial interactions, bioassays were performed on Petri dishes under laboratory conditions. Studies included two experimental series set out by means of complete randomization in four replications. Bioassays were carried out under daily 12-hour (7 a.m. – 7 p.m.) artificial lighting using high-voltage SON-T Agro type lamps (mean light intensity at table level about 3000lx). Its special SGR 140 type frame guaranteed proper and uniform plant lighting (U – about 80%). Air temperature in the room ranged between 22–25 °C.

Seeds of the tested species (*Phleum pratense*) were placed on Petri dishes on 3 chromatography filter paper layers (Whatman No 3001917) at two different densities – 10 and 20 seeds. Filters were wetted every day with 3 ml respectively of water extracts prepared from leaves of *F. arundinacea, L. multiflorum* and *L. perenne*. Controls were wetted with distilled water.

In order to achieve water extracts, leaves of the above species were taken at full tillering, shooting, earing and flowering stages. The plant material after air-drying was stored in the dark under proper conditions to avoid microbial damage of allelochemicals. 50 g of dried leaves were then covered with 1000 ml of distilled water, and the solution filtered through filter paper after 24 hours. Extracts were stored at 5 °C.

The emergence energy of *Phleum pratense* seeds was estimated after 5 and germination ability after 10 days. Measurements of root system length and seedling height were done on the same days as germination ability estimation. Study results were statistically analysed by means of variance analysis. Tukey's confidence intersections ($p \leq 0.05$) were applied to verify the significance of the differences between estimated average values.

Results and Discussion

Studies revealed significant influences of the water extracts from the leaves of the tested grass species on seed germination, seedling height and root length of *Phleum pratense* (Table 1).

The parameters evaluated differed depending on the donor species, its development stage and the density of the tested acceptor-plant. When compared to the control, the greatest negative allelopathic influence was the result of water extracts prepared from *L. multiflorum* and *F. arundinacea* leaves. Also other authors (Luu *et al.,* 1982; Naovi, Muller, 1975, Peters, Luu, 1985; Wardle *et al*., 1996; Takahashi *et al*., 1994) pointed to allelopathic interactions of those grass leaf extracts. In all cases, higher inhibition was observed with lower densities of acceptor plants (Figure 1 A, B). Also *L. perenne* caused weaker seed germination as well as seedling and root elongation in situations where plants had more substances in water extracts of the species (at density of 10 seeds)**.** However, with reference to the controls, this inhibition was obvious only during seed germination and seedling root growth of *Ph. pratense*. The allelopathic properties of *L. perenne* were also confirmed by the studies of Bourdot (1996), Beyschlaga *et al.* (1996) or Kryzeviciené and Paplauskiené (2004).

Table 1. Seed germination, seedling height and root length of *Phleum pratense* under the influence of water extracts from leaves of tested grasses depending on the species, development stage and density of tested species

Differentiating factors	Parameters			
	Germination energy. %	Germination capacity. %	Seedling height cm	Root length. cm
Mean for the donor-species				
Festuca arundinacea	56	64	3.6	1.5
Lolium multiflorum	50	57	3.1	0.6
Lolium perenne	72	79	4.1	1.6
$LSD_{0.01}$	3.1	3.1	0.4	0.2
Mean for the donor development stage				
Tillering	61	67	3.9	1.7
Shooting	64	74	3.7	0.5
Heading	51	59	3.5	1.5
Flowering	61	67	3.3	1.1
$LSD_{0.01}$	4.0	2.1	0.5	0.2
Mean for the acceptor density				
at 10 seeds density	51	59	3.1	0.8
at 20 seeds density	67	74	4.1	1.6
$LSD_{0.01}$	2.1	2.1	0.3	0.1

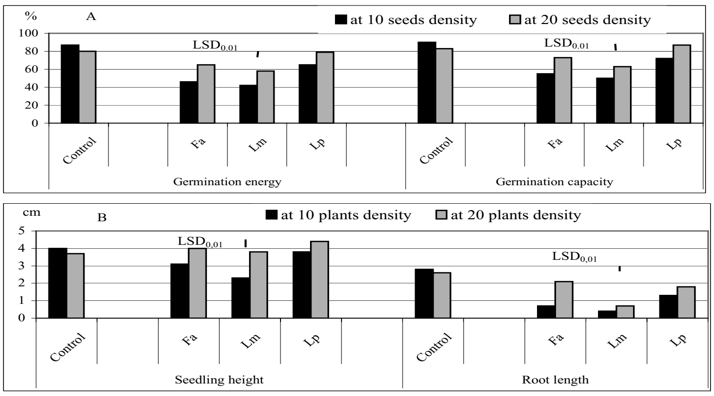

Figure 1. Seed germination (A), seedling height and root length (B) of *Ph. pratense* at 10 and 20 seedling densities under the influence of water extracts from *F. pratensis, L. multiflorum* and *L. perenne* as well as under control conditions (distilled water)

Results of these tests indicate a great differentiation in the values of measured parameters depending on the date of leaf harvest for bioassays. The germination of *Ph. pratense* seeds was mostly inhibited by extracts from leaves taken at the heading stage. In turn, their highest number was recorded under the influence of extracts from leaves harvested at shooting stage**.** The shortest seedlings were observed in objects where the filter paper was wetted with extracts prepared from leaves taken during grass flowering. Those extracts also significantly inhibited the root length. However, the shortest roots of *Ph. pratense* were recorded under the influence of water extracts from leaves at the shooting stage (Table 1). More intense negative influences of the water extracts from leaves collected at heading and flowering in comparision to tillering were also observed by Kryzeviciené and Paplauskiené (2004). Also Smith and Martin (1994) observed the highest negative effects of the interaction of water extracts from leaves of *F. arundiancea* and *L. multiflorum* entering the generative stage. According to Weidenhamer (1996) the worst parameters at lower test plant density are contradictory to competition for resources and therefore may prove the phytotoxic influences of allelochemicals. Also Fischer *et al.* (1994), Thijs *et al.* (1994) and Weidenhamer *et al.* (1987) established the allelopathic properties of neighboring donor-plants when various sowing densities of acceptor plant were applied.

Conclusions

Experiments revealed significant influences of water extracts from leaves of tested species on seed germination and preliminary growth and development of *Phleum pratense* seedlings. The allelopathic potential of these extracts was different depending on the species and its development stage.

Stronger inhibition of *Phleum pratense* growth in treatments with lower seedling density is contradictory to effects which would be expected from competition for resources and may indicate allelopathic interactions.

Reduced seed germination, worse than under control conditions and reductions of seedling height and their root length prove the potential influence of allelochemicals contained in the extracts on the growing conditions of the tested plants. This may be one of the reasons for changes in sward floristic composition. Species may be weakened during early growth and development stages by allelochemicals excreted by other species less sensitive towards these substances.

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Effect of tree density and species on botanical evolution diversity in a five years experiment in a silvopastoral systems

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Abstract

Silvopastoralism is a sustainable way of land management that promotes pasture biodiversity compared with intensive managed grasslands. The objective of the experiment was to evaluate the botanical composition evolution and biodiversity after seven year experiment of two pasture mixtures (ryegrass and cocksfoot) established under two tree species (*Pinus radiata* and *Betula alba*) at two densities (833 and 2500 trees/ha) in no fertilised plots. Main results indicate that biodiversity was lower in those plots sown with cocksfoot at higher density with *Pinus* and lower density with *Betula*. Sowing with cocksfoot and Agrostis of these systems would improve the pasture quality as forage.

Keywords: silvopastoralsim, dicot, biodiversity

Introduction

Europe holds close to 50% of the autochthonous domestic animal species. Sivopastoral systems can be a land management strategy to preserve these breeds in more marginal areas. These breeds are adapted to more severe conditions that those breeds with an extensive use in more conventional farms. Knowledge about the behaviour of herbaceous strata developed under different tree species at different densities will help to understand the potential as forage for these breeds and to promote biodiversity under these systems.

Materials and Methods

The experiment was established in Atlantic Spanish area in Lugo (NW of Spain) following a randomised block design in spring 1995. *Pinus radiata* and *Betula alba* afforestation was made at a density of 833 and 2500 trees/ha in an abandoned agronomic land with an initial pH of 6.8. Every plot consisted of 25 trees distributed in a square of 5x5 trees. Pasture was established after soil preparation with 25/kg ha *Dactylis glomerata* L. var Saborto + 4 kg/hs *Trifolium repens* L. var Ladino + 1 kg/ha *Trifolium pratense* L. var Marino. No fertilization was applied. Every year pasture production was estimated by harvesting an area comprised between four inner trees in the plots three times during the spring and one in the autumn, with the exception of the first year when two harvests, one per season, were made. Samples were transported to laboratory, where species were separated by hand and botanical composition was estimated based on percentage of dry matter. Alpha biodiversity and abundance diagrams for the third harvest (before summer) of the seventh year of the experiment were made (Magurran, 1989). ANOVA was used for statistical analyses.

Results

Alpha-biodiversity, when cocksfoot was sown, was positively and negatively affected by a reduction of the density under *Pinus* and *Betula*, respectively. *Hypericum*, *Daucus*, and *Taraxacum* contributed more than 45% to pasture in most of the cases (reaching 72%). But, *Holcus*, *Plantago* and *Agrostis* represented a low percentage of the pasture, but they appeared in most of the treatments. Clover was mainly associated to birch stands (Table 1).

Table 1. Species pasture contribution expressed as number of species which represented more than 10% to pasture with respect to total in each treatment. Number of total species between brackets

	833 trees/ha-Dg	2500 trees/ha-Dg	833 trees/ha-Lp	2500 trees/ha-Lp
Pinus	60(12)	50(8)	45(12)	40(10)
Betula	57(7)	36(11)	50(11)	17(12)

Abundance curve distribution varied with the density and tree species (Figures 1 and 2). Pinus curves presented a higher proportion of co-dominant species, but birch curves presented a shorter number of dominant species. Flat curves were generally associated to low density. The contribution of number of species with respect to total number of species that contributed more than 10% to pasture was always higher when *Pinus* was established as can be seen in Table 1.

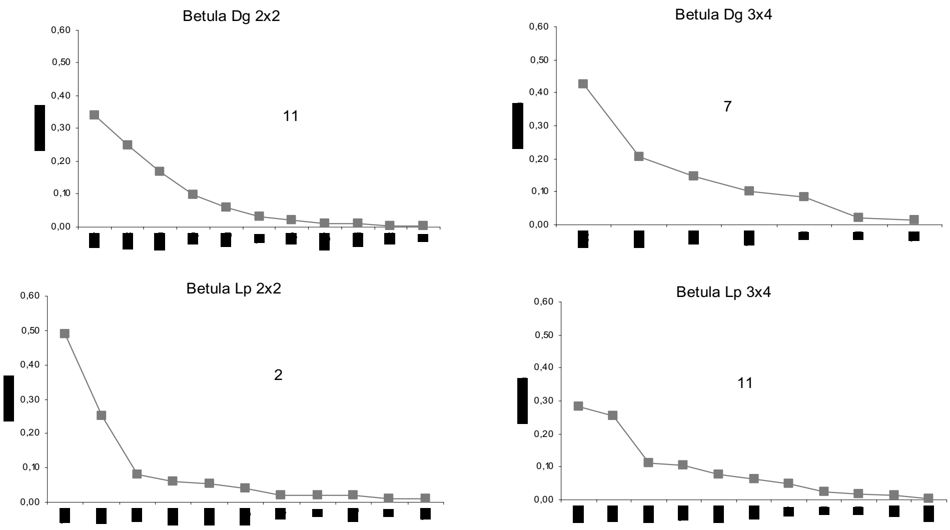

Figure 1. Abundance diagram per species in *Betula* treatment. Dg: *Dactylis glomerata*; Lp: *Lolium perenne*; Dau: *Daucus carota*; Ant: *Anthemis*; Bri: *Briza*; Tar: *Taraxacum*; Hyp: *Hypericum*; Agr: *Agrostis*; Hl: *Holcus lanatus*; Tc:*Trifolium campestre*; Tr: *Trifolium repens*; Pl: *Plantago lanceolata*; Cer: *Cerastium glomerata*

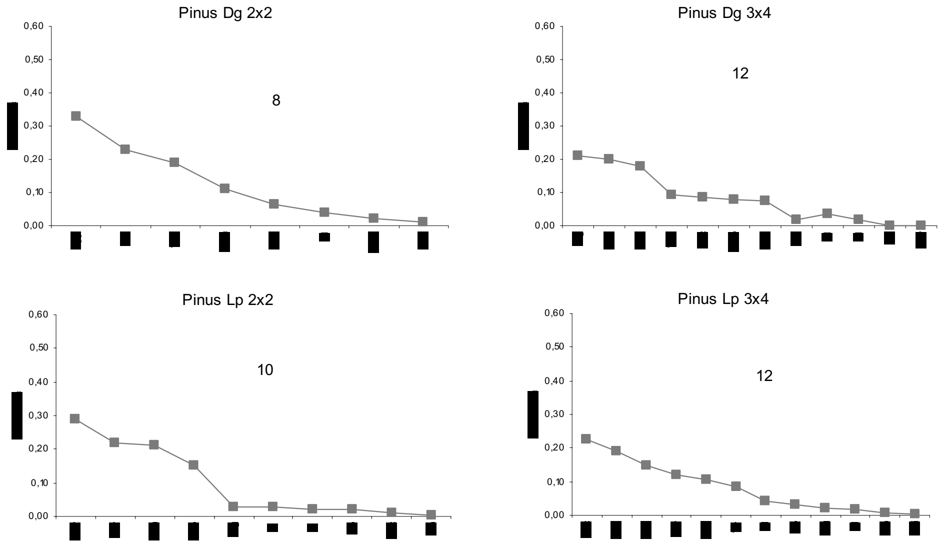

Figure 2. Abundance diagram per species in *Pinus* treatment. Dg: *Dactylis glomerata*; Lp: *Lolium perenne*; Dau: *Daucus carota*; Ant: *Anthemis*; Bri: *Briza*; Tar: *Taraxacum*; Hyp: *Hypericum*; Agr: *Agrostis*; Hl: *Holcus lanatus*; Tc:*Trifolium campestre*; Tr: *Trifolium repens*; Pl: *Plantago lanceolata*; Cer:*Cerastium glomerata*. Rob: *Rumex obtusifolius*; Mus: Moss; Ra: *Rumex acetosa*; Hm: *Holcus mollis*

Discussion

Rigueiro *et al*., (2005) have described tree growth and pasture development in these treatments Cocksfoot persisted much better than ryegrass under shading as was previously described (Mosquera *et al.*, 2005). More important shading effect under *Pinus* caused a reduction of number of species under 2500 trees/ha than under 833 trees/ha. However, the lower effect of shading on pasture of the birch, caused higher biodiversity under more dense stand, when cocksfoot was sowing. This can be explained because there are few species better adapted to grow up under more extreme shading (*Pinus,* high density) conditions and, on the other hand, few species can dominate the sward in favourable conditions (*Betula,* low density). Generally, cocksfoot sowing caused a reduction in the number of species, due to the better establishment of this species than ryegrass.

Main species presented in the pasture were result of low soil fertility derived from the lack of fertilization during the seven years of study. *Daucus carota*, as happened with *Anthemis*, was the main species when light input was higher (*Betula* at a density of 833 trees/ha) and ryegrass was sowing. However, *Taraxacum* grown up better at higher density. *Hypericum* and *Anthemis* have low forage value compared with the medium forage value of *Taraxacum* and *Daucus*. Fertilization, even at low rate, as well as grazing would enhance the proportion of grasses, with higher grazing value.

On the other hand, there are species with lower contribution to pasture in most treatments like *Holcus* and in most of them like *Plantago* or *Agrostis*. White clover is associated with light conditions like those present under birch, but it only appeared in this plot with more light input and when no cocksfoot was sowing under *Pinus*. White clover needs light to survive, but also needs higher pH than the other species. *Pinus* reduced significantly the pH in the

plots (Rigueiro *et al.*, 2005) and birch leaves re-introduced cations in the systems when they fall, which enhance the proportion of dicot species.
Sowing with cocksfoot enhance the presence of this species in the pasture, which has higher forage quality than those found in ryegrass plots. *Agrostis* could be introduced as sown species in the initial mixture in order to improve forage quality under shading.

Conclusions

Tree density and species, as well as sown sward mixture modified the behaviour of pasture biodiversity. Higher number of species was present in those inter-medium light inputs and when no cocksfoot was sown. *Betula alba* was better for silvopastoral systems than *Pinus radiata.*

Acknowledgements

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Shading effect on establishment and productivity of cocksfoot (*Dactylis glomerata* L. cv. Artabro)

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Abstract

Silvopastoral systems are sustainable systems of land management as it is declared in the Agenda 21. Knowledge about pasture establishment under shading conditions will improve pasture establishment in silvopastoral systems. This experiment aims to analyse the effect of shading on establishment and productivity of *Dactylis glomerata* L. cv. Artabro. The experiment was carried out in Lugo (NW Spain) in 1996 (when a sowing with 30 kg ha^{-1} of cocksfoot was made) and monitoring continued throughout 1997. Shading was simulated with a plastic mesh that intercepted a 50% of incident radiation that reaches the pasture. Shading conditions enhanced a quicker establishment of cocksfoot, being *Capsella bursa-pastoris* L. Medik the main species under light conditions in the first harvests. Due these facts there were not differences on pasture production in the first spring of the experiment. Cocksfoot contributed almost 80% of pasture of all treatments in the spring of the second year, which enhanced pasture production under light conditions. The lower effect of summer drought on shaded pasture enhanced pasture production during the autumn in both years.

Keywords: silvopastoral systems

Introduction

The importance of wood need in the European Union, together with the reduction of many dairy farms, have caused land use changes from grasslands and shrublands to forestland.
The establishment of silvopastoral systems makes compatible animal production with forest production which allow to obtain income at a short (milk, meat) and long-term (timber products). Furthermore, it reduces the needs of investments in clearings, as animals use biomass developed under the trees for feeding. These systems have been successfully used from 1960´s in New Zeland and Australia, especially with *Pinus radiata* D. Don.
Sowing in these systems is important as a way of improving pasture production and the quality of food for animals. The establishment and productivity of pasture is usually affected by incident radiation (Mosquera *et al*., 2001); and the knowledge of the effect of shading on pasture establishment will allow us to predict the behaviour of the sowing species in silvopastoral systems and therefore to improve the profitability.
The aim of this work was to evaluate the effect of simulating shading (50% of reduction of incident radiation) on the establishment and development of cocksfoot.

Materials and Methods

The experiment was carried out in Lugo (NW Spain) in 1996 and 1997. The experiment design was a randomised block with three replicates, and it consisted of a sowing of a monoculture of 30 kg ha^{-1} *Dactylis glomerata* in plots of one square meter with and without reduction of incident radiation in spring 1996. The incident radiation was reduced by 50% through the use of a black plastic mesh located 0.5 meter above the soil with a metallic structure.
Pasture samples were taken in May, July, September and November of 1996 and April, June,

July, October and November of 1997. Sampling consisted of harvesting two squares of 0.3 × 0.3 m in each experimental unit at a height of 2.5 cm above soil level. Samples were transported to laboratory, where botanical composition was estimated by hand separation. Samples were dried at 60 ºC during 48h in order to estimate dry matter.
Treatments were evaluated with the ANOVA using the statistic program SAS (1985).

Results

First year pasture production (1996) was lower than the in the second (1997) due to the delay in the initial growth in the first part of the year. It is in accordance with the recommendation that it is more adequate to sow pastures in autumn in the area.

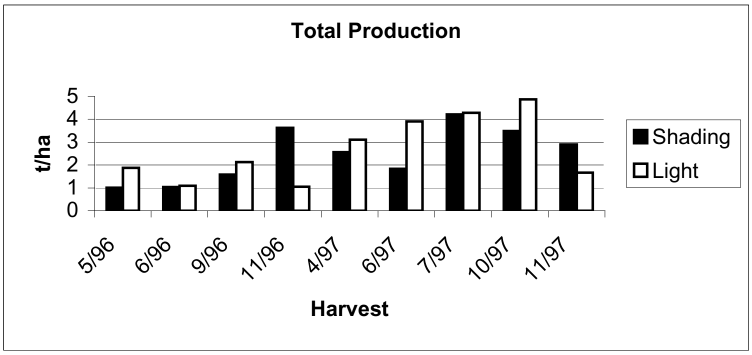

Figure 1. Pasture production (t DM/ha) under shading (black bars) and light (light bars) conditions in each harvest

There was no effect of light input on pasture production during the spring of 1996, which can be explained by the worse initial establishment of *Dactylis glomerata* under light conditions (Figure 2).

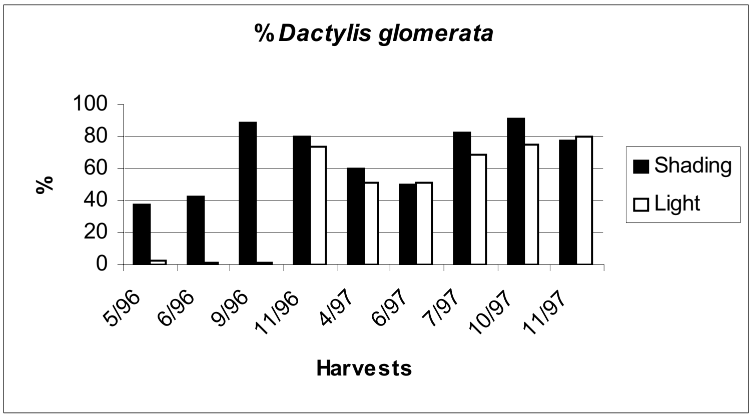

Figure 2. Percentage of *Dactylis glomerata* under shading (black bars) and light (light bars) conditions in each harvest

However, cocksfoot was better established under shading conditions and *Capsella bursa-pastoris* (Figure 3) contributed more to pasture in the first two harvests and *Trifolium pratense* in the third harvest (Figure 4) under light conditions. This fact benefited pasture production under shading conditions in the autumn as *Dactylis glomerata* had higher growth rate than *Capsella*.

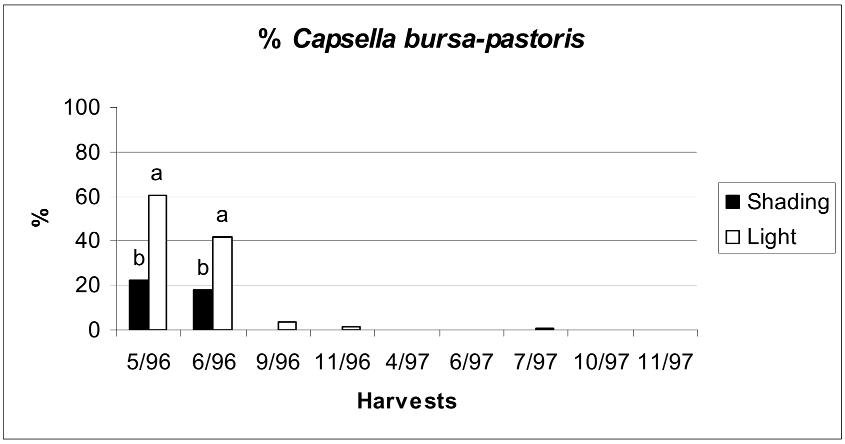

Figure 3. Percentage of *Capsella bursa-pastoris* under shading (black bars) and light (light bars) conditions in each harvest

However, pasture production was higher under light conditions in most of the harvests of the second year (Figure 1) due to the good proportion of cocksfoot in both treatments (shading and light) (Figure 2). Pasture production was higher in shaded treatments in autumn of both years this can be explained by the more reduced effect of drought on cocksfoot under shading conditions during the previous summer, which enhanced the recovery of pasture when precipitation starts again after summer.

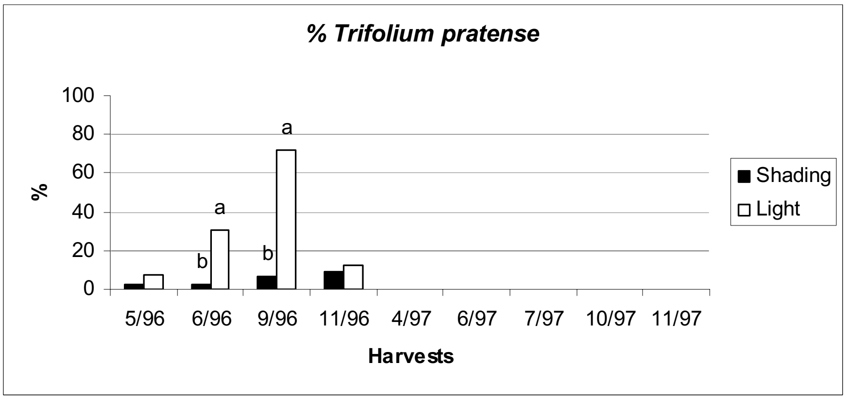

Figure 4. Percentage of *Trifolium pratense* under shading (black bars) and light (light bars) conditions in each harvest

Discussion

One of the main problems associated to pasture production during the first year of establishment is the presence of some dicots which low quality like *Capsella bursa-pastoris*, which has higher initial growth rate compared with *Dactylis glomerata* due to better competition for resources under light conditions. This fact is even more important when the competiton is established with cocksfoot as this species has a very low establishment rate in unshaded treatments. This competitive relationship disappeared under shading conditions.
Capsella bursa-pastoris is a spontaneous species that disappears after first year, and it makes not advisable to eliminate it through chemical or mechanic systems (Remón-Eraso, 1991). This fact can be avoided with the use of species in the mixture like ryegrass, with better establishment growth rate than cocksfoot or with autumn sowing which allows pasture establishment prior *Capsella* development, reducing its contribution to pasture. On the other hand, this is not a problem in silvopastoral systems where light input is reduced (Mosquera et al., 2001). Silvopastoral systems can enhance autumn production in those areas with important summer drought.

Conclusion

Pasture production was usually better under light conditions, after *Capsella bursa-pastoris* encroachment disappearance, as this last species grows initially up better than cocksfoot under light conditions. Shading can improve pasture production through the extension of grazing season in autumn in areas with summer drought.

Acknowledgements

We would like to thank J. Javier Santiago Freijanes for his field work and data processing and M.T. Piñeiro-López and Divina Vázquez-Varela for their laboratory analyses. This study was made thanks to financial assistance of CICYT.

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Relationship between plant diversity and herbage production in Mediterranean grasslands

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Abstract

The relationship between biodiversity and productivity is an issue of great interest in grasslands that has not yet been fully investigated. In this study, we compared two Mediterranean grasslands, one dominated by annual and the other by perennial species. Both species diversity and herbage production were measured in random plots, 0.25m^2 each in size. No significant correlation was found between plant diversity and herbage production in any of the two grassland types. This was attributed to the fact that only a few species were contributing to bulk herbage production. The results suggest that as Mediterranean grasslands evolve from temporary (annual) to permanent (perennial) plant communities they become more species-rich and at the same time more heterogeneous in terms of the contribution to biomass of the constituent species.

Keywords: species richness, productivity, annual grassland, perennial grassland, Greece

Introduction

The relationship between biodiversity and productivity has been the subject of several studies and reviews over the last few years (e.g. Tilman, 1999; Waide *et al*.,1999; Loreau, 2000; Loreau *et al.*, 2001), but not yet resolved. The pattern of this relationship and its causal mechanisms are still in dispute (Waide *et al*., 1999). Different diversity-productivity patterns are obtained with different coexistence mechanisms, indicating that there is no reason to expect any general relationship between them (Mouquet *et al.*, 2002). According to Tilman *et al.* (1997), two basic mechanisms are involved, the sampling effect and the niche differentiation effect. Loreau (1998; 2000), on the other hand, considers that the two major types of mechanisms by which biodiversity influences productivity are the complementarity effect and the selection effect.

Biomass production is an important property of grassland ecosystems that has been found to depend on temperature and precipitation (Papanastasis, 1982). The relationship between plant diversity and grassland productivity is still rather vague. Recent experimental studies in which species richness was manipulated have shown a positive relationship between species diversity and productivity in grasslands (Tilman *et al*., 1996; Hector *et al.*, 1999). These results contradict patterns often observed in nature where the most productive ecosystems are typically characterized by low species diversity (Loreau *et al.*, 2001). In plant communities, the relationship between plant species richness and productivity is generally expected to be "hump-shaped" or unimodal (Grime, 2001). In a survey of the ecological literature, Waide *et al.* (1999) have found approximately 200 relationships of which 30% were unimodal, 26% positive linear, 12% negative linear and 32% non significant. Furthermore the same authors concluded that the relationships found differ with scale; most studies considering plants at the within-community scale (ecological scale) reported no pattern at all, while at the local scale (geographic scale) studies of plant communities exhibited mostly unimodal relationships or no relationship at all.

In this paper species richness and herbage production (live biomass) were studied in two types of Mediterranean grasslands with the aim of comparing their relationship.

Material and Methods

The research was carried out in Lagadas county, 60 km to the north of the city of Thessaloniki, in central Macedonia, N. Greece (40º 47′ N, 23º 12′ E), at an altitude of 450–550 m. The climate is Mediterranean-type with cold winters. Soils are derived from metamorphic rocks and have a sandy-loam (SL) texture. The vegetation belongs to the *Coccifero-carpinetum* association of the *Quercetalia pubescentis* (Dafis, 1973). Grasslands constitute a small but very important part of the study area characterized by a high diversity of plant species.

In early spring 2003, two types of grasslands, with four replicates 0.1ha each, were identified. One was dominated by annual species, resulting from the abandonment of cultivated arable fields about 10 years ago, and the other by perennial species. In each of the 8 replicates, the species present were recorded and the total above ground biomass was harvested as described in Papadimitriou *et al.* (2004) and Zarovali *et al.* (2004b) respectively. In half of the quadrats harvested, the live biomass was sorted manually into the constituent species.

The relationship between species richness and herbage production was investigated by applying the best fit method of regression analysis. Furthermore, the average biomass of each species for each type of grassland was categorized into classes (5 g DM m^{-2} each) and the number of species belonging to each class was calculated. All statistical analyses were carried out using the software SPSS 11.0 for Windows.

Results and Discussion

In both types of grasslands a total of 102 species were recorded which belonged to 76 genera and 24 botanical families. The most numerous families were *Gramineae* (25 species), *Compositae* (18 sp.), *Leguminosae* (15 sp.) and *Caryophyllaceae* (12 sp.) containing 69% of the total number of species.

Species richness was found to be significantly higher in the perennial grassland reaching a mean of 13 species per quadrat (0.25m^2), than in the annual grassland, where it reached 9 species per quadrat (Papadimitriou *et al.*, 2004). On the contrary, Zarovali *et al.* (2004b) found that live biomass was lower in the perennial (198.8 g DM m^{-2}) compared with the annual grassland (215.2 g DM m^{-2}) by 7.6% though with no significant difference.

For both types of grasslands, no significant relationship was detected between species richness and productivity (Fig. 1). Similar results were also found by Gross *et al.* (2000) when examining the relationship between species density and above-ground net primary productivity (ANPP) among fields within grassland communities where in most cases (three out of four) no relationship was detected and only in one case a significant negative linear relationship was found. As Gross *et al.* (2000) and Waide *et al.* (1999) reported, there is scale dependence in the relationship between diversity and productivity, even in situations where unimodal patterns emerge at a broader scale. A further investigation of this aspect at different spatial scales is needed but goes beyond the aims of this paper.

In terms of the average biomass of each species for each type of grassland and the number of species (frequency) falling into each class of biomass (Table 1), only a few species were contributing to the bulk of herbage production. In the annual grassland, 81% of the species appeared to have a herbage production of 0 to 5 g DM m^{-2}, while only one species provided a yield of 40.85 g DM m^{-2}. In the perennial grassland, the differences observed between the species average production were even greater. Here, 91% of the species fell into the first class (0-5 g DM m^{-2}), while two of them exhibited a production of 49.80 and 43.65 g DM m^{-2} respectively. Zarovali *et al.* (2004a) report that the group of grasses in the same grasslands comprised 51% of the production in the annual grassland, while the group of perennial C4 grasses constituted 61% of the biomass production in the perennial grassland. These results indicate that a sampling effect (Tilman *et al.*, 1997) or a selection effect (Loreau, 1998; 2000) is probably involved in the relationship between species richness and herbage production. Furthermore, they indicate that as Mediterranean grasslands evolve from temporary (annual) to permanent (perennial) plant communities they become more species-rich and at the same time more heterogeneous in terms of the contribution to biomass of the constituent species.

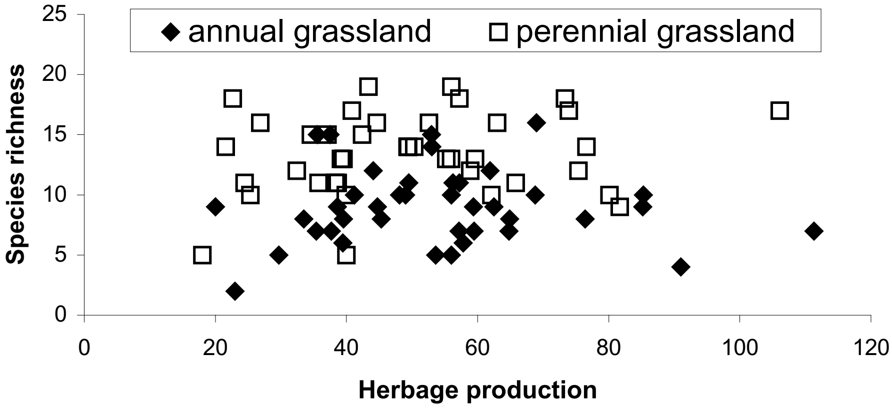

Figure 1. Relationship between species richness and herbage production (g DM 0.25m^{-2}) in the two types of grasslands

Table 1. Frequency distribution of the average biomass production (g DM m^{-2}) of the species in the two grasslands

Classes of live biomass	Annual grassland		Perennial grassland	
	no of species	percentage	no of species	percentage
0–5	42	80.77	52	91.23
5–10	6	11.54	3	5.27
10–15	2	3.85	0	0.00
15–20	1	1.92	0	0.00
40–45	1	1.92	1	1.75
45–50	0	0.00	1	1.75
Total	52	100	57	100

Conclusion

In both types of grasslands studied, annual and perennial, no significant relationship was found between species richness and productivity, while only a few species contributed to the bulk of herbage production. It seems that as Mediterranean grasslands evolve from annual to perennial plant communities they become more species-rich and at the same time more heterogeneous in terms of the contribution to biomass of the constituent species.

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Investigation of some factors accelerating formation of protein-rich yield of legume/grass swards from the sowing year

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Abstract

A whole complex of factors and their interactions influence the potential of legumes, which is greatly dependent on legume species, successful establishment and management. The aim of the experiment was to determine yield formation intensity from the sowing year onwards. Legume/grass mixtures were sown with and without a cover crop of barley, peas for whole crop or barley for grain. Red clover and lucerne were sown in the binary mixtures with perennial ryegrass, and ryegrass sown as a monoculture and either fertilised with nitrogen or not. Lucerne /grass sward sown with a cover crop of peas for whole crop produced the highest protein (CP) yield in the sowing year and for the total two years' yield. The lucerne/grass sward grown without a cover crop was more productive in the second year than in the sowing year. The lowest 2-year protein yield was produced by lucerne/grass sown with barley for whole crop. Red clover/grass swards generally produced a lower dry matter and especially protein yield compared with analogous lucerne/grass swards. In most cases legume/grass swards produced earlier and higher yield than pure grass swards which were fertilised with 60 and 180 kg nitrogen ha^{-1} in the sowing and the next year, respectively.

Keywords: red clover, lucerne, yield, protein, cover crop

Introduction

Red clover, lucerne and other perennial legumes play an important role in grassland husbandry as a major source of protein-rich forage and as a basis for crop rotations in organic farming (Younie, 2000; Wilkins and Vidrih, 2000). Perennial legumes are usually sown with a cover crop of barley for grain, but the development of legumes in that case can be impeded (Kadziulis *et al*., 1995). The stand density and yield of legumes are particularly dependent on the conditions of establishment on more acid soils (Daugeliene, 2002). In less favourable conditions legumes are sown without a cover crop or with an oats-vetch mixture (Petraityte *et al*., 1990) or with peas for green forage (Vasilev and Kertikov, 2003). The growing of perennial grasses instead of legumes needs heavy nitrogen fertiliser rates to ensure high yields (Kadziulis and Kadziuliene, 2000). The aim of our experiment was to determine the feasibility of accelerating the formation of protein-rich yield in the sowing year by the use of appropriate combinations of perennial legumes and their cover crops.

Materials and Methods

Field studies were conducted on a loamy *Endocalcari-Epihypogleyic Cambisol* in Dotnuva (55^{o} 24' N). Soil pH varied between 6.5–7.0, humus content was 2.5–4.0 per cent, available P 50–80 mg kg^{-1} and K 100–150 mg kg^{-1}. Legume/grass mixtures were sown with and without a cover crop of barley (*Hordeum vulgare* L.) or peas (*Pisum sativum* L.) for whole crop or of barley for grain. Red clover (*Trifolium pratense* L.) and lucerne (*Medicago sativa* L.) were sown in mixtures with perennial ryegrass (*Lolium perenne* L.), and ryegrass also sown as a monoculture and either fertilised with N or not. The layout was a randomised block design with four replicates, and plot size of 2.5×13 m, P and K were applied according to the need based on soil analysis. The yields of swards were taken at flowering stage of the legumes. The swards were cut twice per year in the first year. Peas were cut at the wax and grain 'greasy' stage for silage, respectively and for one treatment – barley for grain – at complete ripeness stage. Nitrogen in the dry matter (DM) was determined by the Kjeldahl method. The yield data were statistically processed using analysis of variance.

Results

The total two years' and especially sowing year's DM yield were highly dependent on sward composition (Table 1). The highest annual DM yields in the sowing year were obtained from red clover/grass swards sown with barley for whole crop or grain and lucerne/grass with peas.

Table 1. Impact of sward composition and sowing method on yield over two years, kg DM ha^{-1}

Treatments: sward+ cover crop[a]	Sowing year 2003			2nd year of use 2004			Total per 2 years
	1st cut	2nd cut	annual	1st cut	2nd cut	annual	
Rcl+Pr	2065	802	2867	3265	2784	6049	8916
Rcl+Pr+Bgr	4880	586	5466	2808	2790	5598	11064
Rcl+Pr+Bwc	5703	297	6000	3166	2700	5866	11866
Rcl+Pr+Pwc	4293	497	4790	3521	2188	5709	10499
Lc+Pr	2979	1066	4045	5496	3695	9191	13236
Lc+Pr+Bwc	6227	488	4715	4572	2892	7464	12179
Lc+Pr+Pwc	4270	1059	5329	5558	3521	9079	14408
Pr N_{60+180}	1394	788	2182	6218	2209	8427	10609
Pr N_0	1439	586	2025	2436	411	2847	4872
$LSD_{0.05}$	815.3	161.5	857.7	710.0	572.8	918.9	1257.0

Rcl – red clover, Lc – lucerne, Pr – perennial ryegrass, [a]Bgr – barley for grain, Bwc – barley for whole crop, Pwc – peas for whole crop.

Lucerne/grass and especially grass or red clover/grass swards sown without a cover crop were considerably less productive. The positive impact of cover crop was very important for the next year's DM yield of lucerne/grass but markedly less so for red clover/grass yield. The lucerne/grass sward was most productive when sown without a cover crop or with peas harvested as a whole crop. Thus, lucerne/grass swards, for all sown combinations over two years of use produced more DM than red clover/grass swards and much more than perennial grass sown alone.

The structure of DM yield in the sowing year varied to a great extent (Figure 1). The cover crop yield exceeded 70–90 per cent of annual yield and only lucerne dominated in the swards sown without a cover crop. A significant share of lucerne was also identified in the yield of the sward sown with peas for whole crop. The higher the legume share was in the total yield, the higher the crude protein (CP) yield was. Figure 2 shows a rather strong correlation between them. The protein yield data do not correspond fully with DM yield and with the amount of metabolizable energy (Table 2). The CP yield in sowing year depended firstly on cover crop and secondly on the perennial legume sown with cover crop.

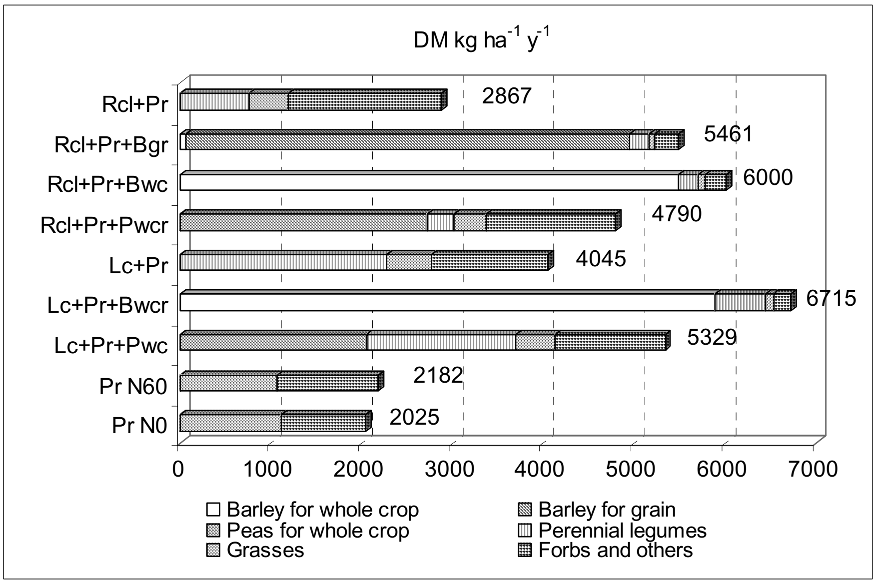

Figure 1. Dry matter yield structure in the sowing year

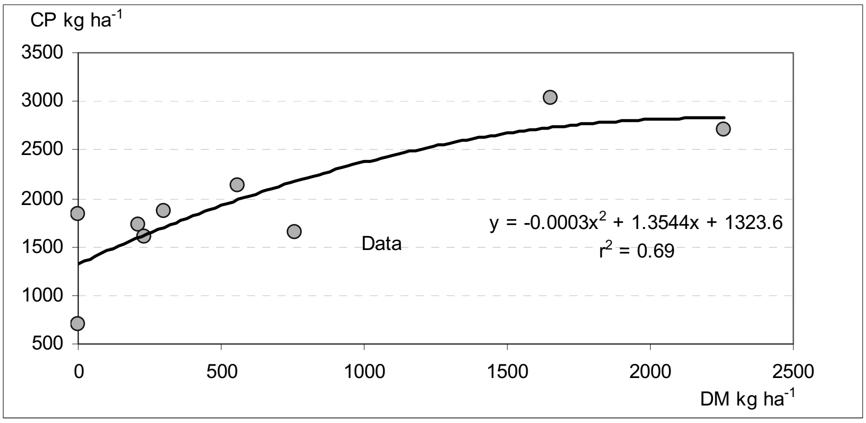

Figure 2. The impact of DM yield of legumes in the sowing year on the amount of CP per two years of use

Peas harvested for whole crop yielded more CP than barley for grain or whole crop. The highest amount of CP in the sowing year was produced by the lucerne/grass sward with a cover crop of peas, and somewhat less by the red clover/grass sward with peas or lucerne/grass sward without a cover crop. CP yield in the next year was by 1.5–3 times higher, the highest in the same lucerne-based swards as in the sowing year, considerably less in the red clover-based swards and in the perennial ryegrass sward fertilised with 180 kg N ha^{-1}. Lucerne-based sward exceeded significantly all other swards by total CP yield over two years of use. Metabolizable energy amount (GJ ha^{-1}) corresponds closely with DM yields but there are some variations in rating of treatments in the sowing year.

Table 2. Crude protein (CP) yield and the amount of metabolizable energy (ME) in the sowing (2003) year and the second year (2004) of swards use

Treatments: sward+ cover crop[a]	Sowing year 2003				2nd year of use 2004		Total per 2 years	
	CP kg ha^{-1}			ME GJ ha^{-1} y^{-1}	CP kg $ha^{-1}y^{-1}$	ME GJ $ha^{-1}y^{-1}$	CP kg ha^{-1}	ME GJ ha^{-1}
	1st cut	2nd cut	annual					
Rcl+Pr	363	146	509	29.5	1149	63.5	1658	93.0
Rcl+Pr+Bgr	585	85	670	54.8	1064	58.8	1734	113.6
Rcl+Pr+Bwc	434	61	495	51.2	1115	61.6	1610	112.7
Rcl+Pr+Pwc	695	91	786	48.4	1085	59.9	1871	108.3
Lc+Pr	529	226	755	41.7	1958	95.6	2713	137.3
Lc+Pr+Bwc	417	120	537	57.0	1590	77.6	2127	134.6
Lc+Pr+Pwc	701	225	925	55.1	2104	94.4	3029	149.5
Pr N_{60+180}	194	139	333	21.2	1508	83.4	1841	104.6
Pr N_0	233	79	312	20.0	387	27.9	699	47.9
$LSD_{0.05}$	95.6	28.6	105.0	8.38	183.5	9.56	211.4	12.48

Rcl – red clover, Lc – lucerne, Pr – perennial ryegrass, [a] Bgr – barley for grain, Bwc – barley for whole crop, Pwc – peas for whole crop.

Discussion

We expected to get earlier and higher protein-rich DM yield in some of the new treatments included in the experiment. The lucerne/grass seed mixtures sown with a cover crop of peas for whole crop fulfilled this expectation. The CP yield was the highest beginning with the first cut for forage in the sowing year and finishing with the last cut in the following summer. Among red clover/grass swards sowing with a cover crop of peas also was the best. It should be noted that the peas seed rate was 0.6 million seed ha^{-1}.

Cover crop barley for grain (yield 4880 kg ha^{-1}) caused some decrease in red clover/grass DM and especially CP yield in the second year of use. CP yield in lucerne/grass swards depended more on cover crop than in red clover/grass swards because of lucerne's higher sensitiveness to light deficiency.

Conclusions

The lucerne/perennial grass sward with a cover crop of peas for whole crop produced the highest protein-rich yield in the sowing year and total two years' yield. The yield of red clover/grass swards was lower than that of lucerne/grass swards but it was less dependent on the cover crop. Lucerne/grass and red clover/grass swards sown with a cover crop of peas for whole crop formed earlier protein-rich yield than those sown with barley or perennial ryegrass even with nitrogen application.

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Fodder galega seed harvesting time and changes in seed quality during storage

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Abstract

Fodder galega (*Galega orientalis* Lam.) is a valuable long-lived legume well suited to extensive grassland farming. Nevertheless, little research has been done on its cultivation compared with clover or lucerne. Research on fodder galega cultivation for seed is even scarcer. As a result, our experimental objectives were as follows: 1) to identify fodder galega optimal seed harvesting time and method; 2) to study changes in seed germination during storage. Seed harvesting was studied over four years in terms of the seed production crop from the first till fourth year of use. Fodder galega seed was harvested using two methods after 60%, 80% and 90% of pods had matured and 14 days after the last term. In 1999 the harvested seed was placed for storage. Seed quality changes were studied for five years, storing the seed in a heated and unheated storage in paper bags. The highest seed yield was obtained when fodder galega was harvested using direct combine harvesting with prior defoliation, when 90% of pods had matured. In drier weather the seed can be harvested using the swath harvesting method. Due to the low seed shattering it is not expedient to hasten fodder galega harvesting, and is better to await more favourable weather conditions or change harvesting method. After five years in a heated storage, seed germination changed little (82–89%), but in an unheated storage seed germination declined to 19–40%. In an unheated storage the seed was best preserved when completely mature. A conclusion can be made that in an unheated storage in paper bags the seed can be securely stored for only two years.

Keywords: *Galega orientalis,* seed yield, harvesting time, seed storage

Introduction

In Lithuania the total area with perennial grasses was 1.16 million hectares in 2004. The most important legumes are white clover, red clover and lucerne, which are commonly grown with grasses. Farmers are looking for new legumes, characterised by longevity and a high adaptability to growing conditions. Fodder galega (*Galega orientalis* Lam.) is one of the longest persisting plants in swards, which is capable of fixing atmospheric nitrogen and notable for a high productivity (Virkajarvi and Varis, 1991; Raig, 1994; Adamovich, 2000.Attempts have been made to grow fodder galega on extensively used or conserved soils, old quarries and fully extracted peatbogs. Fodder galega cultivation protects the soil from erosion and prevents the spread of weeds. (Vavilov and Kondratjev, 1975). Galega can be grown on various soils if they are not acid and waterlogged. According to soil requirements, fodder galega is similar to lucerne and sainfoin, but can produce very high yields. Experimental data show that this long – lived plant survives in pure stand for 15–19 years (Drikis, 1995; Adamovich, 2000). Fodder galega has some disadvantages, such as very slow development in the sowing year and in the first year of use and sensitivity to frequent cutting or grazing (Raig, 1994; Lillak and Laidna, 1999). Compared with other legumes (clover, lucerne) little research has been done on its cultivation. Research evidence on fodder galega cultivation for seed is even scarcer. During the recent years the demand for galega seed has been on a steady increased. However, the amounts produced still cannot meet the demand and as a result, it is very important to increase galega seed yield. The experimental objectives were as follows: 1) to identify fodder galega optimal seed harvesting time and method; 2) to study changes in seed germination during storage.

Materials and Methods

Experiments were carried out during 1996–2004. Four field experiments were carried out on a sod gleyic loam soil (Epicalcari – Endohypogleic Cambisol in the central part of Lithuania (55°23' N, 23°51' E). The soil contained on average 2.63% of humus, 0.17N, 104 mg $kg^{-1}$of P, 125mg kg^{-1} of K and pH 7.0. Fodder galega (cv. 'Gale') was sown at a seed rate of 10 kg ha^{-1} and at row spacing of 23 cm with a cover crop of spring barley. The experiment was designed as a randomized complete block with 4 replications and a plot size of 2.5m × 14.0m. Seed harvesting was investigated over four years in a fodder galega seed production crop from the first till fourth year of use. Fodder galega seed was harvested using swath and direct combine harvesting after 60±5%, 80±5% and 90±5% of pods had matured and 14 days after the last term (90% matured pods). The analysis of galega pods maturity was made twice a week starting with the fifth – sixth week from the beginning of flowering. For this purpose, 4–6 samples from each $0.25m^2$ plot were cut from representative places of the stand. The pods picked from a stem were divided into 4 groups of maturity: green, yellowish – green, yellow – semibrown and dark brown. Seed harvesting time was determined according to the number of brown and yellow – semibrown pods, expressed in per cent. Prior to direct harvesting fodder galega crops defoliated using 5 l ha^{-1} Reglon. The crop was thrashed by a combine Sampo 500 after 5-7 days. Fodder galega cut into thin swaths was dried on 20-30 cm high stubble for the same number of days and then it was thrashed by a combine. The seed was dried, cleaned and seed quality was estimated. Seed yield data were corrected to 100% purity and 13% moisture content. In 1999 the seed was left for quality testing. The seed was stored for 5 years in different conditions in 1kg paper bags in two different places, in a winter-heated room and unheated wooden storage at a relative air humidity varying from 35% to 85%.

Results and Discussion

Fodder galega crop flowered for 24–48 days irrespective of the weather conditions. Due to the lengthy flowering, seed ripening was uneven. Even when most of the pods had turned brown, part of pods were still green, underdeveloped, and part of the inflorescences were still flowering. Having marked individual inflorescences, seed quality was determined among the groups of various ripeness for the treatments harvested by different methods (Table 1). When fodder galega pods were green, the seed harvested by different methods were still underdeveloped, 1000 seed weight amounted to 4.11–5.31g. Seed germination was low 52–72% and did not meet the standard. In more mature yellow or semibrown pods the seed had reached the weight maximum and the germination still had a tendency to increase. The quality of the seed of this pod maturity group was similar to the quality of fully ripe seed. Consequently, harvesting time of fodder galega seed crop can be determined according to the content of yellow and brown pods.

Fodder galega seed yield is generally higher than that of other legumes and depends on the age of the crop and the weather conditions (Vavilov and Kondratjev, 1975; Raig, 1994). During our experimental period the highest rate of precipitation fell in 1998. The driest growing season occurred in 1999. The lowest seed yield was produced by fodder galega in the first year of use (Table 2). Due to the drought and frosts in May the seed yield in the fourth year of use declined more than twice compared with the seed yield in the second and third year of use. Averaged data from four years indicate that the highest seed yield 521 kg ha^{-1} was obtained when fodder galega was direct-harvested after 90% of pods had ripened. The approximate harvesting dates ranged between 30 July (1999) – 20 August (1996). Comparison of swath harvesting and direct harvesting involving defoliation shows that for two years significantly higher seed yield was obtained in the direct harvesting treatment. In the other two years the seed yield was similar for both harvesting methods. When the seed was harvested without defoliation the seed yields obtained were significantly lower. Only in very dry year 1999 the seed yields were similar for both direct harvesting with prior application of the defoliant reglon and for seed harvesting without defoliation. Most researchers consider direct harvesting method as the best technique and recommend harvesting fodder galega after 70–80% pods had matured (Vavilov and Kondratjev, 1975; Spruogis, 1999). Early harvesting of fodder galega when 60% of pods had ripened was not justified. Lower seed yields were obtained in all years of use. A two-week delay in harvesting resulted in a seed yield reduction, however, this decline was not significant every year.

Table 1. Fodder galega seed quality of different maturation and harvested by different methods (Mean of 1996–1999)

Harvesting method	Green pods, green seed		Yellowing-green pods, green seed		Yellow pods, light yellow seed		Brown pods, yellow seed	
	1000 seed weight, g	germi-nation, %	1000 seed weight, g	germi-nation, %	1000 seed weight, g	germi-nation, %	1000 seed weight, g	germi-nation, %
Swath	4.11	62	6.32	81	7.19	87	6.70	90
Direct after defoliation	4.24	52	6.02	81	6.89	82	6.88	92
Direct without defoliation	5.31	72	7.10	88	6.95	82	6.69	89
$LSD_{0.05}$	1.01	29	0.54	5	0.54	8	0.46	6

Table 2. Fodder galega seed yield, harvested by different methods and at different times

Method of harvesting	Matured pods, %	Seed yield kg ha^{-1} 1996	1997	1998	1999	Average
Swath	60±5	107	532	493	184	329
Swath	80±5	144	643	703	239	432
Direct	80±5	187	639	748	272	462
Swath	90±5	192	737	728	282	485
Direct	90±5	235	758	775	315	521
Direct[×]	90±5	183	662	685	316	462
Swath[a]		177	650	714	272	453
Direct [a]		202	655	709	315	470
Direct[a×]		168	603	673	332	444
$LSD_{0.05}$		14	56	80	33	26

a – harvesting 14 days after last term (90% matured pods); × – direct harvesting without defoliation

Consequently, fodder galega harvesting should not be hastened and one can await better weather conditions. In drier weather one can use swath harvesting, while in wetter years one should use direct harvesting with prior defoliation of the crop. Seed germination when the crop was harvested at the earliest dates only in 1996 did not meet the standard (80%). In 1999 germination of the seed that was placed for a five-year storage period amounted to 92–98% (Table 3).

Table 3. Variation of fodder galega seed germination (%) harvested in 1999 and stored in a heated (ht) and in an unheated (un) storage over five years

Method of harvesting	Matured pods %	1999	Germination %							
			2001		2002		2003		2004	
			ht	un	ht	un	ht	un	ht	un
Swath	60±5	95	84	86	91	49	79	32	82	22
Swath	80±5	96	89	81	90	62	77	29	86	29
Direct	80±5	95	86	85	84	60	87	30	84	19
Swath	90±5	98	88	83	91	64	78	38	87	33
Direct	90±5	95	89	84	91	59	78	27	86	40
Direct[×]	90±5	97	91	86	92	64	81	41	85	37
Swath[a]		95	93	89	89	55	74	36	85	31
Direct[a]		92	91	82	82	53	78	23	89	23
Direct[a×]		95	89	87	87	59	76	31	86	22
For trial $LSD_{0.05}$		3	8		7		8		7	
Mean		95	89	85	89	58	79	32	86	29
For storage $LSD_{0.05}$		3	3		2		3		2	

a – harvesting 14 days after last term (90% matured pods); × – direct harvesting without defoliation

The average content of hard-husked seed was 26%, seed moisture 8.5–9.6%. A large significant decline (up to 49–64%) in the germination of the seed stored in the unheated storage occurred in the third year of storage, whereas in the heated storage the seed germination varied, though not significantly, totalling 84–91%. In the fifth storage year in the unheated storage better germination was exhibited by the seed harvested when matured pods accounted for 90%. The germination of seed stored in the heated room did not differ appreciably and met the standard.

Conclusions

The best seed harvesting time of fodder galega is when 90% of pods have ripened. Due to the strong attachment of pods to stems it is not expedient to hasten harvesting. Harvesting time and method can be chosen subject to the weather conditions. In rainy weather it is better to use direct harvesting with a prior defoliation. The seed kept in an unheated room in a paper bag can be stored for two years. After three years of storage seed germination dramatically declines and does not meet the standard.

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Accumulation of flora occurring on the molds in the Malopolska region in relation to the soil moisture levels

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Abstract

Market economy has developed during the last fifteen years in Poland. Over this period fallow lands have become a substantial problem in agriculture. Statistical data suggest that in the years 1996–2002 their percentage share of the agricultural area increased from 6.6 to 11.9%. Hence, the investigations reported here were conducted in 64 ha of abandoned grassland of formerly State Ruled Agricultural Area in Polanowice near Cracow (altitude of 220 m). It was shown that within the study area, water is the main factor influencing the formation of meadow flora. Waterlogged, and periodically wet as well as optimally wet stands were selected. *Carex acutiformis* Ehrh. and *Carex gracilis* Curt. were characteristic of the waterlogged stands, *Holcus lanatus* L., *Polygonum bistorta* L., *Scirpus silvaticus* as well as *Deschampsia caespitosa* L. – of the periodically wet and *Alopecurus pratensis* L., *Poa pratensis* L. and *Festuca rubra* L. type flora of the optimally wet areas.

Keywords: stand, soil, waterlogged, floral accumulation, meadow

Introduction

The high level of water in the soil inhibits and even prevents hay harvesting. Experimental treatments are also difficult under such conditions. Flora of lower forage value occurs in meadows with unregulated soil water levels (Dembek, 1993; Dzwonko and Loster 1990). This flora has low amounts of nutrients and because of its taste, is reluctantly eaten by grazing animals (Dobromilski and Kwarta, 1993; Zastawny, 1992). For example, *Holcus lanatus* L. is characteristic of the wet meadows and is avoided by the animals in the pasture. Occasionally after its consumption in hay, some diseases can occur in livestock as a result of the formation of tight balls in the alimentary canal (Filipek *et al*., 1993). Characteristics of the floral accumulations as well as the composition and characteristics of the soil are presented here on the basis of the results obtained from the meadows in Polanowice and Skrzeszowice regions.

Some agri-environmental programs exist which encourage extensive utilization of meadows with subsidies. Many should take advantage of this economic aid. The meadows investigated in this study should be only cut to avoid being overgrown by bushes and trees. Waterlogged areas or peat-bogs store huge amounts of water during floods and give it back during droughts. Therefore maintenance of the natural character as well as function of waterlogged areas, which are dwindling ecosystems, is a problem concerning not only one country but the whole world.

The aim of the study was to compare floral accumulations in relation to the moisture levels in the soil.

Materials and Methods

The investigations were carried out in a meadow of formerly State Ruled Agricultural Area in Polanowice near Cracow (altitude of 220 m) which had been fallow. In the 1970s some amelioration works were done in the study area in order to regulate agricultural water connections. As a result of inaccurate reconnoitring of the soil conditions and defective amelioration works, drought occurred in one part while flooding took place in the other. Furthermore the worsening economic situation within agriculture influenced the condition of the meadow. Within the often uncut, occasionally grazed meadows and without any melioration works, fertilization or other treatments, characteristic floral assemblages formed (Matuszkiewicz, 1984). The annual rainfall during the investigated period (2001–2003) fluctuated from 404 to 745 mm. Whereas the average rainfall for the six months (April to September) ranged between 270–556 mm. Average annual temperatures during the investigation period varied from 6.3 to 7.4 ºC and in the growing season from 12.2 to 13.5 ºC.

The object of the study was a meadow of 64 ha area located along the amelioration ditch of a length of about 6 km. In the spring they are partly flooded; water stays at the surface for a short time whereas the soil water level is quite high during the whole growing season. Utilization of these meadows ceased 7 years ago. Between 2001–2004, the floral composition of the sward was determined using the 10-scale Klapp method to gain a representative sample of the area. Twenty-four photographs of the flora were taken from places characteristic of particular soils with respect to their moisture level. For certain assemblages, soil samples in four replicates were collected in order to estimate pH level, organic matter, total nitrogen and content of assimilable macroelements – employing the methods commonly used in soil science. Presentation of the results is limited to the most typical floral assemblages found in the study area.

Results and Discussion

An increase in fallow areas in Poland is associated with a dramatic decrease in the animal population, which is much smaller than in the late 80s. The balanced rural or ecological plans which have been implemented concerning the maintenance of extensive and swamp meadows seem to be appropriate and farmers need to be encouraged to take an advantage of them. Care of the natural environment is also of great importance in Poland.

After cutting stopped, the meadow was exposed to the excessive growth of weeds, especially low-value dicotyledonous species (Dobromilski and Kwarta, 1993). The soils were classified as degraded molds made from loess. The chemical composition of the soil is presented in Table 1. The moisture level is optimal for 27% of the area whereas 73% is too wet. Under conditions of high soil water levels *Carex acutiformis* Ehrh. and *Carex gracilis* Curt. (Table 2) are the dominant species in the sward. Their frequency in the botanical composition fluctuates from 20 to 24%. In the *Carex acutiformis* Ehrh. assemblage, there were large amounts of *Holcus lanatus* L., *Poa trivialis* L., *Agrostis alba* L., *Festuca rubra* L. and *Deschampsia caespitosa* L. Other species were of lesser importance. On the other hand, in the *Carex gratilis* Curt. accumulation *Festuca pratensis* Huds. and *Poa trivialis* L. were the dominant grass species. However, *Equisetum palustra* and *Carex riparia* were also present in substantial amounts.

In temporarily swamped stands, *Holcus lanatus* L., *Polygonum bistorta* L., *Scirpus silvaticus* L. and *Deschampsia caespitosa* L. occur. In stands of optimal moisture levels, the *Alopecurus pratensis* L., *Poa pratensis* L and *Festuca rubra* L. type flora appears (Table 3). In the study meadows, groups of rushes e.g. *Phragmites communis* Trin. and *Phalaris arundinacea* L. also occured. The botanical composition of such accumulations is very simplified.

Table 1. Results of chemical analysis of the soil

Accumulations with	pH in H_2O	pH in 1mol KCl dm^{-3}	Content [g kg^{-1} soil]		Assimilable [mg kg^{-1} soil]		
			Org. matter	Total N	P	K	Mg
Alopecurus pratensis L.	6.53	6.03	32.0	4.33	521	319	178
Poa pratensis L	6.11	5.73	29.9	3.86	483	287	112
Festuca rubra L.	6.10	5.75	25.8	3.08	468	254	108
Carex gracilis Curt.	6.15	5.88	11.8	1.83	354	123	85
Carex acutiformis Ehrh.	6.13	5.82	11.7	1.71	335	148	88
Phragmites communis Trin.	6.25	5.78	11.5	0.94	277	72	74

Table 2. Floral accumulations under waterlogged conditions (%)

Species	Accumulations with	
	Carex acutiformis (4)*	*Carex gracilis* (5)
Holcus lanatus L.	3	8
Poa trivialis L.	5	8
Agrostis alba L.	1	7
Festuca rubra L.	3	7
Deschampsia caespitosa L.	3	5
Calamagostris canescens Wet.	–	2
Avenastrum pubescens Huds.	–	1
Festuca pratensis Huds.	7	1
Poa palustris L.	1	1
Carex gracilis Curt.	8	20
Carex acutiformis E.	24	8
Carex caespitosa L.	6	7
Carex riparia Curt.	7	–
Trifolium hybridum L.	2	+
Lotus uliginosus Schk.	4	4
Lathyrus paluster L.	+	–
Equisetum palustre L.	8	4
Ranunculus repens L.	5	6
Geum rivale L.	3	2
Polygonum bistorta L.	4	3
Rumex acetosa L.	2	3
Cirsium oleraceum Scop.	3	2

* number of photographs

They are places of longterm, and even annual deep surface overflows derived from the outflows of the soil water and from the surface flows. According to Okruszko (2000) such conditions result in soil rotting which has indications of widely implied degradation.

Table 3. Floral accumulations under optimal moisture conditions (%)

Species	Accumulations with		
	Alopec. pratensis (5)	*Poa pratensis* (5)	*Festuca rubra* (5)
Alopecurus pratensis L.	70	–	–
Glyceria aquatica L.	7	–	–
Phalaris arundinacea L.	6	–	–
Poa palustris L.	5	1	1
Poa pratensis L.	5	24	2
Poa trivialis L.	4	8	1
Deschampsia caespitosa L.	1	5	–
Agrostis stolonifera L.	+	–	–
Agropyron repens L.	+	–	–
Agrostis alba L.	–	1	1
Agrostis vulgaris With.	–	–	5
Arrhenatherum elatius L.	–	–	1
Cynosurus cristatis L.	–	–	4
Dactylis glomerata L.	–	6	3
Festuca rubra L.	–	4	32
Festuca pratensis Huds.	–	3	–
Holcus lanatus L.	–	2	–
Phleum pratense L.	–	2	2
Lotus corniculatus L.	–	1	–
Trifolium hybridum L.	–	3	–
Trifolium pratense L.	–	4	2
Trifolium repens L.	–	2	2
Plantago lanceolata L.	–	11	5
Ranunculus acer L.	+	–	–
Rumex acetosa L.	+	3	–
Ranunculus repens L.	+	6	3
Taraxacum officinale Web.	+	–	–
Achillea millefolium L.	–	–	4
Cirsium oleraceum Scop.	–	4	–
Cerastum vulgatum L.	–	–	2
Equisetum palustre L.	–	4	–
Galium verum L.	–	–	8
Geum rivale L.	–	2	3
Lychnis flos-cuculi L.	–	2	3
Mentha arvensis L.	–	–	2
Pastinaca sativa L.	–	–	5
Potentilia anserina L.	–	–	7

Conclusions

The water connection system was the main factor affecting floral assemblages in the meadow. In the waterlogged stands, except the grasses of small nutrition value, it is the sedge type flora which mainly occurs. In the temporarily swamped stands, sedges are accompanied by horsetails and bullrushes.

Results of the study suggest that the investigated meadows need to be extensively utilized. The question is, whether it is worth reverting these meadows to their previous state. If yes, a decision needs to be made on how to limit expected costs. Additional financial support to farmers maintaining waterlogged areas seems to make sense. It can be supported by the fact that uncut meadows overgrow first with reed and then with bushes and trees i.e. alder and birch.

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Yielding of permanent meadows under the influence of fertilization accepted as organic

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Abstract

Mineral fertilization (NPK) was compared with the application of manure, the preparation Bio-algeen S-90 and oversowing with red clover on permanent meadows in 2001–2003. All these treatments significantly increased hay yield, however the yield significantly similar to mineral fertilized meadow (at a rate comparable to the mineral fertilizer) was achieved only by using the combination of manure (20 t ha^{-1}), Bio-algeen S-90 and oversowing with red clover (Trifolium pratense). Therefore, achievement of high yields of hay from meadows in organic farms is possible, but it requires more knowledge than currently exists for mineral fertilization.

Keywords: permanent meadows, NPK, bovine manure, Trifolium pratense, Bio-algeen S-90, yield

Introduction

Application of fertilizers is still a widely discussed issue and is associated with fodder production, plus the economy, i.e. development of grasslands and in holistic agriculture. New farming systems require fertilization recommendations based on experiments. Money (1993) reported that due to people's economic activity, including production of artificial fertilizers, man disturbs nitrogen cycling in nature. Wilkins (1996) focused on the necessity of a thoughtful application of mineral fertilizers in relation to developing rules for environment protection.

Organic and integrated agriculture is developing in Europe and Poland (Szymona, Sawicki, 2001), thus special attention should be paid to the nutrient potential of papilionaceous plants and of organic fertilizers. Besides, new fertilizing products considered as permissible for organic agriculture appear on market, but there are no numerous experimental results that would confirm their properties.

Therefore, the aim of present paper is to evaluate the effects on production of permanent meadow as a result of fertilization with bovine manure, with application of papilionaceous plants and with preparation Bio-algeen S-90 in comparison to mineral fertilization.

Materials and Methods

The experiment was set up by randomized blocks of treatments in four replications on permanent meadow in the Wieprz river valley near Kock. Plots were 4 × 5 m dimensions. The meadow was situated on chernozem soil. Eight fertilization levels (Table 1) were applied in the experiment. Mineral fertilizers were applied in form of: ammonium nitrate 34%, granulated superphosphate 46%, potassium salt 50%. Bovine manure contained 0.53% N, 0.31% P_2O_5 and 0.62% K_2O, on average. The phosphoros fertilizer was sown once, the nitrogen for the 1st (60 kg ha^{-1}) and 2nd cut (40 kg ha^{-1}), and the potassium for both the 1st and 2nd cuts. Manure was applied in spring and the mineral fertilizer rates were adjusted to NPK levels in the manure. The fertilization was made in 2001–2003, but the oversowing with red clover (Trifolium pratense) was carried out at the end of August 2000 at a seed rate of (10 kg ha^{-1}). Preparation Bio-algeen S-90, accepted in organic agriculture by the European Union, was also applied in the experiment. It is a liquid substance containing 7% of dry matter, including 3.5% of organic matter (amino acids, vitamins, enzymes, monosaccharides and polysaccharides, lipids). It also contains (240 mg N kg^{-1}, 60 mg P_2O_5 kg^{-1}, 950 mg K_2O kg^{-1}, and small amounts of B, Fe and Zn. The producer informs us that it increases forage yields and improves the soil fertility through mobilization of nutrients for plants (it easily forms mineral-organic complexes). In the present experiment, the preparation was applied twice by spraying at a 1.8 l ha^{-1} rate onto the grass for every cut.

Table 1. Hay yields from the meadow in Wieprz river valley near Kock (t DM ha^{-1}) and yield increase (%)

Symbol	Fertilization: mineral (kg ha^{-1}), manure (t ha^{-1}), Bio-algeen (l ha^{-1})	Years			Mean for 2001–2003	Mean increase of yield in 2001–2003 (%)			
		2001	2002	2003		annual mean	1st cut	2nd cut	3rd cut
A	0	5.21	4.03	3.40	4.21	0	0	0	0
B	N 100, P_2O_5 60, K_2O 120	10.14	9.22	8.83	9.40	123	167	108	51
C	Bovine manure	8.46	7.81	7.25	7.84	86	106	62	34
D	Oversowing with	6.84	5.73	4.73	5.77	37	54	29	18
E	*Trifolium pratense*	5.81	5.24	4.31	5.12	22	38	18	11
F	Bio-algeen S-90 *	9.28	8.52	7.88	8.56	103	124	89	25
G	C + D	8.96	8.67	7.71	8.45	101	131	81	17
H	C + E	9.47	9.57	8.45	9.16	118	136	92	46
	C + D + E								
	Means	8.02	7.35	6.57	7.31	–	–	–	–
	LSD ($\alpha \leq 0.05$): fertilization – 0.62, years – 0.46								

* 1.8 l ha^{-1} (600 l of water).

The upper layer of meadow soil taken in 2000 analysed at: pH 5.8, N-total – 0.293 mg, P_2O_5 – 9.6 mg and K_2O – 2.8 mg per 100 g of soil (available forms). Subsequent years of study (2001–2003) should be considered as extremely warm with mean annual temperatures at the levels of 8.0 °C, 9.1 °C and 8.2 °C, respectively and mean annual for 1981–1995 of 7.4 °C. When comparing the annual rainfall for the 1981–1995 period (535 mm average), the 2001 year should be considered as extremely wet (748 mm), the 2002 year as medium (593 mm) and the 2003 year as dry (468 mm). August drought was present in 2002 and 2003. Three hay harvests per annum were taken during the study years: 1st cut – beginning of June, 2nd cut – end of July, and the 3rd cut – beginning of October.

Two-variable variance analysis and multiple Tukey's intersections were utilized for statistical computations.

Results and Discussion

Regardless of the experimental factors, 7.31 t ha^{-1} of hay on average was harvested annually during 2001–2003 (Table 1).

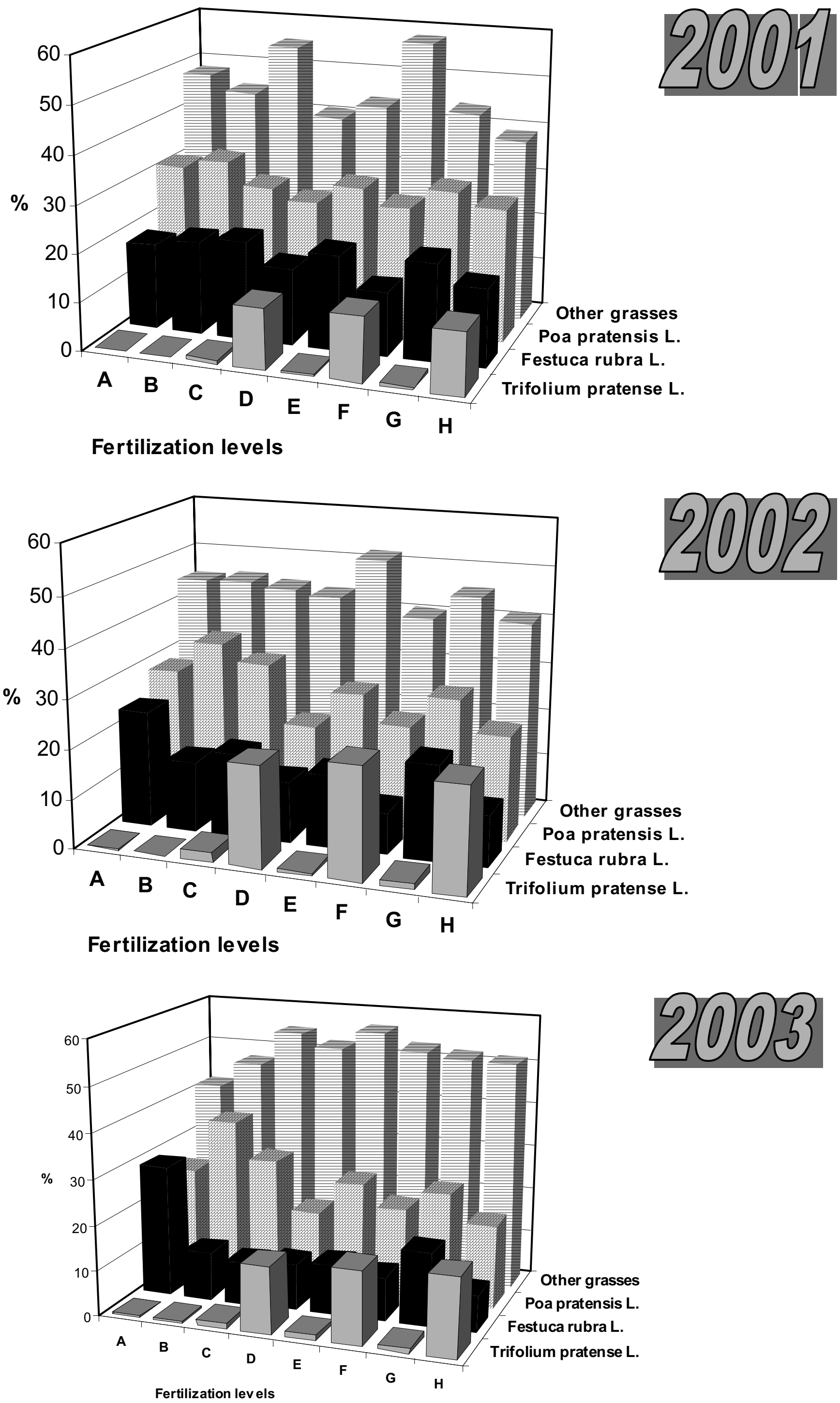

Figure 1. Botanical composition of meadow sward depending on year of study and fertilization levels

The highest average yields were from meadow fertilized with NPK, and from meadow with manure application, plus oversowing with clover plus Bio-algeen S-90 spraying, yields being not significantly different. Manure application, comparable to mineral NPK, led to a reduction in mean of yield by 17%. Scurtu (2001) recorded yields lower only by 15% in similar werk. Czuba (1979) found decreases of 30–60%. It may be supposed that good effect of manure fertilization treatments in general was due to the spring date of its application as well as its good quality. Oversowing with red clover and Bio-algeen S-90 application resulted in increases at the levels of 37% and 22% per year, on average, respectively, against unfertilized meadow but yields were much lower compared with other treatments receiving bovine manure. The yield enhancement from the different treatments was most marked at the first cuts.

Analysis of the botanical composition of the sward showed that the meadow included quite differentiated species, but Poa pratensis and Festuca rubra dominated. Trifolium pratensis applied by oversowing ranged from 12.6% to 22.7% in the sward (Figure 1). Jankowski *et al*. (1995) found that 50% Trifolium pratense in a grass/red clover sward might give the same yield as a120 kg N ha^{-1} applied mineral fertilizers.

Conclusions

Application of good bovine manure in spring leads to the achievement of mean hay DM yields considerably higher by than that from unfertilized meadows but lower than that fertilized with mineral fertilizers (NPK at similar level as in the manure). When applying the manure, spraying with Bio-algeen S-90 and oversowing with red clover in addition on a yield at the level similar to that from meadow fertilized with a comparable rate of NPK, may be achieved. These results are of great importance in view of existing opinions that high hay yields cannot be achieved in organic farms due to the prohibition of application of mineral fertilizers.

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Seed production potential of tetraploid red clover varieties

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Abstract

Red clover (*Trifolium pratense* L.) is an important forage crop in Estonia. Apart from its valuable properties, red clover has some drawbacks under the climatic conditions of Estonia: it has unstable seed productivity, insufficiently resistant to overwintering conditions and diseases. The aim of this study was to compare initial breeding material of European tetraploid red clover for productivity of seed yield in order to elucidate most promising entries.

Twenty-five varieties of tetraploid red clover of different origin and maturity were studied in field experiments at Jõgeva Plant Breeding Institute (58°45´NL, 26°24´EL, yearly air temperature 4.4 °C, precipitation 655 mm) during 2001–2004. Seed yield variation between the varieties was very large. The varieties Varte and Ilte have been bred for Estonian conditions and demonstrated the potential for high seed yields over the trial period.

Keywords: seed yield, persistence, tetraploid, red clover, variety

Introduction

Red clover (*Trifolium pratense* L.) is the most important forage legume in Estonia. Apart from its valuable properties, red clover has some drawbacks under the climatic conditions of Estonia: it has unstable seed productivity, insufficiently resistant to overwintering conditions and diseases. The average seed yield of tetraploid red clover varieties in Estonia is 200 kg ha^{-1} with large year-to-year variations, depending on the agro-climatic conditions in the growing year. The aim of this study was to compare the seed yield productivity of tetraploid red clover varieties in order to select the most promising entries for use as initial material in further breeding.

Materials and Methods

The seed yield potential was studied in two field trial cycles at Jõgeva Plant Breeding Institute (58°45'NL, 26°24'EL, mean annual air temperature 4.4 °C, annual precipitation 655 mm). Red clover was sown in July 2001 and 2002 without a cover crop with 4 replications in a randomized block design, plot size 6m^2, seeding rate of 12 kg ha^{-1} of 100% germinating seeds. The trial included 25 tetraploid red clover varieties (of which 16 were *T. pratense subvar. praecox* and 9 *T. pratense subvar. serotina*) originating from 10 European countries (table 1). The trials were carried out on calcarious cambisol (K_o), and the agrochemical characteristics of its humus layer were as follows: content of organic matter 2.5 and 2.8%, pH_{KCl} 6.1 and 6.4, P content was 239 and 149 mg kg^{-1} and K content was 163 and 166 mg kg^{-1}. The preceding crop was spring wheat. Prior to sowing, 500 kg ha^{-1} (equal to 24 kg P and 83 kg K ha^{-1}) of compound fertilizer Kemira Skalsa was applied. Later no fertilizers were used.

The seed yield of clovers depends on weather more than any other crop cultivated in Estonia. The air temperature during the vegetation period of 2002 was much higher than usually. There was a record sum of effective (>5 °C) daily temperatures – more than 351° over the long-term average (1420 °Cd). The yearly amount of precipitation (211 mm) accounted for 54% from long-term average. During the maturation and harvest period of the red clover seeds, in August of that year, the weather was very dry and in the first half of the month the air temperature was high as well. The winter conditions in 2002 and 2003 were severe, the sum of negative temperatures (<0 °C) reached as low as – 928°, while the long-term average is – 776°. This had an impact on the overwintering of the varieties in the trial. The effective temperatures amounted to 1500 °Cd in 2003, which is 80 °Cd more than the average. The precipitation was 488 mm during the vegetation period of 2003 at Jõgeva (long-term average is 413 mm). August in particular was wetter than usual, and the precipitation amounted to 187 mm, which is 215% above the average. The winter conditions of 2003/2004 were favourable and the sum of negative temperatures reached 504 °Cd, which is more than – 200 °Cd less than usual. The effective temperatures amounted to 1480 °Cd in 2004, 60° more than the average. The second half of the summer was extremely wet with only 5 days without rain from 11th of August till the end of September (1 day in August and 4 in September) and the total precipitation during this period was 203 mm.

The seed was harvested by direct combining (Hege 125C) from the first crop of the clover and cleaned by the Kamas-Westrup laboratory seed cleaning machines. The seed yield data re-calculated to 100% live seed is presented in Table 1. Winterkill percentage was estimated by of visual observation of the plots. Analysis of variance was performed using the computer statistics program Agrobase.

Results and Discussion

Low seed yields and high seed prices traditionally have been the primary limiting factors to the widespread use of tetraploid cultivars in the world (Taylor and Quesenberry, 1996). The seed yields of the red clover is influenced by the weather in the seeding year, the wintering conditions, the weather in the utilisation year of the sward, the occurrence of plant diseases, pests, weeds and the effectiveness of their control. The presence and the effectiveness of pollinators must also be taken into account (Rincker and Rampton, 1985; Smith *et al.*, 1985; Miller and Steiner, 1995). The yearly fluctuations of the seed yield of red clover in Estonia can be attributed mostly to the weather, the most influential characteristics of which are air temperature, the duration of sunshine, and precipitation in the period of flowering, seed maturation and harvest (Kotkas, 1976). In Estonia, the total precipitation in August in particular has a significant negative impact on the seed yield and its quality (Bender, Aavola, 1998). Depending on weather conditions, the seed yield of red clover may vary up to several hundred percent and under unfavourable conditions it may fail completely (Bender, 2000). The weather conditions do not influence the seed yield of early and late type varieties of red clover equally in every year because their blooming and maturation periods differ (Toomre *et al.,* 1969).

The trials that were carried out showed that in case of the early varieties, the seed yields were highest on the first utilisation year as expected and dropped drastically in the second year (Table 1). The harsh winter of 2002/2003 strongly affected the varieties with poor winter hardiness (the average persistence of non-Estonian varieties was 24% vs. 90% in case of the variety Varte), whereby damages were extensive in the stand of the 2nd utilization year. The herbage in the first utilisation year survived the winter relatively well. Toomre *et al.* (1969) found that in case of early red clover varieties originating southwards from Estonia, the annual and biennial plants are prevalent, while in case of the varieties of northern origin the perennial plants dominate, much like in case of the late type varieties of red clover.

The average seed yield of early varieties in 2002–2004 was 136 kg ha^{-1}, varying from 73 kg ha^{-1} (Temara) to 218 kg ha^{-1} (Varte). The varieties Varte, Markus and Mars showed very high yields over many experimental years, except in 2004 when germination of seeds within the heads occurred in massive amounts due to the weather conditions, and all the varieties had very low seed yields. The seed yield data in 2004 does not express the biological seed yield capability of the varieties (Table 1).

Table 1. Winter survival and seed yield of tetraploid red clovers 2002–2004

Variety	Origin	Winter survival, %					Seed yield, kg ha^{-1}				
		1st cycle of trial		2nd cycle of trial		AVG	1st cycle of trial		2nd cycle of trial		AVG
		2002	2003	2003	2004		2002	2003	2003	2004	
T. pratense subvar. praecox											
Varte	EE	100	90	95	85	95	181	145	485	29	218
Markus	GE	95	40	85	65	70	184	64	548	23	208
Mars	GE	95	45	85	70	75	199	72	479	21	196
Vulkan	CZ	90	45	85	70	75	107	59	391	37	154
Sprint	CZ	90	45	85	75	75	95	58	355	32	141
Dolly	CZ	80	10	80	40	55	50	41	409	38	136
Vyliai	LI	100	45	90	80	80	86	63	306	35	127
Radyka	PL	80	15	75	60	60	45	44	371	25	125
Kvarta	CZ	90	30	85	70	70	104	36	308	37	124
Cyklon	CZ	75	10	75	40	50	45	37	350	50	123
Skriveru tetra	LA	100	25	90	70	70	95	31	328	27	120
Tempus	CZ	90	15	80	70	65	142	19	268	33	117
Titus	GE	75	5	75	60	55	47	19	358	28	115
Vesna	CZ	90	10	85	60	60	142	15	225	21	101
Barfiola	NL	90	5	80	70	60	106	7	249	20	96
Temara	GE	90	15	80	60	60	89	19	158	17	73
LSD $_{0.05}$							28	14	64	7	19
Average		89	26	83	65	66	107	46	349	30	136
T. pratense subvar. serotina											
Ilte	EE	100	95	95	90	95	369	299	216	17	225
Vivi	SW	90	70	90	75	80	344	168	231	7	188
Divaja	LA	85	30	80	65	65	395	51	292	6	186
Kolpo	NO	100	80	95	85	90	349	169	196	10	181
Fanny	SW	95	45	85	75	75	353	111	233	4	175
Sara	SW	90	35	80	70	70	349	50	208	4	153
Nancy	SW	90	40	80	75	70	348	57	166	5	144
Kiržinai	LI	80	40	85	75	70	253	47	202	3	126
Tepa	FI	95	35			65	190	32			111
LSD $_{0.05}$							65	42	36	1.4	25
Average		92	52	86	76	76	328	109	218	7	165

AVG – average

As the trial was carried out without a disease control, early and severe infection of clover-mildew (*Erysiphe trifolii*) affected the seed yield of the early varieties in 2002. The assimilating surface was destroyed, the growth of the plants stopped and the genetic potential of the seed yield of the varieties was not realised in spite of perfect weather conditions during the bloom and harvest periods.

The late varieties showed somewhat higher average seed yields when compared to the early varieties over the trial period but not in every year and the yields were greatly influenced by the weather conditions of that particular year.

Slepetys (2003) reported that in a wetter year, the second-year late red clover often produced higher seed yields than the first year clover but in a drier year the seed yield of the first year clover was higher. This only applied to varieties with good winter resistance and was obvious only in the variety Ilte (Table 1). The seed yield shown in the second utilisation year by the variety Ilte exceeded the seed yield shown in the first year of utilisation by 38%.
2002/2003 did not affect the late varieties as much as the early varieties (the average persistence was 46% in case of non-Estonian varieties, and 95% in case of the variety Ilte) (Table 1). The average seed yield of late type varieties in 2002–2004 was 165 kg ha^{-1}, varying between 111 kg ha^{-1} (Tepa) and 225 kg ha^{-1} (Ilte). In both trial cycles the variety Divaja showed the highest seed yield in the first utilisation year but in the second utilisation year the variety Ilte surpassed all other varieties tested in this group.
The foreign varieties that yielded higher in the first year of utilisation did not significantly out yield the domestic varieties. In the second year of utilisation the Estonian varieties considerably out yielded all the foreign varieties in the trial (Table 1) and none of the foreign varieties out yielded the local varieties in average seed yield over the entire experimental period.

Conclusions

Among the studied tetraploid red clovers, early varieties Mars and Markus (Germany) and a late variety Divaja (Latvia) showed outstanding seed yield potential in the first year of utilisation, as they yielded more than the varieties bred in Estonia. None of the foreign varieties exceeded the seed yield of Estonian varieties as a mean of the experimental years.
The special interest of breeder did not result in finding material to create a variety earlier than the standard variety Varte. The very early type variety Temara produced a relatively poor yield in Estonian conditions in all harvest years. The varieties Varte and Ilte, which have been bred under local conditions, showed good seed yield potential through both experimental years.

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Biodiversity in intensive grasslands: effect of management, improvement and challenges

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Abstract

Intensified grasslands are usually the dominant type of grassland in many countries in Europe but are generally of poor ecological value. Several management factors may affect biodiversity of these grasslands including fertilisation, grazing and cutting management. Their effects on grassland biodiversity are described in this paper. In most cases, intensive and profitable grass production from semi-natural grasslands appears to be incompatible with maintaining a high level of biodiversity. Two key questions then arise: how to restore biodiversity in intensive grasslands while limiting the technical and economical consequences? How to choose the target species on an objective basis? Some solutions are considered in the paper but it is suggested that 1) new tools (i.e. indicators) are required to evaluate the functions of biodiversity and to achieve biodiversity restoration goals and 2) in the short-term the research priority is to understand and predict biodiversity at the field and farm-scale.

Keywords: grassland, biodiversity, intensification, improvement, challenge

Biodiversity and intensive grassland: an emerging concern

The Rio Summit in 1992 and the resulting Convention on Biological Diversity, increased global awareness on the importance of sustainable development for wildlife protection. Agriculture is integral to achieving this goal of sustainability, not only because farming practices have the potential to destroy, protect or create biodiversity, but also because agriculture is simultaneously an economic and social activity. In the agricultural context, grasslands have been recognized as potential species-rich habitats composed of various types of plants, animals and micro-organisms.

In most countries of Europe, biodiversity in grasslands is endangered by two opposite trends: intensification of practices and abandonment. Both have led to the reduction of plant species number (Baldock, 1993; Peeters & Janssens, 1998). Within the list of important ecological habitats of the annex I of the European Council Habitat Directive, 65 pastures types are endangered by intensification of farming practices and 26 by extensification (Rook *et al.*, 2004). However, both pressures are not uniformly widespread throughout the continent. In their report for the European Environment Agency, Petit *et al.* (1998) pointed out that in western and north-western Europe grasslands have already been greatly intensified in the past, and hence little further losses in biodiversity are now expected. On the other hand, greater reduction in biodiversity caused by intensification will probably occur in the future in the northern part of central and Eastern Europe (from Austria to Estonia). In the Mediterranean countries, as well as in mountains, land abandonment from agriculture will continue to be an important pressure on biodiversity.

The substantial efforts of scientists on grassland biodiversity are relatively recent. In addition, most of the studies have been undertaken in species-rich or "high biological value" grasslands. Consequently, biodiversity of wet, calcareous or alpine grassland, is better known than for intensified grassland dominated by species such as ryegrass (*Lolium perenne* L.), cocksfoot (*Dactylis glomerata* L.) or white clover (*Trifolium repens* L.). Intensified grasslands are usually the dominant type of grassland in lowland regions, representing millions of hectares in Europe, and are frequently the main forage resource for grass-based farming systems. Therefore, restoration of grassland biodiversity at a large scale throughout Europe raises the question of biodiversity recovery in these intensive grasslands.

The aim of the present paper is to present a general overview on: i) the management factors involved in grassland intensification affecting biodiversity, ii) the possible way to restore biodiversity in improved grasslands or arable land and iii) some key questions which can be addressed about research and environmental policy. The term "intensive grassland" will principally be used to indicate high stocking rate, high fertilizer inputs and frequent and early cutting of fodder.

1. Grassland management and biodiversity in intensive conditions

Most studies about grassland biodiversity have concentrated at the field level, or even at lower scales, when the development of landscape ecology has shown that the relevant scale for explaining species dynamics is rather the landscape level (Burel *et al.*, 1998). At the landscape level, grasslands, including those that were intensified, are generally considered as positive for biodiversity. Interesting results were shown in this way by Feodoroff *et al.* (2005). They compared a gradient of land-use intensification from old-growth forest to mixed landscapes dominated by crops in Morvan Regional Park (Burgundy, France). Local species richness increases from woodland to crop to grassland for these three types of land use, indicating a better biodiversity for grassland. Local species diversity of woods and crops is higher when grasslands are surrounding these land covers. At landscape level, the highest number of species per unit of surface is found in mixed landscapes dominated by grasslands. Maintenance of permanent pastures in a landscape, even if intensified, therefore appears more beneficial for biodiversity than other types of land use. For some populations like fossorial water vole (*Arvicola terrestris scherman* Shaw), regional and local factors have been identified as being important (Giraudoux *et al.,* 1997). The ratio of ploughed land and of permanent grassland to farmland is a key factor, but local practices like sward height management, linked to intensification of grazing, also appear crucial.

At the field level, several management factors may affect biodiversity of grasslands: use of organic and mineral fertilizers, grazing and cutting, drainage and in some cases use of pesticides, anthelmintics, ploughing and reseeding. The most studied effects concern those vascular plants, but all forms of life are influenced by the quality of the habitats. These various factors interact, for example for farmland birds in the UK. Their population decreases were linked to large-scale temporal changes in invertebrate numbers and seed resources (McCracken & Tallowin, 2005).

a) Fertilisation

Fertilizer supplies result in an increase in nutrient availability for plants. In this condition, only a few fast growing plant species can compete for light, eliminating less competitive plants. This results in a decrease in the species richness. On the other hand, in very poor soils, only a few slow-growing species are able to compete for nutrients. Consequently, higher biodiversity is usually observed for intermediate situations (Al Mufti *et al.*, 1977; Grime,

1979) where the competition is lower and where a large number of mesotrophic species can coexist with some oligotrophic and some eutrophic species. However, the question of the determination of threshold levels is very complex because of the variety of soil, climate and type of fertilizer. From different studies, it appears that a significant reduction in plant diversity is generally observed even for fertilizer levels which are very low in comparison to the normal application rates in intensive grasslands. For nitrogen, a reduction of half of the total number of plant species can be observed for fertilisations between 20 and 50 kg N ha^{-1} $year^{-1}$. Tallowin (unpublished) observed that the average number of forb species was very low where nitrogen inputs exceeded 75 kg N ha^{-1} $year^{-1}$. High forb diversity was only found in grasslands receiving less than 75 kg N ha^{-1} $year^{-1}$. The influence of soil available phosphorus on the number of plant species is less known but Peeters *et al.* (1994) and Janssens *et al.* (1998) have found a maximum of 10 dicots at values above 50 mg P kg^{-1} of dry soil (EDTA-acetate extraction method). The potassium effect on grassland biodiversity seems to be less depressive and high number of plant species may persist with relatively high potassium soil content between 100 and 200 mg K kg^{-1} dry soil as demonstrated by Peeters *et al.* (1994).

Substantial amounts of manure may also influence the species composition of grasslands. Beside the nutrient content of these organic inputs, specific effects are related to the importation of seeds and the smothering of the sward by liquid or solid manure. In intensive grasslands, seed importation concerns a very few species of poor ecological value like broad-leaved dock (*Rumex obtusifolius* L.) or *Umbelliferae* species. The effect of covering a sward by manure is similar to the screen created by litter accumulation. Foster and Gross (1998) showed the negative effect of litter in seedling establishment of new species. A nitrogen fertilisation increased living plant and litter biomass, and reduced plant biodiversity. Litter removal resulted in an increase in species richness, proving the reality of this screen effect.

High fertilizer inputs effects are not limited to plant species as it leads to tremendous changes in chemical, biological and, indirectly, physical status of soil. Grassland soils contain an abundant and diverse micro-organism, micro- and macrofauna community. Intensive management of grassland commonly impacts negatively on the diversity as a whole, but not necessarily on the density of soil fauna (Bardgett & Cook, 1998). Intensification tends to promote low diversity in soil fauna, favouring bacterial-pathways of decomposition and dominated by bacterial-feeding fauna, whereas more extensive systems present a more diverse habitat dominated by a fungal-feeding fauna more persistent than the bacterial-feeding fauna. Moreover, interactions occur between above and belowground diversity, as shown by Benizri & Amiaud (2005). They found decreases in plant biodiversity with increasing nitrogen fertilization treatments in a grassland trial. Similarly, bacteria extracted from rhizosphere of highly fertilized plots showed a lower catabolic ability (Biolog® plates): they were not able to consume as many chemical compounds than bacteria from unfertilized treatment. The authors emphasize that it would be linked to a lower diversity in root rhizodeposit exudates by the plants in the fertilized treatment.

The addition of fertiliser can benefit some grass- or worm-eating birds such as geese and waders. However, in general the use of fertilizer not only reduces the range of potential invertebrate preys in the sward (through a reduction in plant diversity) but the resulting tall and dense vegetation also limits access to food by birds into these swards.

b) Grazing and cutting management

The primary role of grazing animals in grassland biodiversity management is maintenance and enhancement of sward structural heterogeneity, and thus botanical and faunal diversity, by selective defoliation due to dietary choices, treading, nutrient cycling and propagule dispersal

(Rook & Tallowin, 2003). These trends may occur in various situations including grazing at low stocking rates in extensive systems (e.g. mixed grass and forb vegetations in highlands), but also in more intensive grasslands. This phenomenon occurs after a few grazing cycles, even when the initial situation is a homogeneous sward (Garcia *et al.*, 2005).

It is now well established that large ruminants are able to enhance plant diversity at low stocking rates, but decrease it at higher rates (Olff & Ritchie, 1998). This could explain apparent contradictions observed in the literature about grazing effects on plant biodiversity. For example, in a global survey of grassland in Lorraine (France), the two main factors explaining plant species richness and related to grazing activity were the stocking rate and the duration of re-growth between grazing periods (Plantureux, 1996). Plant diversity was limited at stocking rates above 1.5 LU ha^{-1}, and re-growth durations under 35 days. Conversely, in Switzerland the conversion of mown sites in alpine species-rich grasslands to grazing resulted in a loss of plant evenness and biodiversity (Fisher *& Wipf*, 2002). The mean loss reached 10 perennial plant species in 50 years of grazing. The observation scale also influences results, as shown by Balent *et al.* (1998): in this study, an increase in the stocking rate resulted in a higher heterogeneity and diversity of the sward at a local scale (field), but in a reduction of these parameters for larger areas (territories).

Heavy grazing produces short dense swards that generate little seed resource and offer limited foraging and shelter opportunities for many invertebrates (Morris, 2000). Low stocking rates conversely produce patches of tall rank vegetation and the accumulation of dead vegetation and litter, depressive for plant seed germination, but favourable for invertebrate species like spiders. A great diversity in bird species would be expected in such situations, but, at a very low stocking rate, the density of sward and litter layer means that invertebrates are generally not readily accessible to foraging birds. From this point of view, an intermediate stocking rate seems to be optimal for foraging birds.

Infrequent cutting management has been proved to be highly linked to species biodiversity. For example, Zechmeister *et al.* (2003) found that the total number of vascular plants and bryophytes of Austrian grasslands decreased from 11.3 to 5.6 per m^2 when the number of cuttings per year increased from 2 to more than 3. When only one cutting was performed, this species richness was 7.1, indicating that a minimum mowing frequency is required to maintain biodiversity. The effect of the number of cuts also appeared to depend on the moisture of the grassland soil.

Agri-environmental policies concerning grasslands have often promoted late harvests in order to preserve flowering plant species, and birds nesting within grassland swards. Intensive grasslands are very far from this situation. In grass silage-making, the harvest occurs very early in the growing season and the number of cuts per year increases compared with hay-making. Few clonal plant species can resist this regime, and the ecological value of these species is low, as underlined by Muller (2002). Multiple cuts per season not only reduces the number of seed heads and flowering plants (and hence the number and type of invertebrates attracted to these swards) but also serves to remove the vegetative food resource for plant-feeding insects (such as sawflies and plant bugs). The encouragement of rapid re-growth of the sward immediately after cutting also means that the period in which these food items are accessible to birds is very short (McCracken & Tallowin, 2005).

An alternative solution to late-cut hay was proposed to find a compromise between quality forage production and biodiversity maintenance in hay fields. It consists of an early cut in the season (e.g. in May for lowlands) and a late cut (e.g. in September) which permits a delay in flowering in the middle of summer. In this case, plant species are able to produce mature seeds at the end of August-beginning of September, when the germination conditions are favourable.

Another alternative to late cutting consists of a late grazing at high stocking rate for a short period at the time when the sward was traditionally cut. This technique allows flowering and seed formation as well as cutting but it is much easier to implement than mechanical cuttings especially if the soil is wet or marshy or located on a steep slope.

c) Water regime

Drainage of the wetter meadows is one of the factors associated with their intensification. The effect of drainage is commonly associated with the influence of an earlier management (grazing, cutting or fertilization or manuring), and an increasing stocking rate, duration of grazing and fertilizers inputs. Typical plant and animal species from wet biotopes thus disappear under the combined action of the drying of grassland soil and intensification of management (Plantureux *et al.*, 1993). In a study comparing grasslands drained for periods ranging from 1 to more than 30 years, it has been demonstrated that dominance of plant species is modified during the growing season following the drainage, and that species disappearance or appearance significantly change after 5 years (Oberlé *et al.*, 1989). Drainage of wet soils improves soil conditions for some invertebrates such as earthworms, but it can also reduce soil penetrability for probing birds and a more vigorous grass growth in spring may reduce access to the soil surface at this critical time for breeding birds (Ausden *et al.*, 2001).

d) Pesticides and other factors

Numerous factors are likely to influence biodiversity in grasslands but few of them really operate in intensive grasslands compared to fertilisation, grazing and cutting management, and water regulation by drainage. This is mainly linked to the huge effect of these management factors, but it may also be recognized that the influence of the other factors has on the whole been studied less. Ploughing and reseeding will not be considered in this paper devoted to intensive permanent grasslands, but it is clear that they significantly modify plant and even other species diversity.

Even in intensive grasslands, pesticides are applied less (frequency and amounts) than in cultivated fields. Most of the pesticides used in permanent grasslands are herbicides controlling forbs and broad-leaved weeds. Farmers generally use such herbicides on grasslands that have already been intensified, and the reduction of plant diversity is thus restricted to a limited number of species of poor ecological value. In addition, insecticides may be directed against soil-dwelling leatherjacket larvae, which although a pest of grassland, can also form an important prey item for a range of farmland birds (McCracken *et al.*, 1995). However, the most widespread use of chemicals is through the application of anthelmintics to control internal parasites of grazing animals, and particular concern has been expressed over the potential insecticide effects of residues excreted in the dung of treated animals. This effect reduces the feeding resources of meadow birds.

2. Improvement of biodiversity in intensive grasslands and arable lands

As intensive management has been proved to impact on species richness of grasslands, alternative solutions are required in order to enhance biodiversity. Three major questions then arise about restoration of plant and animal diversity in permanent grasslands: Which objectives can be defined in term of particular species to be promoted, how farming practices should be applied to obtain the desired goals, and what are the economic consequences of such modifications. To fully answer these questions is quite difficult mainly because of the complexity of the relationships involved, the frequent conflicts between ecological and economical aims, and the relative lack of detailed knowledge on many of the related mechanisms.

Until now, prescriptions for biodiversity restoration have generally been directed at preserving a limited number of selected species (i.e. birds or plants). However, species differ in their requirement of vegetation structures and soil conditions, and hence the management scenarios for grassland biodiversity restoration may therefore differ depending upon the priorities set. The main focus on techniques to restore grassland biodiversity has been directed at vegetation restoration, and less frequently at bird protection. Other species are generally ignored, or the recovery of the ecosystem is assumed to be beneficial to a wide range of species. However, this is not always the case.

Enhancement of biodiversity depends on the initial conditions (i.e. soil seed bank limitation, landscape characteristics such as fragmentation and diversity), and on the ability to change grassland abiotic conditions and management (i.e. soil nutrient content, intensity of management). The duration of agricultural intensification appears to be a key factor for an effective restoration, as shown by many studies on seed-bank in European grasslands (Bakker *et al.*, 1999). The biodiversity of recently intensified grassland is easier to restore. Landscape environment also acts to speed up the recovery in diversity, as animal and plant re-colonization is better when grasslands are surrounded by species-rich areas. In this context, the importance of ditches, hedgerows and others field boundaries have been mentioned by several authors like Smart *et al.* (2002), Blomqvist *et al.* (2003) or Aude *et al.* (2004) namely as a source of seed rain. The relative influence of abiotic conditions and dispersule dynamics is frequently discussed. Studying the re-introduction of *Silaum silaus* L. in intensive grasslands of the Saale river flood plain in Germany, Bischoff (2000) concluded that slow dispersion was the main limiting factor for the re-colonization by this plant species. When seed-bank and plant dispersion are not limiting, the presence of gaps and the sward height created by management is a crucial condition for the germination and growth of this plant species.

The most common means used in diversity restoration includes extensive management, and techniques to overcome biotic and abiotic constraints (Walker *et al.*, 2004). Extensification of management involves the reduction or the cessation of mineral and organic fertilisation, and/or a decrease in the stocking rate and the number of cuttings per year. Over most studies, the effects of the reduction in fertilizer rates have been found to vary greatly between situations. Re-establishing original plant communities frequently takes more than 10 or 20 years, and the final goal is not always reached. Several reasons may explain this phenomenon: initial soil nutrient content may be very high, and if the soil is deep and plant growth and consequently plant nutrient uptake limited by extensification, the reduction of soil fertility is very slow. The floristic recovery is thus generally more efficient if the depletion of nutrients is subsequently accelerated by hay-making. As described previously, biodiversity is significantly reduced at low levels of fertilizer, especially for nitrogen. Atmospheric depositions of nutrients that are increasing are now considered to slow down extensification effects on biodiversity. This could explain the relatively weak differences observed by Haas *et al.* (2001) in South Germany when they compared the number of plant species in extensified and intensive grassland systems: in organic and extensified grassland, plant species richness was only slightly higher (29.0 and 26.8) compared with the intensively used permanent grasslands (24.7).

It has been demonstrated that mixed management (grazing + cutting) is preferable than grazing or cutting alone, for most plant species (but not for all species) but, as with the reduction in nutrient supply, the results are very variable among studies. In such situations, a late harvest permit of the production of many seeds, and the following grazing period opens gaps in the sward where seeds can germinate. Moreover, grazing for short periods induces an increase in sward heterogeneity that is highly favourable for plant and animal diversity. Although it is well known that different livestock species (e.g. cattle, sheep, goat, horse) have different grazing preferences, the impact of this on plant biodiversity – and evidently on other species – is not yet understood well enough (Rook *et al.*, 2004).

Overcoming abiotic constraints generally involves the depletion of soil nutrient status, but may also require the restoration of the water regime of drained soil. A thorny question is the persistence of non-labile elements like P in soil. The problem is particularly serious in countries like France where huge amounts of P (basic phosphorus slags used for pH elevation) have been added for many years. P accumulates in grassland soils as they are rich in organic matter that easily binds with this element. Several techniques have been proposed to "remove" P from grassland soil: reasonable (whatever is meant by reasonable) N fertilizer application for a few years seems to be a good compromise because it is efficient and has little effect on environment pollution. More drastic techniques have been suggested like deturfing or addition of chemical material that absorbs nutrients or makes them unavailable for plants. The cost of these techniques is usually high and the techniques of soil nutrient depletion are not easily accepted by farmers. When soil pH has been increased for a long time in acid grassland, acidophilic species have disappeared. Application of acid materials has been proved to reduce pH efficiently and restore the initial situations in few years.

If extensification or modification of abiotic constraints are not enough to improve biodiversity, biotic constraints may be solved by the introduction of species (plant species). Oversowing, direct drilling or mechanical disturbance of the sward is suitable in this objective. The results of such experiments are variable and illustrated by an abundant literature (Walker *et al.*, 2004).

In particular, species-rich grassland restoration by re-introduction of plant species is often faster and easier on arable land than on intensified grassland. After sowing, seedlings can easily establish on a bare soil since there is no competition with mature plants. The soil nutrient status is also more favourable on arable land since the organic matter content and thus the mineralization of organic nitrogen are lower.

Finally, economical considerations have to be taken into account in restoration of intensive grasslands. In a recent contribution, Hodgson *et al.* (2005) have tried to answer the following key question: "How much will it cost to save grassland diversity?" Comparing a very large range of situations, they found a positive exponential relationship between intensification of practices and net returns of grassland production. At the same time, this increase in financial benefit was associated with a decrease in grassland plant diversity, from intermediate to high levels of intensification. In the case of lowland grassland in UK, the total potential number of plant species was divided by 2 (40 to 20) when the estimated economic yield increased from about 500 to 5000 £ ha^{-1}.

Conclusions

In most cases, intensive grass production from semi-natural grasslands appears to be incompatible with maintaining a high level of biodiversity. Existing but very rare counter-examples can be identified concerning organisms adapted to highly intensified conditions. The key question is thus: how to restore biodiversity in intensive grasslands while limiting the technical and economical consequences? As these negative consequences are mostly unavoidable, financial support or regulations are required, as now proposed by EU and its member States. Two aspects arise about these policies dealing with i) the relative lack of knowledge on grassland biodiversity and ii) the objectives of biodiversity enhancement and its evaluation.

Despite many studies on grassland biodiversity, many aspects still remain unknown. Firstly, it must be noted that the biodiversity of low productive grasslands (fens, marshlands, calcareous swards namely) have been investigated more than lowland and intensive grasslands. As clearly demonstrated by Leps (2004), biodiversity trials failed to address a lot of topics. There are still many species, and even genus and families that are not studied in grassland ecosystems. Landscape and species scales are the main concern of biodiversity research, whereas genetic diversity is completely ignored in grassland studies. Below-ground studies are also rare, as noticed by Bardgett *et al.* (1998): "research is needed to test the hypothesis that grassland soil biodiversity is positively linked to stability, and to elucidate relationships between productivity, community integrity and functioning of soil biotic communities". Reseachers in grassland biodiversity thus have many questions to address in the future.

As previously mentioned, conservation or restoration of biodiversity are generally oriented on selected species. The choice of these target species is not always ecologically justified, and a more objective basis is therefore required. Biodiversity is not a simple concept, and Noss (1990) described it in a hierarchical approach based on the distinction between composition, structure and function. Biodiversity may also be considered through its ecological, agronomic and heritage functions (Clergué *et al.*, 2005; Maljean & Peeters, 2001). From this point of view, the restoration of functions ensured by biodiversity would be a way to choose the appropriate management of grasslands. This process requires new tools (indicators) to evaluate these functions and to achieve biodiversity restoration goals. In particular, while there is a need for a better understanding of many issues relevant to grassland, there is also a need for the identification of some research topics where fast results can be achieved in the context of intensified grassland. It is suggested that research priorities should be:

- *Restoration of species-rich grassland*: A large-body of past and present studies have been focused on this issue. There is a need for some consolidation of what is now known about this issue before many other new projects in this area can be developed. The majority of future research in this area should be directed at field (rather than small-plot) scale and should focus much more on the practicalities of achieving results at this scale.
- *Maintenance of species-rich grassland*: Although restoration is important, there is no point in increasing the amount of species-rich grasslands if the best management to maintain them is unclear. Many current and previous studies have been directed at cutting regimes and now there is a need for the development of appropriate grazing management techniques. It is essential that the latter involves research at the field-scale so that the implications of livestock grazing behaviour can be taken into account.
- *Semi-improved and improved grassland*. Given that these form the majority of grasslands across Europe, there is a need for a greater consideration of what can be done to enhance their biodiversity value while maintaining a satisfying level of forage production. Practicalities of implementation of management actions dictate that the options for silage fields should be considered separately from those for grazed fields. In silage situations, it will be feasible to consider either margin or whole-field approaches. In grazed situations, the cost of fencing and difficulty of directing any actions solely at the margins dictate that field-scale options should be given priority for those situations. In both situations, greater attention needs to be given to ensuring (a) that the approaches taken address both summer and winter issues for the biodiversity under consideration and (b) that the management implemented makes sense in terms of the phenology of the target organisms. Manipulating vegetation structure has the potential to achieve quicker

results than actions to reduce soil nutrient status. Managing grasslands in order to take into consideration the phenology of the target organisms certainly needs some future research. Nevertheless there is a need to direct more attention towards ways of achieving summer and winter issues for the biodiversity, which fit with farming practice. Although landscape-scale issues will be important in grassland situations, it is suggested that in the short-term the research priority is to understand interactions at the field and farm-scale.

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Behaviour of white clover and timothy in a perennial ryegrass sward under grazing

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Abstract

A decrease in N fertiliser use may open up new perspectives for white clover (*Trifolium repens* L.) and timothy (*Phleum pratense* L.) to become important components of seed mixtures for pastures in Flanders. In this study, the influence of the proportion of timothy in the mixture and the sowing depth on the presence in the sward is evaluated as well as the behaviour of white clover in these seed mixtures. The experiment was established in 2002 on a sandy loam soil. It was managed in a rotational grazing system with heifers and 150 kg ha^{-1} N was applied yearly. Eleven weeks after sowing, a mixture 40/60 (40% timothy seeds and 60% ryegrass seeds) resulted in a significant lower timothy frequency than a 75/25 mixture. Later on, the difference between the 2 treatments became smaller and not significant. Sowing the ryegrass 1.5–2 cm deep followed by broadcast sowing of timothy did not increase the frequency of timothy in comparison with sowing the mixture 1.5–2 cm deep. White clover established very well. A monoculture of timothy favoured the clover establishment. The 40/60, 75/25 mixtures and a pure stand of ryegrass did not differ in clover frequency.

Keywords: mixtures of species, timothy, white clover, botanical composition

Introduction

In establishing pastures for grazing, there is a renewed interest in using seed mixtures of several grass species and white clover, because the application of nitrogen fertiliser (mineral and organic) has declined considerably and the mowing percentage has increased. In these new circumstances the dominance of perennial ryegrass (*Lolium perenne* L.) in the sward can decrease and other species like meadow fescue (*Festuca pratensis* Huds.), smooth-stalked meadow grass (*Poa pratensis* L.), timothy (*Phleum pratense* L.) and white clover (*Trifolium repens* L.) can persist and play a significant role in the composition of the sward. It is very important that these species can establish in the sward from the very beginning, to be competitive with perennial ryegrass. In this study, the influence of the proportion of timothy in the seed mixture and the sowing depth on the presence in the sward is evaluated as well as the behaviour of white clover in these mixtures.

Materials and Methods

The experiment was established in August 2002 on a sandy loam soil in Merelbeke (Flanders). Eight treatments were imposed in a complete block with 3 replicates (Table1). Each plot had a size of 80 m^2 (10 m × 8 m). Grass mixtures containing 40% or 75% timothy seeds correspond respectively with 120 or 360 gram of timothy per kg seed mix. This is similar to the timothy content in commercial mixtures (100–280 g kg^{-1}). In treatment 2 and 4 perennial ryegrass was sown 1.5–2 cm deep with a motorised plot drill and timothy was broadcast sown afterwards, followed by rolling the seedbed. In all the other treatments the grass seeds were mixed and sown 1.5–2 cm deep with a plot drill. The white clover seeds were always broadcast sown afterwards, followed by rolling.

Table1. Sowing density and distribution of the number of grass seeds in the treatments (%)

Treatment	Quantity of seeds in the mixture (%)			Sowing density kg ha^{-1}	
	Timothy cv. Dolina	Perennial ryegrass		Grasses	White clover
		Diploid (D) cv. Paddok	Tetraploid (T) cv. Merkem		
1 40/60 mixed	40	30	30	40	4
2 40/60 separate	40	30	30	40	4
3 75/25 mixed	75	12.5	12.5	40	4
4 75/25 separate	75	12.5	12.5	40	4
5 100/0	100			15	4
6 0/100 D		100		30	4
7 0/100 T			100	45	4
8 0/100 D+T		50	50	40	4

The other treatments were a pure stand of diploid or tetraploid perennial ryegrass, a combination of these types and timothy, oversown with white clover.
The pasture was grazed by young heifers in a rotational grazing system and cut once a year. In the sowing year 100 kg N ha^{-1} was applied and in the following years 150 kg N ha^{-1}. The presence of timothy and white clover was measured by the frequency method using squares of 10 cm × 10 cm (45 determinations per plot). In April 2003 and 2004 the botanical composition on the dry matter was determined by separation of the constituents in samples of 0.500 kg per plot.

Results and Discussion

Timothy

Timothy plants were widespread in the sward when timothy/ perennial ryegrass combinations 40/60 or 75/25 were sown and the timothy survived without any problem (Table 2). The timothy plants were detected in 63–94% of the squares 11 weeks after sowing and in 70–92% of the squares after two years. Earlier experiments under grazing conditions with a considerably higher level of nitrogen fertilisation (>300 kg N ha^{-1} yr^{-1}) in the same location showed a good emergence of timothy but a very fast and severe decline in the number of plants (Carlier *et al*., 1988). A lower N fertilisation (150 kg N ha^{-1}) was favourable for the timothy development because it allowed it to be more competitive with perennial ryegrass.

Table 2. Timothy frequency in the sward (%). Merelbeke 2002–2004

Treatment	Timothy frequency in the sward (%)								
	Oct 02	Apr 03	July 03	Sept 03	Oct 03	Apr 04	June 04	Aug 04	Oct 04
1 40/60 mixed	63a	70a	61a	47a	58ab	87ab	80ab	76ab	70a
2 40/60 separate	65a	75a	65a	35a	43a	78a	74a	62a	76ab
3 75/25 mixed	94b	98b	81b	52a	76c	98b	91c	92bc	87abc
4 75/25 separate	92b	94b	88b	47a	65b	93b	86bc	83bc	92bc
5 100/00	100b	99c	97c	96c	97d	99b	99e	100c	100c
Average 40/60	64	73	63	41	51	83	77	69	7
Average 75/25	93	96	85	50	71	96	89	88	90

Treatments with the same letter in the same column are not significantly different (P < 0.05)

In April 2003 and 2004 the proportion of timothy in the dry matter production was determined. The high frequency of timothy in the sward was reflected in its contribution to the dry matter production: 25% (17.9–30.6%) of the dry matter in 2003 and 20% (12.4–27.2%) in 2004. Timothy was found more frequently in the sward when the mixture 75/25 was used in comparison with the mixture 40/60 but the difference was only significant in the first half of the 2003 growing season. Later on the difference became smaller. There were no differences in timothy frequency between sowing of the mixed grass seeds 1.5 cm deep in comparison with sowing each species at the optimal depth (1.5 cm for perennial ryegrass and <0.5 cm for timothy).

White clover

Broadcast sowing of white clover, followed by rolling is a good system to obtain a good emergence of the clover because in practice, a mixture of grass/clover is sometimes sown to deep (> 2 cm) for a good clover emergence. The clover frequency was higher in the grass seed mixture with 100% timothy seeds compared to all the others, but mostly the differences are not significant (Table 3). No other significant differences were found, except between treatment 1 and treatment 8 in April 2003. This can be explained by the considerable variation in clover emergence and colonisation between the replicates. This is illustrated by the high coefficient of variation in each period of determination (>22%). Grass seed mixtures with 40% or 75% of timothy seeds were not associated with higher clover frequency in this experiment, in comparison with a seed mixture of 100% perennial ryegrass. There was no difference in clover frequency between a diploid and a tetraploid perennial ryegrass sward. In the research of Fothergill and Davies (1993) and Fougere and Legall (2002) tetraploid varieties permitted a better white clover presence due to their more open growth habit, which allowed more space and light penetration, but Van Eekeren and Wagenaar (2002) did not detect significant differences. However in all the treatments there were enough white clover plants widespread over the sward to colonize it. The growing conditions – a moderate N fertilisation, rotational grazing and some cutting – were favourable for clover establishment in 2003 and 2004. As a result, the clover frequency increased up to 50–75% for the mixtures of timothy and perennial ryegrass and up to more than 95% for the pure stand of timothy. Timothy is classified as a companion grass species with an intermediate compatibility with white clover (Frame *et al*., 1998).

Table 3. White clover frequency in the sward (%). Merelbeke 2002–2004

Treatment	White clover frequency in the sward (%)								
	Oct 02	Apr 03	July 03	Sept 03	Oct 03	Apr 04	June 04	Aug 04	Oct 04
1 40/60 mixed	46a	48bc	33a	35ab	37a	56a	60ab	60a	57a
2 40/60 separate	50ab	20ab	28a	36ab	37a	53a	59a	69a	63ab
3 70/30 mixed	62ab	17ab	19a	42ab	34a	53a	56a	63a	62ab
4 70/30 separate	61ab	29ab	31a	55ab	44ab	69ab	71bc	77ab	68ab
5 100/00	79b	77c	79b	77b	73b	93b	96d	100b	97c
6 0/100 D	52ab	31ab	39a	48ab	41ab	76ab	72c	58a	75ab
7 0/100 T	57ab	32ab	44a	66ab	48ab	62a	66abc	64a	72ab
8 0/100 D+T	43a	19a	25a	27a	41ab	65a	64abc	57a	50a
Average 40/60	48	34	31	35	37	54	60	64	60
Average 70/30	62	23	25	49	39	61	63	70	65
Average 0/100	51	27	36	47	43	68	67	60	66

Treatments with the same letter in the same column are not significantly different ($P < 0.05$)

In April 2003 and 2004 the proportion of white clover in the dry matter production was determined. As expected the proportion of white clover in the dry matter was very low in April 2003: < 3% for the mixtures with perennial ryegrass and 14 % for the pure stand of timothy. In spring 2004 the clover proportions were respectively 7% (5–10%) and 27% of the dry matter. There were no marked differences between the seed mixtures with perennial ryegrass. This illustrated the difference in competitiveness between a pure stand of timothy and mixtures of timothy and perennial ryegrass, even with a high proportion of timothy in the seed mixture.
In 2005–2006 the proportions of each component of the mixtures in the dry matter will be determined 4 times during the growing season to evaluate the impact of timothy on the clover growth.

Conclusions

The use of the perennial ryegrass and timothy seeds combinations of 40/60 and 75/25 by weight allowed the establishment of a sward with a substantial frequency of timothy.
A rotational grazing system with a moderate N-fertilisation of 150 kg ha^{-1} yr^{-1} was favourable for the competitiveness of timothy and white clover
Sowing seed mixtures of perennial ryegrass and timothy 1.5–2 cm deep did not decrease the number of timothy seedlings in comparison with sowing both species at the optimal depth for their seed sizes.
A high quantity of timothy seeds in the mixture resulted in a significantly higher frequency of timothy only in the beginning.
Only a pure stand of timothy favoured the frequency of white clover.

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Concentrations of condensed tannins in forage plants as a function of their developmental stage

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Abstract

Condensed tannins (CT) can have either beneficial or detrimental effects on ruminants, depending on the concentration in which they are fed. In an outdoor experiment, we aimed to determine the optimal time for harvest with respect to tannin concentrations. The seasonal dynamics of the CT concentrations of the harvestable biomass were investigated as a function of the biomass allocation to the leaves and stems of *Onobrychis viciifolia, Lotus corniculatus* and *Cichorium intybus* during the course of a vegetation period in Zurich, Switzerland. The CT concentrations were higher in leaves than in stems, and the leaf mass fraction of the harvest (LFH) decreased steeply with time in all investigated plant species. However, between the 5th and the 20th week after sowing, the concentration of CT in leaves approximately doubled in *Onobrychis* (from 5 to 9% of DM) and in *Lotus* (from 2 to 5% of DM), but was nearly stable in *Cichorium* (0.5% of DM). Over time, any reduction in total amount of CT, due to the declining proportion of leaves in the harvestable biomass (LFH), was almost exactly balanced by the increasing concentration of CTs in leaves. This resulted in almost constant CT concentrations in the harvestable biomass during the season: 6% DM for *Onobrychis*, 2.5% DM for *Lotus* and <1% DM for *Cichorium*.

Keywords: tannin concentrations, seasonality, *Onobrychis viciifolia, Lotus corniculatus, Cichorium intybus*

Introduction

Condensed tannins are secondary plant metabolites which are found in a wide variety of taxa of both woody and herbaceous species. Agronomic studies show that when fed at low to moderate concentrations (0.5–5% DM), tannins can exert many beneficial effects on ruminants. Condensed tannins can increase the liveweight gain, wool growth and milk production, stimulate reproduction in sheep and reduce the risk of bloat in cattle without reducing voluntary feed intake (Aerts *et al.*, 1999; Barry and McNabb, 1999; Min *et al.*, 1999). These positive effects have mainly been attributed to the CTs' ability to form insoluble complexes with dietary proteins protecting them from degradation by microorganisms. This process results in an increased N-use efficiency by the animal, an enhanced supply of essential amino acids and a lowered N-excretion into the environment. Furthermore, at elevated concentrations, CTs have anthelmintic properties against a variety of gastrointestinal parasites (Aerts *et al.*, 1999; Athanasiadou *et al.*, 2001; Niezen *et al.*, 2002; Marley *et al.*, 2003). Thus, the cultivation of tanniferous plants offers promising prospects for increasing animal productivity and health, whilst at the same time allowing a reduction in the application of chemical and pharmaceutical products, such as anthelmintics and detergents (bloat control), which is especially desirable in organic farming. However, if CTs are fed at concentrations exceeding 5% DM, they reduce the voluntary feed intake of the ruminant, lower the digestibility of the fodder, and thus reduce the animals' growth rate and overall performance (Aerts *et al.*, 1999). Hence, for a practical application of tanniferous plants it is desirable that the CT concentration of the chosen plant is close to, but below 5% DM. Generally, concentrations of plant secondary metabolites are a function of the plants' developmental stage, seasonality, and response to fluctuations in resource availability. Our experiment aimed to characterise the dynamics of tannin concentrations in three plant species for which beneficial effects on ruminant health have previously been found, and to report the optimal times of harvest with respect to CT concentrations. We hypothesized that (1) tannins are not evenly distributed throughout the plant, but are located in higher concentrations in leaves than in stems and that (2) the proportion of stems in the harvestable biomass will increase as plants grow older, resulting in (3) decreasing concentrations of tannins over time.

Materials and Methods

This outdoor experiment was conducted with potted plants at the Swiss Federal Research Station for Agroecology and Agriculture FAL Reckenholz in Zurich, Switzerland. Three tanniferous plant species with two 'cultivars' each; *Onobrychis viciifolia* (sainfoin; Visnovsky and Handelssaatgut), *Lotus corniculatus* (birdsfoot trefoil; Oberhaunstädter and Lotar) and *Cichorium intybus* (chicory; Puna and Lacerta), were studied to investigate their biomass allocation to leaves and stems, and their tannin concentration, at seven points in time during the course of the vegetation period (from sowing until leaf senescence) in 2003. All results reported here refer to the pooled data of the two cultivars per species. Each cultivar was grown in monoculture in square pots with a volume of 12 litres at a density of 5 plants per pot. The soil was formed by mixing 2 parts of potting soil with 1 part of loamy field soil. A total of 126 experimental pots (3 species x 2 cultivars x 7 harvests x 3 replicates) were arranged in a split plot design with 'species' as the main plot and 'time of harvest' as the sub-plot. Within each block, pots of a given species were positioned randomly and in close proximity to each other to form artificial swards, and then surrounded by additional non-experimental pots, used in order to minimize border effects. In seven successive, destructive harvests, one pot per block and cultivar was selected at random, and plants were cut off at 5 cm above ground level. This 'harvestable biomass' from each pot was separated into leaves and stems, dried at 60 °C for 48 h, weighed and analysed for CT using a modified version of the HCL-butanol assay described in Terrill *et al.* (1992). After each harvest, pots within each artificial sward were sealed in order to ensure that neighbouring plants in the harvested pots did not experience competitive advantages.

Results

Over the entire vegetation period, concentrations of CT in the plants for any given tissue decreased in the order *Onobrychis* > *Lotus* > *Cichorium*. As expected, the mean tannin concentrations were roughly three times higher in the leaves than in the stems of *Onobrychis* (7.48 ± 0.26 and 2.35 ± 0.20% DM, respectively, mean and se) and *Lotus* (4.20 ± 0.23 and 1.25 ± 0.07% DM, respectively), but similarly low in both organs for *Cichorium* (0.49 ± 0.05% DM). In stems, the tannin concentrations were stable over time in all investigated species (data not shown). In contrast, the tannin concentrations in leaves of *Onobrychis* and *Lotus* increased during the experiment (Fig. 1). In *Onobrychis,* tannin concentrations of leaves increased from 5 to over 8% DM, between 5 weeks after sowing in spring and leaf senescence in autumn. Similarly, in *Lotus,* the CT concentration of leaves increased from 2 to 5% DM. As expected, the proportion of leaves – where most tannins are located – decreased in the harvestable biomass as plants grew older (Fig. 2). In the very young plants (5 weeks after sowing), leaves contributed 100, 80 and 100% to the harvestable biomass of *Onobrychis*, *Lotus* and *Cichorium*, respectively. At the end of the experiment, these contributions had decreased to 60, 35 and 80%, respectively, due to stem growth and leaf loss. With regard to the overall tannin concentration of the harvestable biomass, the increasing concentration of CT in the leaves was almost exactly balanced by a dilution effect due to the increasing proportion of 'tannin poor' stems in the harvest. As a result of these two effects, the tannin concentration of the harvest was nearly constant for all investigated species (Fig. 3): ca. 6% DM in *Onobrychis*, 2.5% DM in *Lotus* and <1% DM in *Cichorium*.

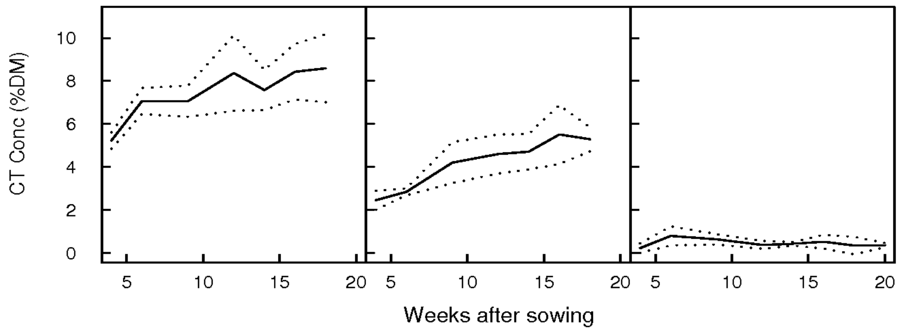

Figure 1. Concentrations of condensed tannins (CT conc.) in leaves during the experiment, as a percentage of the leaf dry mass (mean and 95% confidence interval). From left to right: *Onobrychis viciifolia*, *Lotus corniculatus*, *Cichorium intybus*

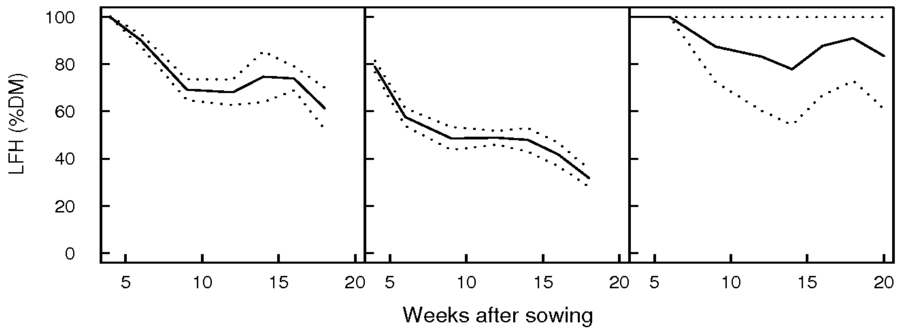

Figure 2. Leaf mass fraction of the harvestable biomass (LFH: g leaves / g harvest) during the experiment (mean and 95 % confidence interval). From left to right: *Onobrychis viciifolia*, *Lotus corniculatus*, *Cichorium intybus*

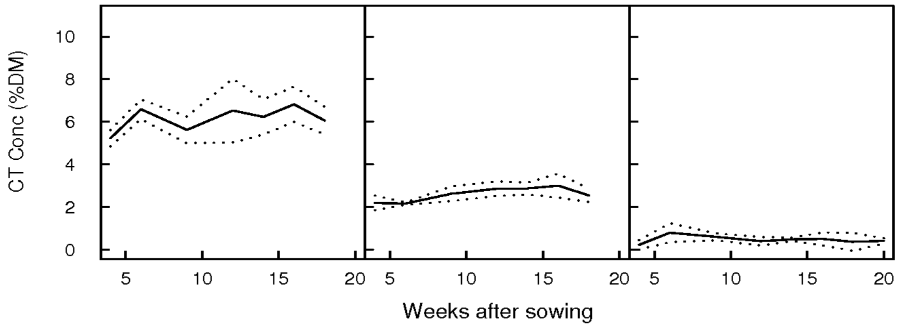

Figure 3. Concentrations of condensed tannins (CT conc.) in the harvest during the experiment (mean and 95 % confidence interval). From left to right: *Onobrychis viciifolia*, *Lotus corniculatus*, *Cichorium intybus*

Discussion

The tannin concentrations reported here are within the range of plant CT concentrations previously reported (Terrill *et al.*, 1992; Jackson *et al.*, 1996; Gebrehiwot *et al.*, 2002; Wen *et al.*, 2003). We found that tannins are mainly located in leaves and to a much lesser degree in stems. This is in agreement with a previous study on three *Lotus* species (Gebrehiwot *et al.*, 2002). With regard to seasonal dynamics, we found a pronounced increase in tannin concentrations in the leaves of *Onobrychis* and *Lotus,* whereas in *Cichorium*, the tannin concentrations were very low during the entire experiment. This is consistent with the observation that 'inherently low-tannin plants show little seasonal variation of CT concentrations' whereas greater seasonal variations have been reported for species with higher tannin concentrations (Gebrehiwot *et al.*, 2002). Tannin concentrations of the harvestable biomass were approximately constant for all investigated species due to a balance between the increasing tannin concentration in leaves and the decreasing fraction of leaves in the harvest. In contrast, previous results showing a pronounced decrease in CT levels of field-grown *Lotus* species in autumn (Roberts *et al.*, 1993; Gebrehiwot *et al.*, 2002), were explained by differences in temperatures, but might also have resulted from leaf loss at the end of the vegetation period. In another field study where *Lotus* from pastures was investigated, it was found that CT concentrations were highest in spring when leaf:stem ratios were highest, and then declined with the onset of grazing (Wen *et al.*, 2003). Our results further emphasise the importance of leaf:stem ratios for the prediction of CT concentrations. If, as shown in our study, the CT concentration of the harvestable biomass is constant during the season, an optimal time for harvest can be determined in relation to agronomic properties such as fodder quality and yield.

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Morphological, phenological and genetic changes in mono-variety swards of perennial ryegrass (*Lolium perenne*)

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Abstract

Synthetic varieties of perennial ryegrass (Lolium perenne) show a wide within-variety genetic variation. Thus, mono-variety swards may experience genetic changes during growth cycles with possible consequences on agronomic value. We analysed phenotypic and genetic changes that occurred in one variety grown in various sites under different exploitation regimes. Twelve swards of diploid perennial ryegrass, variety Herbie, were sampled at vegetative stage. The twelve sampled populations were transplanted to one site and compared to original seed lots under replicated designs. They were assessed for phenotypic traits (leaf elongation, tillering, heading date) and genotyped with 13 micro-satellite markers. Phenotypic traits exhibited a wide range of variation within the variety controls and within each sward. Significant differences in means among swards were demonstrated for some phenotypic traits, especially tillering rate and heading date. This was mainly due to the recruitment in some cut swards of a new morphotype with shorter leaves, more tillers and later heading. This study clearly demonstrated the occurrence of genetic changes in swards of perennial ryegrass. The underlying mechanisms and the agronomic consequences have to be investigated.

Keywords: perennial ryegrass, phenotypic traits, genetic changes, morphotype

Introduction

Perennial ryegrass (*Lolium perenne*) is a cross-pollinated species, where bred varieties are synthetics which exhibit a wide range of variation for most traits, including morphological characters or neutral molecular markers.

Breeding efforts were mainly devoted to improvement of productivity. However, in order to conciliate production and environment preservation attributes, increasing perenniality of sown swards appears to be a critical objective. Perenniality means the achievement of productive and high quality swards maintained over numerous growth cycles and years.

Numerous studies showed that, over time and in interaction with exploitation regimes and soil and climate constraints, production and forage quality of the sown swards declined. In grasslands with many species, these changes were associated with changes in botanical composition (Mosimann, 2002).

In swards with a single species, and even more with a single variety, the reasons for such changes in agronomic values have still to be identified. They can be associated with either random death of individual plants as an effect of aging, plastic response of plants to constraints, selective adaptation of the plant population to the conditions experienced by the population, or combinations of these mechanisms. Selective adaptation of plant population to constraints would mean non-random genetic changes.

Possible genetic changes of a single-variety sward have never been measured. Thus, our research objective was to analyse phenotypic and genetic changes that could occur in one variety grown in various sites under different exploitation regimes. This was undertaken with both phenotypic traits related to plant morphology, phenology and composition and with neutral molecular markers. The present contribution mainly deals with morphological and phenological traits.

Materials and Methods

The diploid cultivar Herbie was used. This cultivar, bred by Van Der Have (NL) and registered in 1990, is classified in the French VCU tests as mid-late for heading date.
Twelve swards were investigated. They were obtained by combinations of locations (5 locations across France), age of the sward (from 2 to 7 years) and the management (grazing *vs.* cutting) (Table 1).
In spring 2003, in each sward, 100 independent tillers were sampled with a minimum distance of 20 cm between two sampled tillers. Thus, it was considered that they corresponded to 100 different genotypes. All tillers were transplanted in one site (Lusignan) for vegetative propagation. The 100 genotypes collected in a sward will be later referred to as a population in the present paper. At the same period, two commercial seed lots of the variety, used as controls, were sampled and 100 individual plants per lot were produced. They were propagated alongside the collected populations.
In autumn 2003, two experimental designs were set up. In the first one, for each genotype, samples with a single tiller were transplanted in 20 cm deep trays in the greenhouse. The distance between samples was 10 cm in both directions. Two replicates were transplanted for each genotype. They were cut several times during the winter to ensure a good plant establishment and the trays were transferred outside in March 2004. The numbers of tillers per plant were counted 4 times during the year (in March, May, September and October). At the same dates, leaf and sheath lengths were measured on 3 tillers per plant. The dry matter yield and biochemical composition (nitrogen, ashes, solubility, sugars, cell wall) were also measured on each plant in May.
The second experiment was set up in the field. Each genotype was transplanted in three replicates in a randomised complete block design. The distance between adjacent plants was 70 cm in both directions. In spring 2004, heading date and plant height at heading were measured. The length of the culm leaf was measured on 3 stems per plant. Rust damage was scored on each plant in July on a 1-9 scale, with 1 for no disease symptom.

Results

As it can be seen from Table 1, small but significant differences in phenotypic traits were observed among collected populations and with the plants from seed lots. We only show the data for heading date, culm leaf length and number of tillers in May, but the situation holds true for most traits. Most of the variation clearly stood out within each population.
In order to investigate the structure within- and among-populations, a multi-variate analysis (PCA: Principal Component Analysis) was run. Both populations obtained from control seed lots were used as active individuals with the collected populations used as supplementary individuals. The data used for multi-variate analysis were the adjusted means for each genotype over replicates in both experiments.
Correlation analysis showed a significant negative correlation between plant height at heading and heading date. Thus, the late heading plants tended to be shorter. Leaf and sheath lengths were highly correlated at any date. All leaf lengths in both high-density trays and the field were correlated. Similarly, tiller numbers were highly correlated to each other. No correlation was found between number of tillers and leaf length, while leaf length was highly correlated to plant height. Rust score was positively correlated with plant height and leaf lengths.

Table 1. Differences among collected and sown populations for three traits

	Location	Age	Exploitation	Heading date (Julian days)	Culm leaf length (mm)	Number of tillers	% of high-tillering morphotype
1	St Ferreol (43.5N, 0.9°E)	2	Grazing	148.5	162	55.2	1
2	Ordiarp (43.18°N, 0.9°W)	4	Grazing	148.8	151	65.9	2
3	Le Pin au haras (48.45°N, 0.01°W)	2	Cutting	151.2	150	61.6	7
4		7	Grazing	149.9	150	63.4	0
5		2	Grazing	144.9	145	60.5	0
6	Theix (45.7°N, 3.02°E)	3	Cutting	149.5	147	60.5	0
7	Lusignan (46.26°N, 0.08°E)	4	Cutting	150.8	144	73.5	17
8		6	Grazing	150.2	147	75.6	1
9		3	Grazing	149.0	145	68.2	5
10		3	Grazing	150.6	143	67.0	4
11		2	Cutting	152.0	138	72.6	25
12		4	Grazing	148.6	149	61.0	0
Seed lot 1				150.5	145	54.4	0
Seed lot 2				148.7	152	64.5	0

This is partly illustrated by the correlation circle in Figure 1 for the 1st and 2nd axes of the PCA.

The first axis accounted for 26.46% of the total variation. It represented aerial morphogenesis (number of tillers, plant height, leaf length). The second axis accounted for 22.25% of the total variation and represented biochemical traits (nitrogen, ashes, solubility, sugars, cell wall). As it may be expected for a synthetic variety, individual genotypes of Herbie control seed lots showed a non-structured cloud. When plotting individual genotypes from collected populations, a number of individuals significantly differed from the original population. A high number of individual genotypes expressing a new morphotype was identified. This is illustrated in Figure 2 for population 11. This new morphotype was characterised by a higher number of tillers, with on average slightly shorter leaves and sheaths and a later heading date. It was not present in the original seed lots. In population 11, another group of plants with longer leaves than the original population was also detected.

The high-tillering morphotype was detected in some populations only. The frequency of occurrence was particularly high in the cut swards, while frequency was very low and even null in the grazed swards (Table 1). At the present stage of analysis, no relationship between age of sward and frequency of this new morphotype has been established.

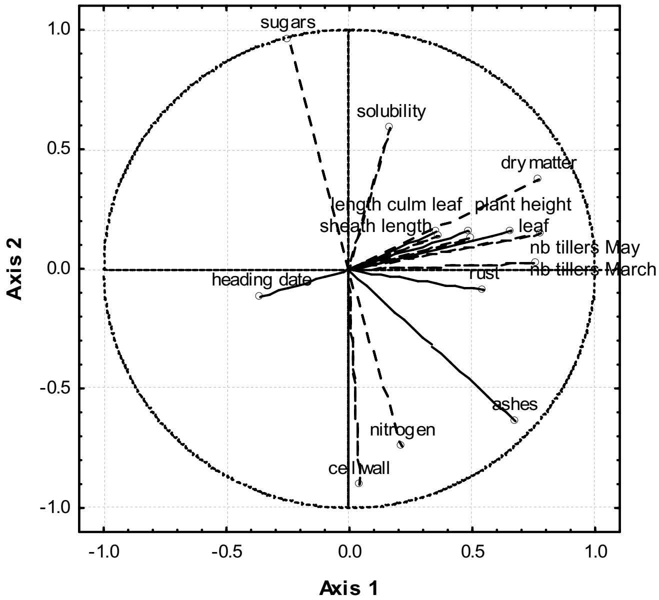

Figure 1. Correlation circle for PCA axes 1 and 2

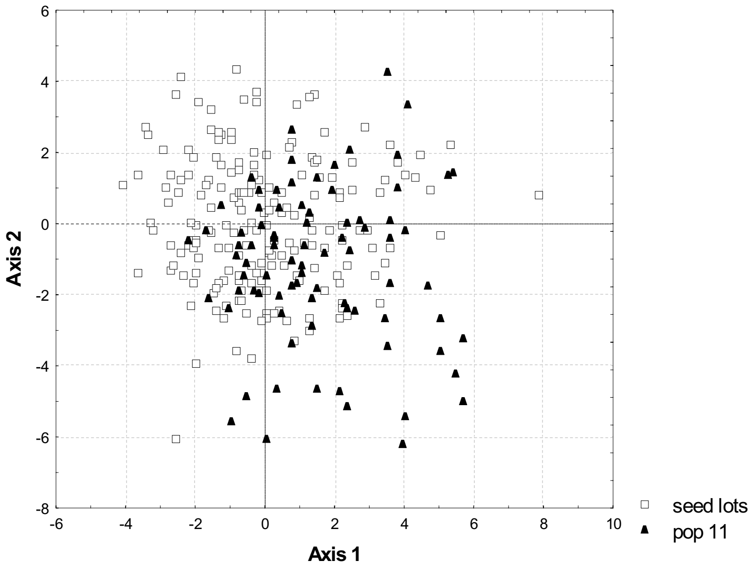

Figure 2. Distribution of the control seed lots and one collected population on PCA axes 1 and 2 scatter plot

Discussion

The present study clearly shows that changes in genetic composition expressed through phenological and morphological traits occur in perennial ryegrass swards. Even if a wide within-sward genetic variance was always present, changes were associated with the appearance of a high-tillering morphotype. This will be confirmed through the analysis of more physiological traits and molecular markers.

This discovery offers new prospects for investigation. Indeed, plant populations of grasslands, even sown temporary grasslands, cannot be regarded anymore as stable but as a dynamic system. The origin of the morphotype identified in the present study has to be established. The mechanisms determining the recruitment of such a morphotype are not clear and neither is its fate in the sward. The presence of higher proportions in cut swards is relevant to the fact that this exploitation regime offers more sites for seedling establisment, as described by Zobel *et al.* (2000) for the species richness. However, the source of seeds has to be questioned as it was demonstrated, again at the inter-specific level, that seed pool had a crucial importance in the maintenance or even the enrichment of the species and genetic richness of grasslands (Pärtel *et al.*, 1996; Tilman, 1997; Foster, 2001).

The consequences of the presence of such a morphotype on the agronomic value, especially production and forage composition, have also to be analysed. This new morphotype, and possibly other morphotypes that could be recruited under other conditions could be regarded as different functional groups (Lavorel et al., 1998) and contribute to the longer term fate of the swards.

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Effect of management intensity on sward productivity and root mass of a permanent meadow

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Abstract

The aim of the study was the comparison of different levels of management intensity on the productivity of permanent meadow on the grass root formation. The field trial was established in 2000 on the typical black-earth soil at moderately dry site. The old meadow was dominated by *Festuca rubra, Poa pratensis* and *Dactylis glomerata.* Three levels of intensity have been used: intensive management (6 cuts per year and 180 kg N ha^{-1}), moderate (4 cuts per year and 120 kg N ha^{-1}) and extensive management (2–3 cuts per year and 90 kg N ha^{-1}). During three following years the dry matter yield, changes in the botanical composition and root formation have been measured for each individual cut. The dry matter yield considerably increased under intensive management but grass root mass was higher under the less intensive grassland management. The average root mass under intensive management (high nitrogen fertilisation and more frequent cutting) in the level 0–10 cm was 1.38 kg DM m^{-2} compared to 1.55 kg DM m^{-2} in less intensive use. The results indicated that root degradation due to effect of intensive management could be the reason of grassland degradation.

Keywords: cutting frequency, grassland, low-input grassland, nitrogen, root grass formation

Introduction

It is known that root development depends on different factors like level of fertilisation, soil moisture, climate and botanical composition (Gaborcik, 1998) but it seems that one of the most important factors is cutting height and frequency (Rutkowska *et al*., 1980). When the sward is defoliated, the plant tries to restore shoot and stops root growth until the equilibrium between shoot and root has been restored (Brouwer, 1962). This indicates that intensive grassland management (high cutting frequency and nitrogen fertilisation) probably decreases grass root biomass. The objective of this work was to study the relationship between management intensity, grass root formation and sward productivity.

Materials and Methods

The studies took place in the years 2000–2002 in Experimental Station 'Jaktorów' near Warsaw. Field trials have been established on the black-earth soil (Typic Haplaquolls acc. to FAO) with pH of 4,8, content of organic carbon 25 g kg^{-1} of soil and nitrogen 0.75 g kg^{-1} of soil. Three levels of management intensity have been used: intensive management (6 cuts per year and 180 kg N ha^{-1}), moderate (4 cuts per year and 120 kg N ha^{-1}) and extensive management (2–3 cuts per year and 90 kg N ha^{-1}).

Each treatment was replicated eight times in a randomised complete block design. The experimental data were evaluated using analysis of variance (one way ANOVA). Botanical composition of sward was determined by visual observation and by botanical-weight method. The grass root mass has been taken by soil-core method (Rutkowska *et al*., 1980; Troughton, 1981) from two layers of the soil (0–10 cm and 10–20 cm) before each cutting each year. The samples of grass root were collected from each treatment, washed with tap water and dried at 20 °C. Climatic conditions and ground water table have been recorded in studies period within 2000–2002. Mean values of growing season have been shown in Table 1.

Table 1. Mean temperatures (°C), sum of annual precipitation (mm), level of ground water (cm) and Vinczeffy index in vegetation period within 2000–2002

	2000	2001	2002
Mean temperature (°C)	13.9	12.7	14.6
Sum of precipitation (mm)	311.3	413.0	383.2
Index of Vinczeffy	0.10	0.18	0.15
Mean level of ground water (cm)	–128	–112	–112

Results

Botanical composition has been changed during three vegetation periods depending on different levels of management intensity. In 2000 meadow sward was dominated by *Festuca rubra* (31.5%), *Poa pratensis* (29%) and *Dactylis glomerata* (13%). High frequent cuts and nitrogen fertilisation increased percentage share of *Festuca rubra* (36%). Moderate and extensive management caused increase *Dactylis glomerata* (36.8%). The yields of dry matter in the years 2000–2002 are presented in table 2. The highest yield was obtained in 2001 year. It was a year with favourable climatic conditions for grass growth and development according to Vinczeffy (Vinczeffy, 1984) (Table 1) The highest yield was harvested from the intensive management with the highest nitrogen fertilisation and cutting frequency of six cuts per year (the average from three years of study was 6.97 t ha^{-1}).

The main root mass (about 97% of total) was found in the top layer of the soil (0–10 cm), irrespectively of management intensity of permanent meadow. The effect of cutting frequency and nitrogen fertilization was significant especially in years 2001 and 2002 (Table 2). The extensive grassland management (3 cuts per year and nitrogen fertilization 90 kg N ha^{-1} y^{-1}) caused higher root mass accumulation in comparison to intensive management (6 cuts per year and 180 kg N ha^{-1}). Average total dry matter production (sum of root mass and above-ground production) indicated that the lowest production was found under the intensive management treatment, in spite of rather good grass yield (Figure 1).

Table 2. Mean grass root mass (kg DM m^{-2}) and yearly dry matter yield (t ha^{-1}) depending on intensity of management

Management	Grass root mass, kg DM m^{-2}				Dry matter yield, t ha^{-1}			
	2000	2001	2002	Mean	2000	2001	2002	Mean
Intensive	1.53a	1.30a	1.31a	1.38a	5.51a	8.95a	6.45a	6.97a
Moderate	1.55a	1.48b	1.38ab	1.47b	6.07ab	8.09a	5.62b	6.59b
Extensive	1.54a	1.65c	1.45b	1.55c	6.29b	6.70b	5.07b	6.02c
$LSD_{0.05}$	0.04	0.1	0.1	0.08	0.65	1.36	0.66	0.35

Values in column followed by the same letters did not differ significantly at the probability level of P = 0,05 according to Newman – Keuls q test

The highest cutting frequency and dose of nitrogen fertilisation increased the aboveground grass yield but decreasing the root mass production. It is also interesting that grass root mass (in top soil layer 0–10 cm) calculated as average for all cuts and treatments was about 1.5 kg DM^{-2} (15 t ha^{-1} y $^{-1}$), higher than shown in the previous studies (Rutkowska *et al*., 1980; Gaborcik, 1998; Tomaskin, 1997). Root accumulation and root 'yield' were also more stable than aboveground grass biomass (Table 2). Root formation and dynamic was depended on management intensity as has been shown at Figure 2.

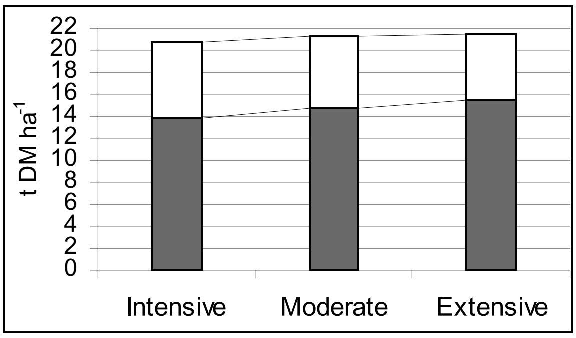

Figure 1. Relationship between root weight (grey) and dry matter yield (white) due to levels of management intensity (intensive, moderate, extensive) on permanent meadow (t DM ha^{-1})

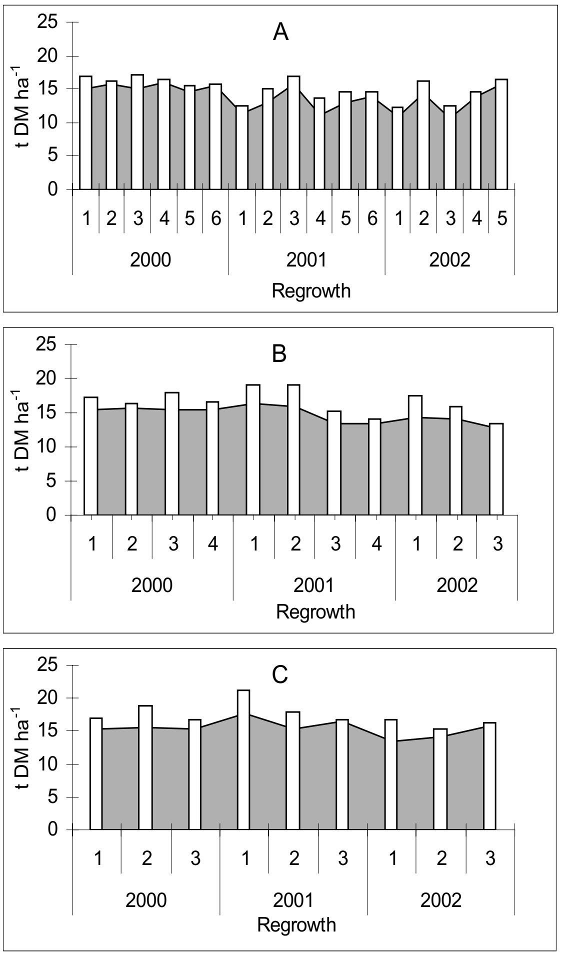

Figure 2. Grass root formation (grey) and total biomass (white) in regrowths due to management intensity (A – intensive, B – moderate, C – extensive) within 2000–2002 (t DM ha^{-1})

Discussion

It is known that grass roots are more resistant to degradation than roots of annual crops (Vertes *et al*., 2004). We should remember however that grass root development depends on the management intensity and root mass productivity decreases as a result of intensive management. This could be one of the reasons for degradation of grassland (Tomaskin, 1997) observed in many regions (Taube and Conijn, 2004). On the other hand however, it means that reduction of nitrogen input and cutting frequency will increase grass root biomass in the soil by about 11%. Grass root accumulation decreased during following years but variability of root mass was lower than changes of grass aboveground yield. The correlation between climatic conditions and root development was also demonstrated, the highest dry matter yield and root accumulation were found in the rather wet 2002 year but grass root development was better on the extensive management than on the intensive one. It seems that not enough attention is paid to the grass root development and degradation due to different grassland management systems and use intensity.

Conclusions

The effect of cutting frequency and nitrogen fertilization on root mass accumulation was significant especially in years 2001 and 2002. Management intensity significantly affected grass root accumulation and intensive management decreased root mass on permanent grassland by about 11%. In each year of three years of study grass root biomass was higher than dry matter yield of aboveground biomass and it was particularly clear in the case of extensive management (average root mass 15.5 t DM $ha^{-1}y^{-1}$ average DM grass yield 6.02 t ha^{-1} y^{-1}). Majority of grass root has been found in the top layer of soil (97% of total root accumulation).

Acknowledgements

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Grasshopper abundance in grassland habitats in Western France

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Abstract

Grasshopper (Acrididae) populations were sampled in different grassland habitats over a 350 km² study area (central-western France) in which agricultural intensification has led to a large decrease in grassland cover (less than 10% in 2002). In July 2003, a spatially random sample of 100 parcels of fodder legume crop, temporary and permanent grassland were studied for grasshopper abundance (density/m²), taking into account their management (grazing, mowing, or recent abandonment). A total of twelve grasshopper species were found, but genera *Chorthippus*, *Euchorthippus* and *Calliptamus* were dominant (more than 95% of total). The average density was 2.9 grasshoppers per m². Variability was high between spatially distant plots of the same grassland type, and between different grassland habitats in the same area. Density of *Calliptamus italicus* was 0.33 individuals per m² and it did not significantly differ between habitats. Average density of genera *Chorthippus* and *Euchorthippus* was 2.50 per m². Grasshoppers from these genera were more abundant in temporary grasslands regardless of type of management, than in permanent grasslands and fodder legume crops. Young fodder legume crops were the less favourable habitats. We discuss the implications of grassland management in terms of grasshopper abundance.

Keywords: biodiversity, agriculture, grasshopper, population density, alfalfa, meadow, set-aside

Introduction

Grasshoppers are a major group of herbivorous insects which can contribute more than half to the total arthropod biomass in grasslands (Baldi and Kisbenedek, 1999). While most studies on this group have addressed agronomic issues (typically negative effects of grasshopper feeding on plant growth), very few have pointed out their functional role as food resources for birds, as well as their potential use as bio-indicators for assessments of ecological change associated with land use (Andersen *et al*., 2001).

In France, agricultural intensification has led to a major decrease in grassland cover over the last 30 years that has been further accompanied by a more intensive use of the remaining grasslands. At the same time, birds associated with grassland habitats have experienced dramatic declines in conjunction with habitat degradation and (or) with scarcity of food resources. In the present paper we describe how different grassland types contribute to grasshopper abundances in an agricultural landscape where farmland birds are, to various extent, of conservation concern, and depend, at one stage or another, on arthropods for their diet.

Materials and Methods

Fieldwork was conducted from 11th July to 25th July 2003 over a 350 km² study area in the Poitou-Charentes Region (Western France). This area is a zone of mixed farming, where recent agricultural intensification has reduced grasslands to only 10% cover. All fields (about 12000) of the whole study area are mapped yearly using GIS within a large research program, conducted since 1994, looking at crop rotations, entomological and ornithological observations. One hundred plots were randomly selected among the grassland fields of the study area. Fallow fields with shrubs were not sampled. The different types of grassland crops included fodder legume fields (alfalfa and clover) less than five years old, temporary grasslands (less than five years old), and permanent grasslands (more than 5 years old). Management by grazing and (or) mowing was also noted.

Grasshoppers were sampled on a field basis by means of removal-trapping by hand-catching inside a cage of 0.7-m high and 1-m x 1-m basis, that was thrown at random within the field ten times. The cage was made of a copper frame surrounded with a canvas mesh. We counted the number of grasshoppers (nymphs and adults) per sample unit (1 m^2). All species were assigned to one of three groups: *Calliptamus* spp., *Chorthippus* spp. – *Euchorthippus* spp., and all other grasshopper species. To identify the dominant species, one adult out of ten was collected for laboratory identification. At the time of the sampling in July, vegetation height and coverage of dominant plant species were determined.

SAS software version 8.1 was used for the analysis of variance performed on mean number of individuals per m^2 per plot, for a combination of grassland types and management types according to seven groups (Table 1). Significance level was set at 0.05.

Results

Twelve grasshopper species were captured but some were rare, e.g. *Aiolopus thalassinus* F., *Chorthippus albomarginatus* De Geer, *Chorthippus dorsatus* Z., *Chorthippus parallelus* Z., *Euchorthippus declivus* B., *Mecosthetus parapleurus* H., *Omocestus rufipes* Z. Dominant species were *Chorthippus biguttulus* L. which was present in 60% of the fields, *C. italicus* (58%) and *E. pulvinatus gallicus* M. (57%). *Pezotettix giornai* Rossi was associated with *C. italicus* in 18% of the samples. Grasshopper relative abundance was mainly accounted for by *Chorthippus* and *Euchorthippus* (84.8%) while *C. italicus* represented a further 11.5% of the total number of grasshoppers caught.

Table 1. Mean number of grasshoppers per m^2 in different grassland habitats (standard errors in parenthesis), and results of the analysis of variance

Grassland habitat	Management type	Number of fields	*Calliptamus italicus*	Gr *Chorthippus / Euchorthippus*
Temporary	Mowing	23	0.32 (0.10)	3.46 (0.61)
Temporary	Grazing	7	0.60 (0.18)	5.34 (1.10)
Temporary	Recent abandonment	21	0.48 (0.10)	2.55 (0.64)
Permanent	Mowing	12	0.23 (0.13)	1.35 (0.84)
Permanent	Grazing	8	0 (0.17)	0.65 (1.03)
Permanent	Recent abandonment	8	0.19 (0.17)	0.97 (1.03)
Fodder legume crop	Mowing	10	0.11 (0.15)	0.77 (0.92)
Analysis of variance: 2–88 df			F = 1.83 Pr >F = 0.10	F = 3.28 Pr >F = 0.006

The average density over the study area was 2.9 grasshoppers per m^2 but means per field ranged from 0 to 19.5 individuals per m^2. Density of *C. italicus* per plot never exceeded 2.9 (average density was 0.33), while density of grasshoppers from the group of *Chorthippus*/ *Euchorthippus* reached 18.7 individuals per m^2 in some samples (average density was 2.5). Densities of other species were comparatively much lower. There was no significant effect of grassland/management type on *C. italicus* density (Table 1) possibly as a result of rather low densities combined to high variance. Conversely, density of *Chorthippus / Euchorthippus* per m^2 was significantly different across grassland and management types (Table 1). Temporary grasslands were the most favourable whatever their management (mean density per m^2: 3.35 ± 0.41 (SE)), while permanent grasslands and fodder legume crops were less favourable (Table 1) whatever their management (permanent grasslands: 1.04 ±0.55 (SE); fodder legume crops: 1.08 ± 0.84 (SE)). Within temporary grasslands, grasshopper density varied with crop age (Figure 1): grasshopper densities of the two main species groups increased from one year old parcels to 3–4 years old parcels, and then decreased afterwards.

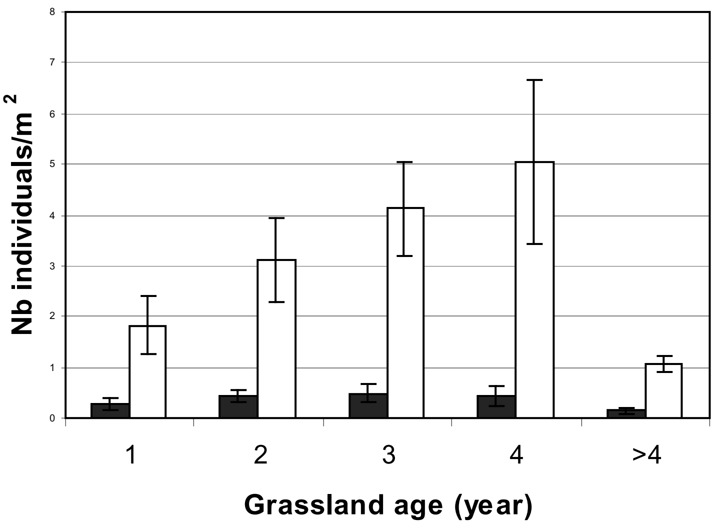

Figure 1. Means and standard errors of the number of grasshopper per m^2 (*Calliptamus italicus*: black columns; *Chorthippus/Euchorthippus*: white columns) in grasslands (fodder legume crops excluded) according to their age

Discussion

Species diversity of grasshoppers found in this study was rather low, and only four species (*E. pulvinatus, C. biguttulus, C. italicus* and *P. giornai*) were dominant in terms of their presence and absolute densities. These four species are known to prefer dry and warm habitats (Descamps, 1968; Louveaux *et al*., 1988). Fields usually contained more than one species, but when only one species was caught, it was often *E. pulvinatus* or *C. biguttulus* (though at very low densities). Some of the fields sampled in 2003 had already been sampled in previous years, and indicated that densities in 2003 were higher than in 1999 (1.06 per m^2), 2000 (0.93 per m^2), 2001 (1.66 per m^2), and 2002 (0.66 per m^2). This may be related to the particular climatic conditions in France in 2003 during spring and summer, exceptionally dry and warm.

Calliptamus spp densities were not affected by grassland type combined with management, but genera *Chorthippus/Euchorthippus* spp clearly showed higher densities in temporary grasslands. Grasshopper density must be low in the first year of a grassland because of the time required to colonise the crops after ploughing (which destroys eggs in the soil).

However, optimal age was found to be 3–4 years in this study, i.e. density was higher than in old grasslands. Moreover, fodder legume crops (such as alfalfa) held surprising low densities compared to other arthropod groups (e.g. Bournoville, 1989). However, all fodder legume crops except one were one year old, so that grasshoppers did not have enough time to colonise these habitats. Management by grazing, cutting or recent abandonment had the same effect on grasshopper densities whatever the species (average densities were respectively 3.1, 2.6 and 2.8 grasshoppers per m^2). Tatin *et al*. (2000) have shown that grazing does not affect population density for *E. declivus*, *C. biguttulus* and *C. italicus* if they are not too much intensive. Guido and Gianelle (2001) found that cutting had different effects on grasshopper abundance according to the grasshopper communities, but one cutting a year is claimed to have no depressive effect on many species. The high variability that we observed between fields managed by grazing or cutting could be explained by the variability of their intensity (Capinera and Sechrist, 1982), and by the amount of fertilizer applications. Low fertilization has been found to increase grasshopper abundance while high fertilization levels lead to a decrease in abundance and in species diversity (Wingerden *et al.,* 1992).

Conclusions

Grasshopper densities in grassland habitats were 2.9 individuals per m^2 in 2003 over our study area, mainly due to four dominant species. Grassland habitat effect combining botanical composition and grassland age, was important for genera *Chorthippus/Euchorthippus*. Management by cutting, grazing or abandonment had the same effect on grasshopper abundance due to the high variability between plots. More studies are needed to quantify the effect of intensity of management on grasshopper abundance.

Acknowledgements

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The yield potential of Estonian perennial ryegrass (*Lolium perenne* L.) cultivars at different mineral fertilisation levels and cutting frequencies

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Abstract

A field experiment was undertaken in 1998 to study the effect of three factors – cultivar, cutting frequency and fertilisation level on the production potential of perennial ryegrass (*Lolium perenne* L.). Estonian cultivars 'Raidi' (diploid) and 'Raite' (tetraploid) were cut either four or six times in a season. Annual mineral compound fertiliser application rates were equivalent to 0, 80, 160, 240, 320 and 400 kg nitrogen (N) ha^{-1} for plots cut at heading stage, and 0, 100, 200, 300, 400 and 500 kg N ha^{-1} for plots cut at shooting stage (to simulate grazing). As an average of 1999–2000 linear ($r = 0.99$) and significant ($P<0.001$) dry matter (DM) and crude protein (CP) yield response to N occurred for each harvest at both defoliation frequencies. As an average of the management systems, the DM and CP yield potential of cv. 'Raite' exceeded that of cv. 'Raidi' by 2–5%. The CP content was satisfactory (>140 g kg^{-1}) for high producing dairy cows at N application rates of 300 kg ha^{-1} (or greater) for simulated grazing and at least 400 kg ha^{-1} when cut for silage. Production of CP per N unit was greater at both lower (due to better nitrogen use efficiency of the plants) and higher fertiliser rates (caused by high CP content relative to the lowest marginal N response quantified as DM production), than at intermediate rates. The highest yields were obtained at maximum fertilisation rates: cutting four times a year resulted in DM production of 12.2 t ha^{-1}. More frequent defoliation was an effective means in increasing the CP yield up to 2.2 t ha^{-1} when the fertiliser rate was equivalent to 500 kg N ha^{-1}.

Keywords: nitrogen, cutting frequency, simulated grazing

Introduction

Cool season perennial grasses exhibit a positive yield response to mineral fertilisation and manuring. Nitrogen (N) has become one of the most important aids in increasing output from grassland (Kopec *et al*., 1992; Whitehead, 1995). The quantities of nitrogen applied are largely determined by the species' yield potential and soil N supply, but in temperate climates the typical recommendation for perennial grassland under intensive management remains between 200 and 400 kg N ha^{-1} (Kopec *et al*., 1992; Whitehead, 1995).

Dairy husbandry in Estonia is on the brink of marked changes, with many producers shifting towards intensive systems of production. During the past decade, a shift has occurred from slow growing grass species to species and cultivars with rapid regrowth and high yield potentials, but poorer overwintering abilities. In this regard perennial ryegrass is gaining popularity as it is tolerant to intensive management, but is susceptible to drought and has rather poor winterhardiness. However, tolerance to adverse weather conditions and winter resistance may enhance markedly when plants are provided with abundant N (Toomre, 1965).

The aim of the current research is to determine the optimum fertiliser rates and defoliation frequencies of perennial ryegrass to take maximum benefit from the DM and CP production potential of two cultivars, released by Jõgeva Plant Breeding Institute in 1993 and 2003.

Materials and Methods

The experiment was established in August 1998 on a calcic luvisol with a pH_{KCl} 6.0, humus concentration of 21.0, N 1.4, phosphorus (P) 0.122 and potassium (K) 0.074 g kg^{-1}, respectively. The amounts of N, P and K applied before sowing were 60, 13 and 25 kg ha^{-1}, respectively. Estonian perennial ryegrass cultivars 'Raidi' (diploid) and 'Raite' (tetraploid) were seeded at a rate of 30 kg ha^{-1}. Plots of 5.88 m^2 were randomised in a complete block and replicated three times. Two management regimes were used: imitation of grazing with 6 cuts at late tillering to stem elongation stage and cutting 4 times per season at heading. The plots were cut by a combine harvester Hege 212. Compound fertilizer Kemira Power 18 (N 18 P 4 K 7.5 + Ca, Mg, S, B and Se) was used in order to fully exploit the ryegrass yield potential. The yearly rates of nutrients applied in the harvest years 1999-2000 are shown in table 1. These were split into five equal top-dressings at simulated grazing and into four at cut swards. Grass samples of 200 g were analysed for N content according to Kjeldahl procedure and DM concentration. The data collected from two management systems were averaged over the two harvest years and subjected to ANOVA using the programme Agrobase 20.

Table 1. Yearly rates (kg ha^{-1}) of plant basic nutrients applied to the perennial ryegrass plots subjected to simulated grazing or cutting

Simulated grazing with 6 cuts	Cutting 4 times
N 0 P 0 K 0	N 0 P 0 K 0
N 100 P 22 K 42	N 80 P 16 K 33
N 200 P 44 K 84	N 160 P36 K 66
N 300 P 66 K 126	N 240 P 52 K 99
N 400 P 88 K 168	N 320 P 68 K 132
N 500 P 110 K 210	N 400 P 84 K 165

Results and Discussion

Both diploid and tetraploid varieties exhibited a linear (r = 0.99) and highly significant ($P<0.001$) increase in DM and CP yields in response to mineral fertilisation levels up to 400 or 500 kg N ha^{-1} in swards subjected to cutting or simulated grazing, respectively (figures 1 and 2). Similar results have been obtained in previous studies (Toomre, 1965). Yield of DM obtained at fertiliser rates above 300 kg N ha^{-1} coincide with those typical for intensively managed grasslands in temperate regions – 8 to 15 t DM ha^{-1} (Whitehead, 1995). DM yields produced in current experiment partly confirm the validity of a grass production simulation model described by Topp and Doyle (2004). According to the model developed for the agroclimatic zone that encompasses Estonia, the application of 200 kg N ha^{-1} should give a DM yield response of 6,495 kg ha^{-1}. This is in agreement with the DM production at the same fertilisation level in current study. Yet, the model seems to underestimate the grass DM yields when 400 kg N ha^{-1} was applied, especially with infrequent defoliation. The grass DM production calculated according to the model is 8,641 kg ha^{-1} whilst the mean DM production of the two perennial ryegrass cultivars was by 1736 (simulated grazing) and 3332 kg ha^{-1} (cutting) higher at Jõgeva (Figure 1).

The annual average DM and CP yields of cv. 'Raite' under simulated grazing surpassed those of the diploid cv. 'Raidi' up to the N application rates of 300 kg ha^{-1} (Figures 1 and 2). However, all the yield differences between the two cultivars were not significant ($P>0.05$). The diploid cultivar demonstrated its better response to nutrient application, when the N rates exceeded 400 kg ha^{-1}. If cut at silage maturity, 'Raite' demonstrated significantly better DM yield potential at all fertiliser treatments. Increasing the annual N fertilisation from 0 till 400 kg ha^{-1} at silage system and till 500 kg N ha^{-1} at simulated grazing caused highly significant DM and CP yield gains in successive treatments.

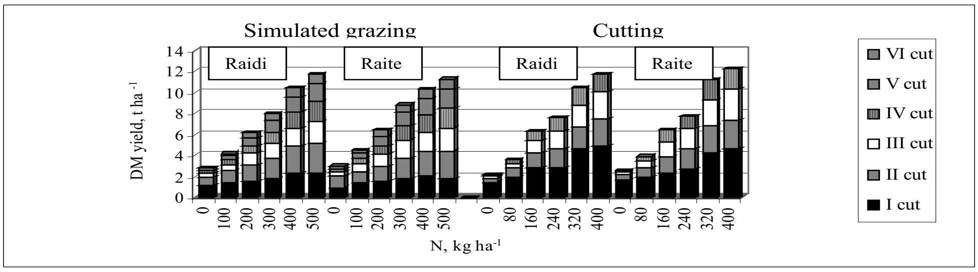

Figure 1. Dry matter yield of perennial ryegrass cultivars 'Raidi' (diploid) and 'Raite' (tetraploid) at different defoliation regimes. Significant effects (P<0.001) of nitrogen at both defoliation frequencies and cultivar effect (P<0.05) do exist at cutting

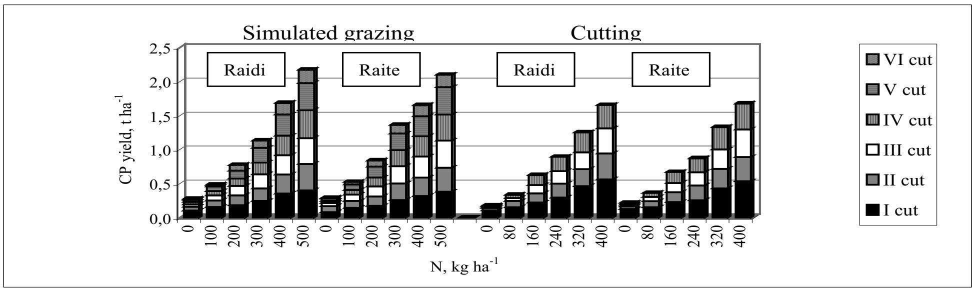

Figure 2. Crude protein yield of perennial ryegrass cultivars 'Raidi' (diploid) and 'Raite' (tetraploid) at different defoliation regimes. Significant effects (P<0.001) of nitrogen at both defoliation frequencies and the interaction between the cultivar and nitrogen rate do exist (P<0.05) at simulated grazing

To meet the protein demand of high producing dairy cattle, forage crops should contain at least 14 or 16 g CP kg^{-1} DM if grazed or ensiled, respectively (Tõnurist, 1982; Older *et al*., 2000). Increasing the mineral fertiliser rates enhanced the mean CP content of the ryegrass cultivars from 116.5 to 192.9 g kg^{-1} DM at frequent and from 96.6 to 152.9 g kg^{-1} DM at infrequent defoliation. Under simulated grazing of studied ryegrass cultivars the fertiliser rate equivalent to 300 kg N ha^{-1} will assure the required forage CP concentration, while at least 400 kg N ha^{-1} is required for the swards defoliated in a later stage.

At the first cut a large increase in DM production as a result of N application is obtained. With the studied cultivars the first silage cut accounts for at least 34–37% (at 240 kg N ha^{-1}) of the annual DM yield. With unfertilised plots the respective figure (64–68%) relates to the depletion of soil nutrient reserves prior to the start of the growing season. If a simulated grazing regime together with maximum fertilisation rates was imposed on perennial ryegrass, the proportion of the first harvest within the total DM yield was reduced to 16–20%, i.e. less than half that for unfertilised plots (31–40%). Thus, the lower the fertilisation level, the less the production potential of ryegrass can be exploited at subsequent harvests.

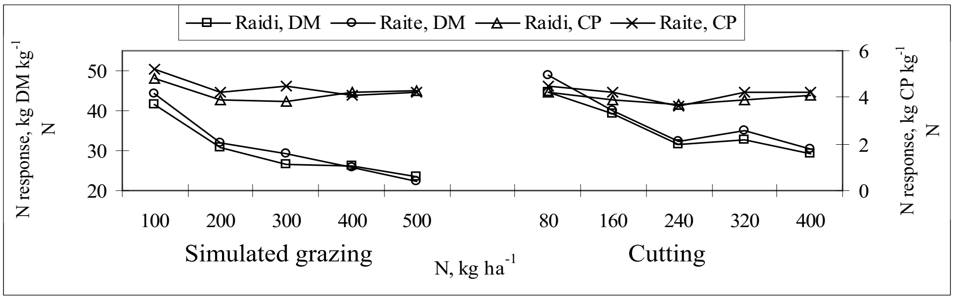

Figure 3. Marginal nitrogen response of perennial ryegrass cultivars 'Raidi' (diploid) and 'Raite' (tetraploid), quantified as dry matter and crude protein production

The diploid cv. 'Raidi' was characterized by more intensive growth earlier in the season. Due to the higher susceptibility of 'Raite' to snow mold (*Fusarium nivale* Ces.) infection, it took several weeks to recover thereby restricting initial growth. In comparison with the diploid, regrowth of the tetraploid cv. 'Raite' was more vigorous after the second silage cut or third simulated grazing at all fertiliser treatments.

Although the different fertilisation levels give a significant positive response, the marginal N response should be regarded as an essential parameter for choosing an appropriate nutrient application rate. Fertilisation efficiency reduces with increasing N application (figure 3). The longer intervals between silage cuts vs. simulated grazing cycles allow the increase of DM production for the last kilogram of N applied, i.e. the marginal N response. Low N application rates tend to raise mainly DM yields, while the CP content will not rise markedly. At N rates above 150–200 kg N ha^{-1} the DM yield of grass will increase relatively less compared with its CP content (Toomre, 1965). This explains the lowest marginal N response quantified as a CP production at intermediate fertilisation levels.

Conclusions

Spring growth of diploid cv. 'Raidi' is more vigorous at both defoliation frequencies. Tetraploid cv. 'Raite' is characterised by more stable production across the growing season. Significant increases in forage CP content and yield were achieved with increasing N supply, but mainly through reducing the intervals between harvests and increasing the number of harvests per year. To meet the cow's nutritional requirements for CP, proper N application rates for the Estonian perennial ryegrass cultivars should be at least 300 or 400 kg ha^{-1} if the grass is grazed or cut for silage, respectively. The silage plots fertilised with 320 or 400 kg N ha^{-1} produce DM yields equal to or bigger than more frequently defoliated plots that received 400 or 500 kg N ha^{-1}. With perennial ryegrass it is possible to attain DM yields exceeding 12 t ha^{-1} and CP yields over 2 t ha^{-1} by imposing 4 or 6 cuts to the swards, respectively. Economic N application rate is higher than the environmentally acceptable 170 kg ha^{-1} as a mean of crop rotation, which will result in reduced DM and CP production.

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A comparative study of simple and complex 'grass-legume' mixtures implanted with or without cover crop

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Abstract

Grass/legume mixtures are often used, in organic farming systems, to improve system productivity and therefore to provide autonomy towards nitrogen resources. However, is the productivity and quality of the forage obtained a function of the mixture complexity?
A temporary grassland trial, in four blocks, was established in 2001 in the south-eastern part of Belgium. In this trial, a complex (5 grass species with 4 legume species) and a simple (2 grass species with 1 legume species) grass/legume mixtures, sown with or without cover crops, were compared. DM yield, nutritive value and botanical composition of the swards were measured over 3 seasons.
Grassland sown under cover crops showed a better yield in the first year but no additional differences were underlined thereafter. No significant difference has been highlighted between the complex and the simple mixtures neither from their dry matter yield nor from their feeding value. In the complex mixture, only one legumes species out of four has persisted more than one winter. In consequence, under our soil and climatic conditions, the most profitable grass/legume mixture was the simplest one's.

Keywords: temporary grassland, grass/legume mixture, cover crop, organic farming

Introduction

During last decade, after a long period of intensive farming systems promotion and following the emergence of different environmental problems (water pollution by nitrate, climatic changes, biodiversity erosion, …), European agricultural policies have searched to favour systems with lower level of inputs.
Such a context has motivated grassland researchers to focus their attention on the study of legumes use and potential in ruminant livestock production systems. Indeed, following its nitrogen fixation in symbiosis with *Rhizobium* bacteria, legume use can lead to high yields of good quality forage. Additionally grass/legume mixture seems to stabilize sward composition by reducing weed invasion (Sanderson, 2004).
Now, some authors underline the superiority, in term of productivity, of complex grass/legume mixtures in comparison with simple ones (Daly *et al.*,1996 cited by Hopkins, 2004; Tilman *et al.,* 1996 and Hector *et al.,* 1999. cited by Drake, 2003). Such results being explained by a better exploitation of soil resources by the complex mixture. However, others authors emphasize the importance of legume presence in the mixture rather than of the grass/legume mixture complexity.
The aim of the experiment reported here was to compare productivity, quality and botanical composition evolutions of complex and simple grass/legume mixtures sown and managed respecting organic farming rules.

Materials and Methods

The study site is located in the south-eastern part of Belgium (49°55´N – 5°22´E, altitude about 480 m above sea level). A temporary grassland trial was established in 2001 (23rd May)

in a field converted to organic farming since September 1997. The grassland was preceded by a triticale-pea mixture crop. The soil is a loam characterised by a large amounts of stones.
The performances of a complex [CM] (*Lolium perenne* (26%, as weight proportion), *L. multiflorum* (13%), *Phleum pratense* (17%), *Dactylis glomerata* (7%), *Festuca pratense* (7%), *Trifolium repens* (17%), *T. hybridum* (17%), *Lotus corniculatus* (3%) and *Medicago lupulina* (3%)) and a simple [SM] (*Lolium perenne* (64 %), *Phleum pratense* (26 %) and *Trifolium pratense* (11 %)) grass/legume mixtures were compared during 3 seasons (one year of establishment and two years of plenty production). Each mixture was sown, at a rate of 40 kg ha^{-1}, with or without cover crops. Detailed information on the type of cover crops and their respective sowing rates are given in Table 1.
Experimental design was a completely randomised block design with four replications. Elementary plot size was of 8 × 1.5 m. Fertilisation scheme was as follow:

- in 2001, before sowing: 15 t of composted cattle manure ha^{-1} (fertilising value: 6 kg of N, 1.9 kg of P and 4.5 kg of K per tonne of fresh product) and a phosphorus correction of 56 kg P ha^{-1}, under the form of natural Gafsa,
- in 2002: a phosphorus correction of 79.5 kg P ha^{-1}, under the form of natural Gafsa,
- in 2003: 17 t of composted cattle manure ha^{-1} and a phospho-potassium correction of 30.5 kg P ha^{-1} (Gafsa) and 67 kg K ha^{-1} (Patenkali).

Three cuts were harvested each year, except during the sowing year where only two cuts were completed. Dry matter yield and grass nutritive value were measured for each plot at each cut, during the 3 seasons. Botanical composition was recorded yearly, in September, during all the trial lasting while sward mineral composition was measured for the two first cuts of the first full exploitation year and this for the pure mixtures and for the mixtures sown under "*Avena-Pisum*" cover crop.

Table 1. Sward mixture codes in accordance to their composition and to cover-crop species

Complex mixture (CM) or simple mixture (SM) without cover crop	
Simple mixture (SM+AP)	+ *Avena sativa* (80 kg ha^{-1}) and *Pisum sativa* (30 seeds m^{-2}) as cover crop
Complex mixture (CM+AP)	+ *Avena sativa* (80 kg ha^{-1}) and *Pisum sativa* (30 seeds m^{-2}) as cover crop
Complex mixture (CM+A)	+ *Avena sativa* (80 kg ha^{-1}) as cover crop
Complex mixture (CM+M)	+ *Setaria italica var. moharica* (15 kg ha^{-1}) as cover crop
Complex mixture (CM+T)	+ *Trifolium alexandrum* (15 kg ha^{-1}) as cover crop

Statistical analyses were performed using a two ways ANOVA, with a mixed model (proc GLM – SAS). The two factors taken into account were the 'mixture' (fix – 7 levels (4 levels for sward mineral composition analysis)) and the 'block' (random – 4 levels). The factor mixture was tested against the interaction 'mixture*block'. Contrast allowed to performed specific comparisons: mixture or cover crop effects, while integrating only 'pure' and 'AP' modalities. Multiple means comparisons were performed with Student-Newman-Keuls test.

Results and Discussion

The complex and the simple mixtures allowed to reach very similar performances (Table 2). So when comparing the modalities 'SM' and 'SM+AP', on the one side, to the modalities 'CM and CM+AP', on the other side, we couldn't find any significant differences during the sowing year or the first year of full exploitation, while taking into account dry matter yield and sward nutritive value. During the second year of full exploitation, DM yield (+5.5%)

(F(1.18) = 16.0; p < 0.001) and energy production (+6.8%) (F(1.18) = 20.1; p < 0.001) of SM was significantly higher than for CM. However, the high proportion of red clover (Figure 1) in SM didn't give significant difference in protein content. This result could be explained by the proportion of cocksfoot and hybrid clover in CM, both species being rich in protein content.

During the sowing year, the cover-crop "*Avena-Pisum*" allowed to increase significantly, whatever the mixture taken into account, dry matter (+12% for CM and +14% for SM) (F(1.18) = 30.9; p < 0.001) and energy (+5.7% for CM and +13.4% for SM) (F(1.18) = 27.7; p < 0.001) productions. There was no additional impact of this cover crop during the two years of full exploitation.

Table 2. Annual dry matter yield [DM] (t ha^{-1}), energy production (10^6 VEM) and crude protein content (g kg^{-1}) from the two mixtures under the different cover-crop

Mixtures	2001			2002			2003		
	DM	Energy	Protein	DM	Energy	Protein	DM	Energy	Protein
CM	5.6^{b}	4.9^{b}	14.4^{a}	15.1^{a}	12.3^{a}	13.6^{ab}	10.4^{b}	9.0^{b}	14.1^{a}
CM+A	6.5^{ab}	5.5^{ab}	12.2^{a}	14.1^{a}	11.4^{a}	14.0^{ab}	9.6^{b}	9.0^{b}	14.2^{a}
CM+AP	7.1^{a}	6.0^{a}	13.2^{a}	15.2^{a}	12.2^{a}	13.7^{ab}	10.3^{b}	8.9^{b}	14.0^{a}
CM+M	6.2^{ab}	5.2^{ab}	13.4^{a}	15.9^{a}	12.9^{a}	13.1^{b}	9.9^{b}	8.6^{b}	13.6^{a}
CM+T	6.4^{ab}	5.3^{ab}	13.9^{a}	14.9^{a}	12.1^{a}	13.0^{b}	10.3^{b}	8.5^{b}	14.6^{a}
SM	5.2^{b}	4.5^{b}	14.7^{a}	14.7^{a}	11.8^{a}	13.7^{ab}	11.6^{a}	10.3^{a}	15.0^{a}
SM+AP	7.2^{a}	5.9^{a}	12.7^{a}	14.1^{a}	11.4^{a}	14.6^{a}	11.7^{a}	10.2^{a}	14.4^{a}

Values marked by different letters within the same column are significantly different (p<0.05).

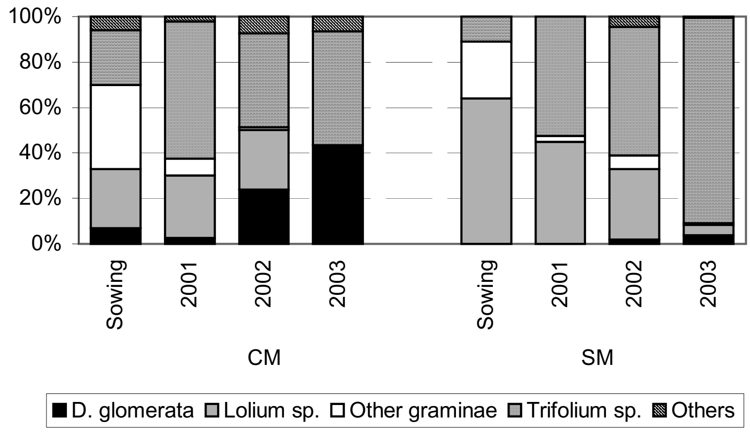

Figure 1. Evolution of the botanical composition of the CM and SM, without cover-crop, during the three years of exploitation

Concerning the botanical composition of the mixtures, sown without cover-crop, there was a clear evolution during the three years of observation (Figure 1). Some species (*Festuca pratense, Lotus corniculatus* and *Medicago lupulina*) that have been sown in the CM were never recorded by the B% method. Others species such as *Phleum pratense*, representing the other graminae in SM, had never represented an important part of forage production. There was a clear evolution of the CM botanical composition towards an association of cocksfoot and hybrid clover, evolution accelerated by the drought summer of 2003 and by the use of a significant part of *Lolium multiflorum* in the mixture. In the SM, following the drought

summer of 2003, there was a big domination of the red clover over the perennial rye-grass. In this trial there was no clear effect of cover-crop use on weed pressure evolution.
There was no effect neither of the mixture complexity nor of the cover crop utilisation on the K, P or Mg sward content. While Na ($F(3.9) = 9.11$; $p = 0.004$) and Ca ($F(3.9) = 8.93$; $p = 0.005$) concentrations were highly significant influenced by the mixture type: the SM showing the highest concentrations (Table 3). This could be linked to the higher legume content of this sward.

Table 3. Mineral concentration (g kg^{-1}) of the forage collected during the two first cuts of the first full exploitation year

	K	P	Na	Mg	Ca
CM	30.57[a]	2.55[a]	0.145[b]	3.19[a]	10.34[b]
CM+AP	30.23[a]	2.54[a]	0.145[b]	3.24[a]	10.53[b]
SM	30.01[a]	2.40[a]	0.200[ab]	3.30[a]	11.27[a]
SM+AP	30.98[a]	2.52[a]	0.230[a]	3.31[a]	11.11[a]

Values marked by different letters within the same column are significantly different ($p<0.05$)

Conclusions

All the mixtures allowed to reach good and similar performances. The only advantage of the CM lies in a better persistence of cocksfoot under summer drought leading to a better grass/legume ratio for silage making. The high legume proportion observed with the simple mixture, during the second year of full exploitation, explained its higher performances and Ca and Na contents.
However, seed cost is higher for the complex mixture. Some species, like *Festuca pratense, Lotus corniculatus* and *Medicago lupulina,* added in the complex mixture, are not adapted to our soil and climatic conditions. Some influent factors like soil, climate, fertilisation favour some species in the mixture. These species dominate more or less rapidly the others that have often a secondary importance. So, the biodiversity advantage of such complex mixture, proposed in organic farming for temporary grassland, is weak under our conditions.
The use of an '*Avena-Pisum*' cover-crop during the sowing year remains a good alternative to improve yield potential with the production of a forage of good quality if cut at flowering stage for the pea and oat.

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Influence of long-term levelled nutrient supply on the biodiversity and forage quality of mowing pastures

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Abstract

This study aims to quantify the long-term effect of different N-, P-, K-supply combinations on the biodiversity and forage quality of mowing pastures. During 17 consecutive years four pastures, located on mineral soils in Central Germany between 210 and 620 m above sea-level and classified as *Lolio-Cynosuretum*, have been fertilised annually with 27 different N-, P-, K-supply combinations. Subsequently the DM contribution of the plant species recorded were estimated and first growth samples from selected supply combinations were analysed on energy and protein content. Biodiversity is expressed in terms of the species number and the Shannon-Index. Nitrogen supply reduces the number of species and dependent on site characteristics increases or decreases the Shannon-Index. Regarding the Shannon-Index site-specific analysis significant influences of the interactions P x K and P x N occur. Here solely without P-supply the Shannon-Index is not reduced by N-supply, whereas at the highest P-supply level the Shannon-Index is reduced by K-fertilisation. Nitrogen fertilisation increases protein content and mostly decreases energy content, increasing P- and/or K-supply does not show an unambiguous effect on energy and protein content.

Keywords: biodiversity, fertilisation, interactions, forage quality, *Lolio-Cynosuretum*

Introduction

The increased use of mineral fertilisers clearly benefited the agricultural productivity of grasslands (Chapman, 2001). The general effect of N fertilisation on grasses is an increase in dry matter yield and protein content. Some studies have reported increases in digestibility of N fertilised forage while others have reported no difference due to the application of N fertiliser (Noller and Rhykerd, 1974). The application of P or K usually has little or no effect on the concentration of crude protein in grass herbage (Whitehead, 2000). At the same time the application of mineral fertilisers has seriously degraded the botanical diversity of grassland communities (Chapman, 2001). Little information exists however on what constitutes optimal or maximal amounts of N-, P-, K-supply for the maintenance/regeneration of species-rich grassland communities with preservation of an adequate forage quality.

Materials and Methods

From 1986 until 2002 four pastures in Central Germany, classified as *Lolio-Cynosuretum* and situated on mineral soils, have been fertilised annually with 27 different N-, P-, K-supply combinations. At each site the experiment was arranged in a Latin rectangle design with three replicates. Altitude and soil characteristics for the different sites are presented in Table 1.
In spring 2002 DM-contributions of occurring plant species were estimated using the Klapp/Stählin method (Klapp, 1929). Based on these DM-proportions, the Shannon-Index H (Magurran, 1988) was subsequently calculated for each plot as follows:

$$\text{Shannon-Index } H = -\sum (P_i \times \ln P_i)$$

Where P_i is the dry matter proportion of the ith species.

Table 1. Altitude and soil characteristics (unfertilised condition) of experimental sites.

	Altitude m above sea-level	Phosphorus[1] mg P 100 g^{-1} soil	Potassium[1] mg K 100 g^{-1} soil	pH[2]
Site 1	210	3.1	10.5	5.3
Site 2	260	1.3	13.0	5.5
Site 3	360	3.0	9.4	5.6
Site 4	620	2.2	11.8	4.8

[1] calcium acetate lactate extraction; [2] determined in 0.01 *M* $CaCl_2$

First growth samples from selected supply combinations were taken. The dried herbage was ground and analysed for *in vitro*-digestibility (IVDOM) as described by Steingass and Menke (1986) and Menke and Steingass (1987). Crude protein content was measured by the standard Kjeldahl method. Metabolisable energy was calculated from the IVDOM using the following equation (Menke and Steingas, 1987; formula 16e):

$$\text{ME (MJ kg}^{-1}\text{ DM)} = 2.20 + 0.1357 \times \text{GV} + 0.0057 \times \text{CP} + 0.000286 \times \text{F}^2$$

where GV is the volume of gas produced by the bacteria in the rumen fluid during the *in vitro*-digestibility test, CP is the crude protein content (in g kg^{-1} DM) and F is the fat concentration (in g kg^{-1} DM) determined in petroleum ether extract.

The data were analysed by means of a *factorial ANOVA* as well as by *LSD-tests*. To ensure normal distribution the species numbers were subjected to a square-root transformation before statistical analysis.

Results

Sites 3 and 4, located at a higher altitude level, both show a higher number of species without N-supply than sites 1 and 2 (Table 2). On the transformed species numbers the factor N exhibits the largest source of variance at all sites, with a reduction of the species number with increasing N-supply. Next to N-, K-supply also lowers the species number on site 1, 3 and 4. On site 2 and 4 also P-fertilisation results in occasional significant species number reductions. For the Shannon-Index, which takes into account not only species richness but also the evenness of the abundance distribution of species, highest values are achieved on site 3 and 4. Contrary to the number of species the Shannon-Index is not only influenced by main effects, for site 3 also interactions of N × P and P × K occur. Here with P-supply the Shannon-Index is significantly reduced by increasing the N-fertilisation from 0 to 160 kg ha^{-1} as distinct from without P-supply. At the highest P-supply level the Shannon-Index is reduced by K-application. N-supply exerts the largest influence on the Shannon-Index for site 2, 3 and 4. Whereas N-fertilisation reduces the Shannon-Index on site 3 and 4, the effect of N-supply on site 2 is not unambiguous.

CP content is increased on all sites with N-supply (Table 3). Contrary, on site 2 with original low soil-exchangeable P-level, increasing the N-application from 160 to 320 kg ha^{-1} without P-supply does not rise the CP content, here the interaction N × P is significant.

On site 2, 3 and 4 the energy concentration mostly decreases with N-fertilisation. Deviating from this on site 3 the energy content rises when, combined with P-supply, the N-fertilisation is increased from 160 to 320 kg ha^{-1}, whereas without P-supply this effect does not appear. Next to the interaction N × P, also a significant effect of the interaction P × K occurs on this site, explained by a reduction of the energy content by K-supply solely without P-fertilisation.

Table 2. Number of species and Shannon-Index depending on nutrient supply and site

N – P – K level ($kg\ ha^{-1}\ a^{-1}$)	Species number[1]				Shannon – Index H			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
0 – 0 – 0	21.3	26.7	33.3	35.0	1.3	1.8	1.8	2.3
0 – 0 – 66	19.7	26.3	26.7	27.0	1.1	1.5	1.7	2.2
0 – 0 – 133	15.7	24.3	27.3	25.7	1.0	1.4	1.7	2.2
0 – 26 – 0	27.3	22.3	33.3	31.3	1.3	1.6	1.8	2.3
0 – 26 – 66	22.3	20.7	30.7	24.7	1.3	1.5	1.9	2.3
0 – 26 – 133	21.3	22.7	25.7	24.0	1.1	1.5	1.9	2.3
0 – 52 – 0	23.0	22.7	35.0	29.7	1.1	1.5	2.1	2.4
0 – 52 – 66	20.7	20.0	29.7	27.3	1.1	1.5	2.0	2.4
0 – 52 – 133	20.3	21.0	23.3	23.7	1.1	1.4	1.7	2.1
160 – 0 – 0	12.0	19.7	23.7	24.3	1.4	1.2	1.7	1.7
160 – 0 – 66	11.3	19.7	19.0	22.7	1.4	1.3	1.5	2.0
160 – 0 – 133	9.0	17.3	12.3	22.0	1.3	1.2	1.4	1.9
160 – 26 – 0	14.0	17.7	19.3	22.7	1.3	1.4	1.5	1.8
160 – 26 – 66	10.0	18.3	19.3	19.3	1.1	1.3	1.5	1.3
160 – 26 – 133	7.3	18.7	16.0	18.0	1.1	1.4	1.5	1.5
160 – 52 – 0	11.0	18.0	19.0	21.7	0.9	1.4	1.6	1.6
160 – 52 – 66	11.3	16.0	14.0	18.3	1.3	1.3	1.2	1.6
160 – 52 – 133	10.3	17.7	14.3	17.0	1.2	1.4	1.3	1.4
320 – 0 – 0	11.7	17.7	21.0	18.3	1.2	1.4	1.6	1.6
320 – 0 – 66	9.7	17.3	12.7	17.3	1.2	1.3	1.1	1.2
320 – 0 – 133	8.3	19.7	11.0	17.0	1.0	1.3	0.8	1.4
320 – 26 – 0	10.3	16.7	16.0	16.3	1.2	1.4	1.2	1.4
320 – 26 – 66	10.7	19.3	10.7	13.3	1.2	1.6	0.9	1.1
320 – 26 – 133	9.7	15.7	12.7	15.3	1.0	1.2	1.2	1.3
320 – 52 – 0	11.3	17.7	19.3	15.3	1.0	1.5	1.3	1.2
320 – 52 – 66	10.7	17.0	10.7	15.3	1.2	1.4	0.9	1.2
320 – 52 – 133	11.0	18.7	12.3	13.7	1.2	1.5	0.9	1.0
$LSD_{0.05}$					0.37	0.28	0.31	0.54

[1] original data (not transformed)

Table 3. Crude protein and energy content depending on nutrient supply and site

N – P – K level ($kg\ ha^{-1}\ a^{-1}$)	ME ($MJ\ kg^{-1}$ DM)				CP ($g\ kg^{-1}$ DM)			
	Site 1	Site 2	Site 3	Site 4	Site 1	Site 2	Site 3	Site 4
0 – 0 – 0	9.6	9.6	9.9	9.9	111	101	116	136
0 – 0 – 133	9.5	9.5	9.3	9.8	104	95	111	139
0 – 52 – 0	9.2	9.5	9.7	9.8	108	92	111	143
0 – 52 – 133	9.4	9.7	9.7	10.2	111	111	109	136
160 – 0 – 0	8.9	9.2	9.7	9.5	163	127	153	177
160 – 0 – 133	8.3	9.4	8.8	9.8	129	120	145	178
160 – 52 – 0	7.9	9.1	9.0	10.0	147	114	155	188
160 – 52 – 133	8.4	9.1	8.6	9.5	121	109	134	167
320 – 0 – 0	8.6	9.5	9.5	10.0	183	130	175	210
320 – 0 – 133	8.5	9.3	9.1	10.0	148	138	167	200
320 – 52 – 0	8.8	9.0	9.5	10.1	163	152	184	224
320 – 52 – 133	8.1	8.4	9.5	9.9	174	148	173	187
$LSD_{0.05}$	0.89	0.72	0.50	0.65	25.6	20.8	23.3	24.8

Discussion

Increasing the N-supply encourages the dominance of fast-growing species with exclusion of less aggressive species, reducing the overall number of species. K-fertilisation decreases specifically the number of herb species. The reducing effect of particularly N- but also of K-supply on the species number applies to all sites. The Shannon-Index however considers not only species richness but also the evenness of the abundance distribution of the species (evenness). Although evenness is predominantly determined by N-supply (results here not presented), the effect of nutrient supply on evenness is not equal for all sites. Other factors such as original soil fertility and plant community composition as well as utilisation intensity appear to interfere on the outcome of fertilisation on the evenness. N- and K-supply reducing species richness combined with nutrient supply and site-specific characteristics both influencing the evenness leads to differing responses of the Shannon-Index to nutrient supply. On site 1 and 2, with original low species numbers and high utilisation intensity, the evenness is increased by N-application whereas on site 4 with a higher species number and lower utilisation intensity the evenness is lowered by N-supply. As the increased evenness of N-supply corrects for the species number reduction more or less uniform values for the Shannon-Indices are found on site 1 and 2, contrary to site 4 where N-supply reduces the Shannon-Index. On site 3 not only N- but also P- and K-supply influence the evenness leading to above-mentioned interactions of N × P and P × K for the Shannon-Index. Here without P-fertilisation the increase of N-supply from 0 to 160 kg ha^{-1} increases the evenness. K-supply combined with 26 kg P ha^{-1} slightly increases the evenness, whereas K-supply with 52 kg P ha^{-1} fertilisation decreases the evenness. The effect of fertiliser application on forage quality is partly due to changes in floristic composition and partly affected by quality changes in individual plants. N-supply has the largest effect with an increase in DM yield and CP content. The N × P interaction on site 2 is probably due to the relative high yield response to N-fertilisation without P-supply diluting the CP concentration. The interactions on site 3 concerning the energy content are possibly caused by changes in floristic composition (exchange of *Lolium perenne* for *Elymus repens*), this needs however further examination.

Conclusions

To achieve higher biodiversity N-supply needs to be discontinued. Site-specific the maintenance of certain P-, K-supply combinations can result in higher Shannon-Index values through increased evenness.

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Changes in the botanical and chemical composition of fodder caused by nitrogen application

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Abstract

It was determined that the two variants of foliar fertilization, namely nitrogen and microelements applied separately and as a combination of both, caused legumes to decline in the sward.
The fertilization variants applied only slightly attend the contents of macroelements in the dry matter of the fodder. The foliar nitrogen fertilization combined with a microelements, equaling 55 kg of nitrogen per hectare, i.e. the dose applied in the nitrogen soil fertilization, had a positive effect only on the content of potassium and magnesium.

Keywords: grassland, soil nitrogen fertilization, foliar fertilization with urea, botanical and chemical composition

Introduction

The intensification of production requires not only a higher yielding capacity, but also the production of improved quality (Stypiński, 1991; Jargiełło, 1995; Wojcieska-Wyskupajtis, 1996). The latter has been gaining greater and greater recognition. In meadow cultivation good quality crops can be produced when nutrients are supplied both through soil and foliage, leading to the intensified and ecologically friendly agriculture (Rogalski, 1993; Jankowski *et al*., 1994).
When applying this sort of fertilization, one faces a significant problem of deciding on the quantity and for which an effect of combined activities of foliar and soil fertilization is the most beneficial to plants.
To establish such a favourable ratio, research was carried out on changes in the biological and chemical composition of fodder caused by varied applications of nitrogen and microelements.

Materials and Methods

This experiment was carried out in the Agricultural Research Station based at Zawady in 1993–1996. The meadow located on mineral soil, created from light clay, was used for this research. The chemical analysis showed a high content of phosphorus and potassium, and a mean one for magnesium.
This experiment was performed via the method of randomized blocs in four replicates. The surface of each plot was 15 m^2 (3 × 5).
The following levels of the soil fertilization were applied :

- 0 – control
- PK (35 kg P and 100 kg K)
- PK + 220 kg N ha^{-1} (as standard)
- PK + 110 N ha^{-1}
- PK + 55 kg N ha^{-1}.

The lower levels of the soil nitrogen fertilization (110 and 55 kg N ha^{-1}) were supplemented through the foliar fertilization:

- with nitrogen – 300 liters of 10% urea solution per hectare (its mean 13.8 kg N ha^{-1} in one spray)
- with microelements – 300 liters of liquid fertilizer Agrosol P (its mean 3 liters of Agrosol P per hectare in one spray)
- nitrogen with microelements – 300 liters of 10% urea solution together with Agrosol P (its mean 13.8 kg N and 3 liters of Agrosol P both applied per hectare in one spray).

Phosphorus and potassium were applied in all the fertilizer combinations. Once, in spring, 35 kg P ha^{-1} was applied in a form of triple super phosphate and 33 kg K for each regrowth as a potassium salt. During the vegetative period three cuts were collected. Afterwards, the green mass was weighed separately from each plot, and 0.5 kg of the green mass was sampled to calculate the initial dry matter, and then for chemical analyses. Hay chemical analyses were conducted for the three cuts to determine the contents of phosphorus, potassium, calcium, and magnesium. From the first cut, additionally, a 1 kg sample (from each plot) was collected for the estimation of a botanical composition.

Results and Discussion

Hay yield remains one of the criteria determining the efficiency of grassland fertilization (Rogalski, 1993). In the current research an impact of the dose and nitrogen application method on botanical composition were analyzed, especially on the number of species in the sward. Orchard – grass and Kentucky – bluegrass were the dominant species in the sward. The higher floristic diversity was found on the plots without nitrogen fertilization. In the third year of the investigation the results showed that in the plots with the foliar nitrogen fertilization the legumes disappeared. The species with a positive reaction to the foliar fertilization was orchard – grass, the proportion of which increased by 50%. The effect of the foliar fertilization on the proportion of Kentucky – bluegrass in the sward was different, as its level remained unchanged during the whole investigation period.

When comparing both kinds of fertilizers, it was observed that the intensity of weed and herb proportion depended more on the nitrogen fertilization than on the foliar one.

One of the most essential indicators of a feed nutritive value is the macroelement content (Grzyb, Sapek, 1983). The fertilization treatments applied only slightly effected the contents of the estimated macroelement in the dry matter of the fodder. The foliar nitrogen fertilization combined with microelements, equaling the 55 kg of nitrogen per hectare, i.e. the dose applied in the nitrogen soil fertilization, had a positive effect only on the content of potassium and magnesium.

Table 1. Content of macroelements (g kg^{-1}D M) in plants from meadows

Macro-elements	Used fertilization								
	0	PK	PK + 220 N/ha	110 kg N + urea	110 kg N + Agrosol P	110 kgN + urea + Agrosol P	55 kg N + urea	55 kg N+ Agrosol P	55 kg N urea + Agrosol P
K	18.3	23.8	19.8	21.3	23.4	20.9	22.2	23.1	22.8
P	2.2	22	2.3	2.3	2.3	2.2	2.2	2.2	2.1
Ca	5.1	6.4	6.0	5.2	4.4	5.0	5.1	4.8	4.8
Mg	2.4	2.4	2.4	2.3	2.2	2.4	2.4	2.3	2.8

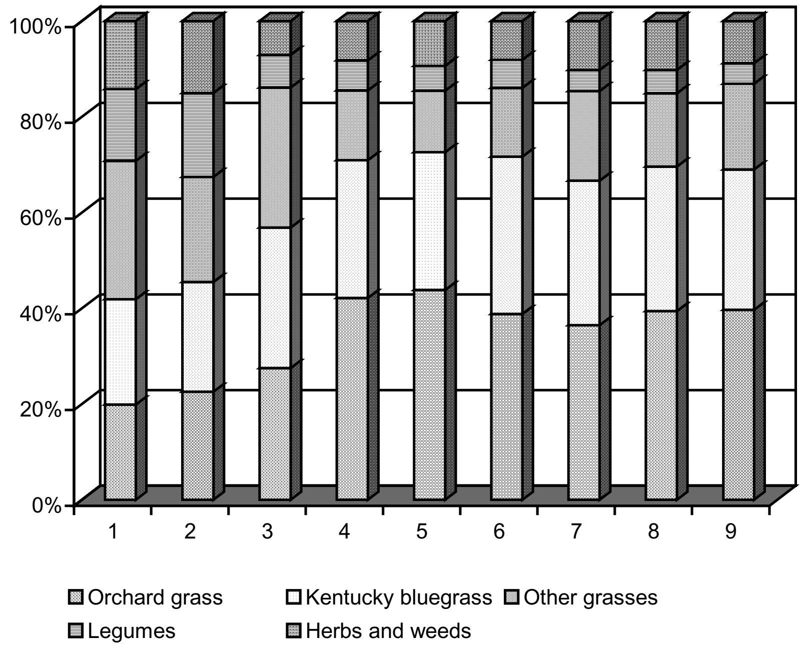

Figure 1. Changes in the botanical composition of the sward from the first cut under the influence of different fertilizer combinations (mean from investigated years)

1. 0
2. PK
3. PK + 220 N kg ha^{-1}
4. PK + 110 N kg ha^{-1} + urea
5. PK + 110 N kg ha^{-1} + Agrosol P
6. PK + 110 N kg ha^{-1} + urea + Agrosol P
7. PK + 55 N kg ha^{-1} + urea
8. PK + 55N kg ha^{-1} + Agrosol P
9. PK + 55N kg ha^{-1} + urea + Agrosol P

As seen from the data presented in Table 1, the content of magnesium in the feed was high (Grzyb, Sapek, 1993) and amounted to 2.12–2.92 g kg^{-1} of dry matter. As for the animals feeding needs, the content of calcium in the plants was too low (Jankowski *et al.,* 1994). Analyzing the impact of the variants of the nitrogen fertilization, a higher potassium content and lower calcium one was observed under the foliar fertilization, especially with Agrosol P.

Conclusions

1. The two variants of the foliar fertilization, namley nitrogen and microelements applied separately and as a combination of both caused legumes to decline in the sward.
2. The investigated fertilizer variants slightly differentiated macroelement contents in the dry matter of the fodder. The foliar fertilization with nitrogen applied with microelements in the dose of 55 kg N ha^{-1} influenced positively only the content of potassium and magnesium.
3. There is a need to apply economic analysis to the effects of foliar grassland fertilization.

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Cutting schedule in combined alfalfa forage and seed production

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Abstract

Under the variable climatic conditions of Serbia, alfalfa seed production is typically organized in combination with forage production. Dependence of dry matter yield and seed yield on cutting schedule was examined in a two-year study (2001–2002). The study involved the seven most widely grown alfalfa cultivars in Serbia, six domestic and one French. Four schedules were examined: early (forage cutting on 5 May), medium (cutting on 15 May), late (cutting on 25 May), each with seed production from the following, second cut; and seed production from the third cut (after forage cuttings on 5 May and 5 June). Over the two years, average yields of forage dry matter for the treatments were 5380, 5850, 6740 and 8850 kg ha^{-1}, respectively. The highest seed yield (633 kg ha^{-1}) was achieved with the late cutting. The early and medium cuttings produced lower seed yields (368 and 378 kg ha^{-1}, respectively). Seed production from the third cut yielded 382 kg ha^{-1}.

Keywords: alfalfa, cutting, hay, seed, yield

Introduction

Under the variable climatic conditions of Serbia, alfalfa (*Medicago sativa* L.) sown in widely spaced rows for seed production has not rendered satisfactory results. In years with higher than average rainfall in July and August, alfalfa seed crops tend to lodge regardless of row separation, resulting in significant yield reductions (Erić, 1988). In dry years, dry matter yield of alfalfa may be significantly reduced in second and later cuttings due to insufficient water supply. These latter conditions are favourable for alfalfa seed production. Therefore, combined production (forage and seed) of alfalfa may considerably increase farming efficiency.

In combined production, the cutting schedule has to be so timed as to reduce the growth rate and lodging of seed plants and harmonize the stage of flowering with the period of maximum activity of pollinating insects (Karagić, 2004).

Materials and Methods

The experimental site was located in northern Serbia 45°20´N, 19°51´E, at 80 m above sea level. This area has a continental semiarid to semihumid climate, a mean monthly air temperature of 11.0 °C, an annual sum of precipitation of around 600 mm and a highly uneven distribution of precipitation. Table 1 shows the mean monthly air temperatures and monthly sums of precipitation for the period April-September. The trial was established according to a randomized block design with four replicates. Alfalfa was sown on 8 April 2000 at a row-to-row spacing of 25 cm and with a seeding rate of 15 kg seed ha^{-1}. Each plot measured 2 × 5 m^2, with eight rows per plot.

The study involved the seven alfalfa cultivars most widely grown in Serbia, six domestic and one French (Table 3). In the second and third years of crop life (2001 and 2002), four harvest-management systems with variable dates of initial harvest were applied. First cutting for forage was carried out on 5 May (budding) in the c_1 system, on 15 May (start of flowering) in the c_2 system, on 25 May (full flowering) in the c_3 system, and on 5 May and 5 June in the c_4 system. The second cutting was used for seed production in the c_1–c_3 systems and the third cutting in the c_4 system. Green forage was removed from the plot immediately after harvest and the dry matter yield determined on air-dry samples.

Table 1. Mean monthly air temperatures (°C) and sums of precipitation (mm)

Month	2001		2002		Long-term average	
	°C	mm	°C	mm	°C	mm
April	11.2	127	11.7	26	11.6	47
May	17.8	75	19.1	87	16.4	57
June	18.2	233	21.7	27	19.8	81
July	22.3	56	23.6	33	21.5	63
August	22.7	30	22.2	55	21.0	47
September	16.1	162	17.0	46	17.1	35
Average/Sum	18.1	683	19.2	274	17.9	330

Alfalfa seed was harvested with a single passage of a Hege harvester, following desiccation with Diquat performed when about 70% of pods on normally developed plants were at the stage of physiological maturity. In 2001, seed harvest was performed on 20 August in the c_1, c_2 and c_3 systems and on 4 September in the c_4 system. In 2002, c_1 and c_2 systems were harvested on 21 July, c_3 on 7 August, and c_4 on 19 August. Seed yield was calculated on the basis of measurements of dried (at 10% moisture) and processed seed per plot. The results were statistically processed by the analysis of variance. Significance of differences between mean values was tested by the LSD test.

Results and Discussion

The average dry matter yield in the first cutting was 5990 kg ha^{-1}, varying from 5380 kg ha^{-1} in the system of early cutting (c_1) to 6740 kg ha^{-1} in the system of late cutting (c_3) (Table 2). Delay in cutting towards the end of May tend to increase dry matter yield but hay quality is reduced (Sheaffer *et al*., 1988; Katić *et al*., 2004). The aggregate yield of the first two cuttings in the c_4 system was 8850 kg ha^{-1}. Limited precipitation in winter 2000/2001 and somewhat reduced air temperatures in April 2001 resulted in low dry matter yields in the early and medium systems of cutting in 2001 (4160 and 5130 kg ha^{-1}, respectively). The average yield of dry matter obtained in 2001 was significantly lower than that obtained in 2002 (6260 and 7120 kg ha^{-1}, respectively).

Table 2. Dry matter yield depending on cutting schedule in 2001–2002 (kg ha^{-1})

Cutting schedule (C)	Year (Y)		Average
	2001	2002	
c_1	4160	6480	5380
c_2	5130	6570	5850
c_3	7390	6090	6740
c_4	8360	9340	8850
Average	6260	7120	6705

LSD	C	Y	C × Y
0.05	281.7	199.2	394.4
0.01	376.6	266.3	532.6

The highest yields of dry matter were achieved by varieties Banat and Slavija (7168 and 7119 kg ha^{-1}, respectively), the varieties with fastest regrowth and tallest plants at the first cutting. A significantly lower dry matter yield was recorded for the late variety, Europe, at 5787 kg ha^{-1} (Table 3).

Table 3. Dry matter yield depending on variety and cutting schedule (kg ha^{-1})

Variety (V)	Cutting schedule (C)				Average
	c_1	c_2	c_3	c_4	
NS-Banat ZMS II	6010	6233	6596	9832	7168
Kruševačka 22	5710	6070	6558	9203	6885
Novosađanka H-11	5070	5907	7113	8772	6716
Zaječarska 83	5324	5840	6855	8657	6669
NS-Slavija	5660	6157	7227	9432	7119
NS-Mediana ZMS V	5360	5631	6730	8651	6593
Europe	4528	5115	6099	7406	5787
Average	5380	5850	6740	8850	6705

LSD	V	C	V × C
0.05	213.7	281.7	427.5
0.01	284.6	376.6	569.6

In the second and third years of crop life, the average seed yield was 440 kg ha^{-1} (Table 4). Most variation in seed yield was caused by weather conditions in the year of growing. In 2002, which had favorable ecological conditions, the yield of seed was 4.3 times higher than in 2001, which had highly unfavorable conditions. Numerous authors (Erić, 1988; Žarinov and Kljuj, 1990) agree that variation in alfalfa seed yield is primarily due to weather conditions in the year of growing. However, yield level may be stabilized to a certain measure by adjusting the cutting schedule.

Table 4. Seed yield depending on cutting schedule in 2001–2002 (kg ha^{-1})

Cutting schedule (C)	Year (Y)		Average
	2001	2002	
c_1	163	573	368
c_2	167	588	378
c_3	225	1041	633
c_4	109	656	382
Average	166	715	440

LSD	C	Y	C × Y
0.05	43.51	30.77	61.53
0.01	58.17	41.13	82.27

The lowest seed yield, 368 kg/ha, was obtained with the early system (c_1), which was cut at the beginning of budding stage. In this system, the regrowth of the seed crop coincided with a period of high soil moisture and low air temperatures, resulting in lush and dense growth which is prone to lodging.

The highest seed yield, 633 kg/ha, was achieved with the system of late cutting (c_3). This yield was significant higher (by 66–72%) then with the other systems. The late cutting system ensured a low crop density, i.e. a reduced number of shoots per unit area. Simultaneously, this system produced the largest number of productive shoots and the largest portion of productive shoots in the total number of shoots. Regrowth rate was significantly faster than with the other systems but the plants were shorter and had a reduced number of internodes. Dry matter content in the stem was significantly higher in relation to the early and medium cutting systems. Owing to these characteristics, plant sensitivity to lodging was reduced and conditions for alfalfa flowering and activity of pollinating insects improved, resulting in a high seed yield (Karagić, 2004).

Two cuttings for forage before taking seed from the third cut (c_4) tended to reduce growth vigor of plants. Two cuts at the beginning of budding exhaust the plants. As a result, this system achieves the lowest density and the shortest plant stature of the seed crops. Additionally, dry matter content in the stem is significantly higher than with the other systems, improving plant resistance to lodging and simultaneously maximizing the yield level. On the other hand, shortage of available soil water in the period of regrowth, intensive growth and budding of the third cut reduces the formation of alfalfa generative parts. Compared with optimum water supply, dry conditions halve the number of productive tillers, which significantly reduces seed yield (Goloborodko and Bodnarčuk, 1998).

All varieties in the study produced maximum seed yields with the system of late cutting (c_3) (Table 5). Highest yields were achieved by Europe and Slavija (773 and 756 kg ha^{-1}, respectively), the varieties least susceptible to lodging. The other varieties had significantly lower yields. Lowest seed yields were obtained with Mediana and Novosađanka with the system of early cutting (c_1) (277 and 267 kg ha^{-1}, respectively). The low yields of these varieties are explained by the presence of the yellow alfalfa (M. *falcata* L.) genes incorporated during breeding (M. *sativa* L. *x* M. *falcata* L.). The yellow alfalfa is susceptible to lodging and its seed yield capacity is low (Galilov, 1988). Effect of genotype on seed yield is particularly pronounced in the third cut. High seed yields in the third cut may be expected only from early genotypes, less sensitive to arid conditions, such as Zaječarska, Banat and Mediana. Their yields were 416, 400 and 397 kg ha^{-1}, respectively.

Table 5. Seed yield depending on variety and cutting schedule (kg ha^{-1})

Variety (V)	Cutting schedule (C)				Average
	c_1	c_2	c_3	c_4	
NS-Banat ZMS II	333	333	573	400	410
Kruševačka 22	407	371	598	374	438
Novosađanka H-11	267	298	550	347	365
Zaječarska 83	372	429	621	416	459
NS-Slavija	436	422	756	369	496
NS-Mediana ZMS V	277	327	561	397	390
Europe	484	467	773	374	525
Average	368	378	633	382	440

LSD	V	C	V × C
0.05	41.47	43.51	82.94
0.01	54.73	58.17	109.5

Conclusion

Ecological conditions in the year of growing have the greatest effect on alfalfa seed yield and yield components. Among these conditions, the total amount and distribution of rainfall play the decisive role. In this study, the yields of alfalfa seed ranged from 166 to 715 kg ha^{-1}.

Variations in alfalfa seed yield level may be controlled by the system of cutting. The system of late cutting ensures a reduced stand density and maximum number of productive shoots. Also, plant height is reduced and dry matter content in the stem significantly increased in relation to the systems of early and medium cutting. Consequently, plant sensitivity to lodging is considerably reduced while conditions for alfalfa flowering and activity of pollinating insects are improved, all resulting in increased seed yield.

The effect of variety on alfalfa seed yield was significant. Highest seed yields were achieved by the varieties Europe and Slavija (525 and 496 kg ha^{-1}, respectively). The lowest seed yield was achieved by the variety Novosađanka (365 kg ha^{-1}). Genotype sensitivity to lodging was closely associated with seed yield – the lower the lodging rate, the higher the seed yield.

Acknowledgements

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Comparison of the ecological applicability and yield capacity of long-term legumes and their mixtures with timothy (*Phleum pratense*)

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Abstract

The suitability of three long-term legumes for permeable karstic and hilly soils, when grown alone and in mixtures with timothy (*Phleum pratense*), was studied in field trials at the Research Station of the Lithuanian University of Agriculture in 1997–1999. Fodder galega (*Galega orientalis* Lam.), which is a relatively new crop to the region, and lucerne (*Medicago sativa* L.), which is not widely grown, were compared with traditional red clover (*Trifolium pratense* L.). The trials were carried out on a sandy moraine loam humic horizon of *Calcary Epihypogleyic Luvisol*, LVg – p – w – cc. Fodder galega was the most productive and persistent of the investigated long-term legumes. Productivity, feed value and soil cover were better for mixtures of galega and timothy with either lucerne or red clover than for pure legumes crops.

Keywords: fodder galega, lucerne, red clover, grasses, mixtures, ecology, productivity

Introduction

Some of the most ecologically sensitive and easily damaged soils in Lithuania occur in the hilly, karstic region of the country (Baležentienė, 2000). Farming is more difficult here because of high soil permeability and the risk of erosion. According to research data, legumes are recommended to be grown in mixtures with grasses (Drikis, 1995). Such mixtures provide more uniform soil cover in the sowing year, higher and more stable yields for a longer period than pure-sown legumes and also better chemical composition (Adamovičs, 2000; Drikis, 1995). Legumes and grasses maintain and increase natural fertility and microbiological properties of soil by accumulating biological nitrogen and organic matter (Arapetyan *et al*., 1998; Raig, 1982). These properties of legumes and their mixtures are expected to provide high-yielding, protein-rich harvests of forage with minimal ecological damage to sensitive soils (Baležentiene, 2000).
The main aim of this research is to compare and select the most productive and suitable long-term perennial legumes and their mixtures for ecological sensitive territories.

Materials and Methods

Field trials were conducted at the Research Station of the Lithuanian University of Agriculture in 1997–1999 on a sandy moraine loam humic horizon of *Calcary Epihypogleyic Luvisol*. The productivity and suitability of a new fodder galega (*Galega orientalis* Lam.) 'Vidmantai', and the not-widely grown lucerne (*Medicago sativa* L.) 'Žydrūnė' were compared with traditional red clover (*Trifolium pratense* L.) 'Arimaičiai', when grown as pure crops and as mixtures with timothy (*Phleum pratense*). The legume mixtures were formed with deep-rooted timothy 'Gintaras II'. The trials design a randomized treatment with four replications is presented in the Tables 1 and 3. The crops were sown without a cover crop and grown without N fertilizer. A basal fertilizer dressing of P_{60} and K_{60} was applied in autumn. The 3-cut system was applied manually at the beginning of the flowering stage. The chemical composition (ChC) of green

mass (GM) was determined by near infra-red rays analyzer (PSCO/ISI IBM – PC 4250). The amount of feed units (FU) and digestible protein content (DP) were calculated according to the chemical composition of dry matter (DM) and coefficient of digestibility (CD).
The meteorological conditions during the growing season (April–October) of the research years were diverse with frequent droughts. The hydrothermic coefficient (HTC) by G. Seljaninov (1971) was lower than the long-term average, except in May 1997 (HTC = 2.6) and June 1997 and 1998 (HTC = 1.7; 2.3). The weather was especially dry in 1999: the HTC was only 1.4 in May, 0.94 in July and 0.7 in September, compared with long-term averages of 1.7, 1.5 and 1.8, respectively.
The level of statistical confidence of the data was calculated by the method of dispersion analysis using the statistical package ANOVA. The least significant difference (LSD) method was used to evaluate differences between crop yields, chemical composition and feed value.

Results and Discussion

Botanical composition of the sown grass stands mainly depended on the biological characteristics of grass. During the first three years the plant density (average 216–241 stems m^{-2}) was lower in the pure sown legume swards than in mixtures (Fig. 1). In this period, mixtures already showed an even and dense cover of soil in the sowing year as well as during the following two years. The highest average plant density (614 stems m^{-2}) was formed in the fodder galega, lucerne and timothy mixture. The density of red clover in the stands began to decline in the second year. Red clover was the least persistent of the legumes that were investigated.

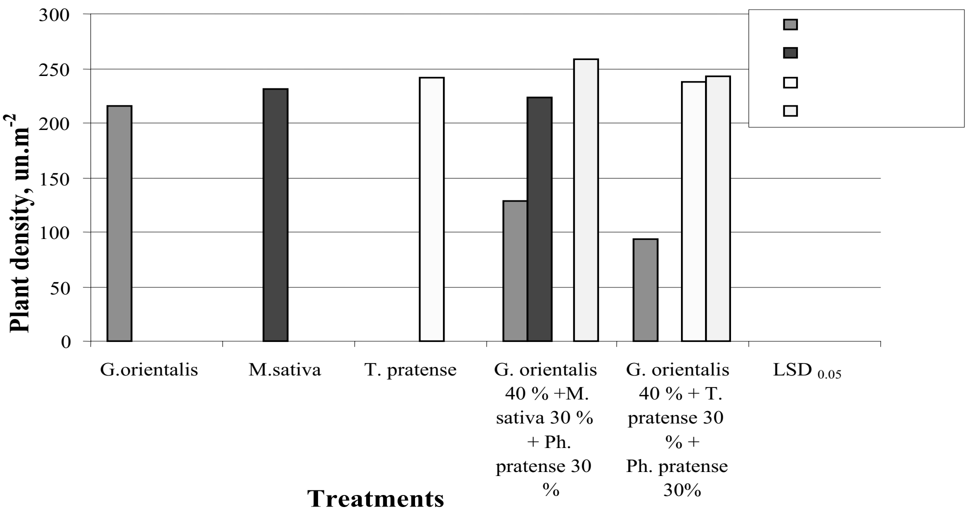

Figure 1. Plant density in pure legume swards and in mixtures (average 1997–1999)

The yield of crops depends on plant height, not only on density (Fig. 2). The tallest plants were in the pure-sown crops. Fodder galega grew to 134 cm, lucerne to 102 cm, red clover to 64 cm and timothy to 72 cm on average. When grown in mixtures, their heights were significantly less due to species composition of the mixture and plant competition. Galega was the tallest in all 3-component mixtures and averaged up to 130 cm (in mixture with lucerne and timothy) and 121 cm (in mixture with red clover and timothy). The height of lucerne in mixtures decreased on average by 4 cm and for red clover by 2 cm. The obtained yield of GM and DM fluctuated respectively morphologic indices (density, plant height) of swards.

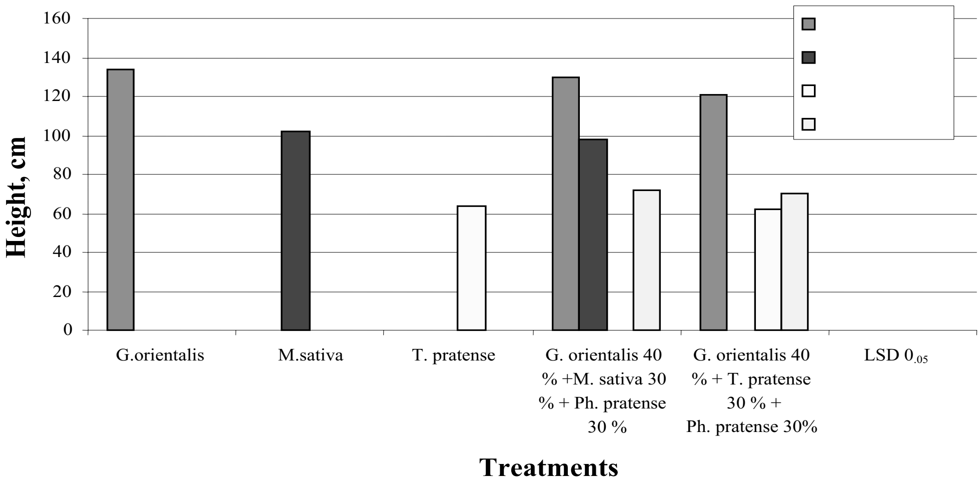

Figure 2. Plant height in pure legume swards and in mixtures (average 1997–1999)

The maximum yield of the pure legumes swards was achieved in galega and lucerne stands (Fig. 3). In case of using 3 – cut/year system the average DM yield of fodder galega, lucerne and red clover came up to 12.5; 11.6 and 9.4 t ha^{-1} respectively. The DM yield of the mixtures was substantially higher than that of pure-sown lucerne and red clover.

The differences in DM yield of the 3-component mixtures were not statistically significant and varied between 13.7 and 13.9 t ha^{-1} on average. Assessment of the nutritive value of the compared crops did not reveal any significant differences (Table 1).

The highest content of protein and fat was obtained in the pure stand of galega (Table 1). The share of these components was smaller in red clover yield but there were higher concentrations of minerals (P, K, and Ca). The highest concentration of FU (0.85 units kg^{-1}) and DP (178.9 g FU^{-1}) was obtained in DM of fodder galega. The content of FU and DP in mixtures was similar to this for red clover.

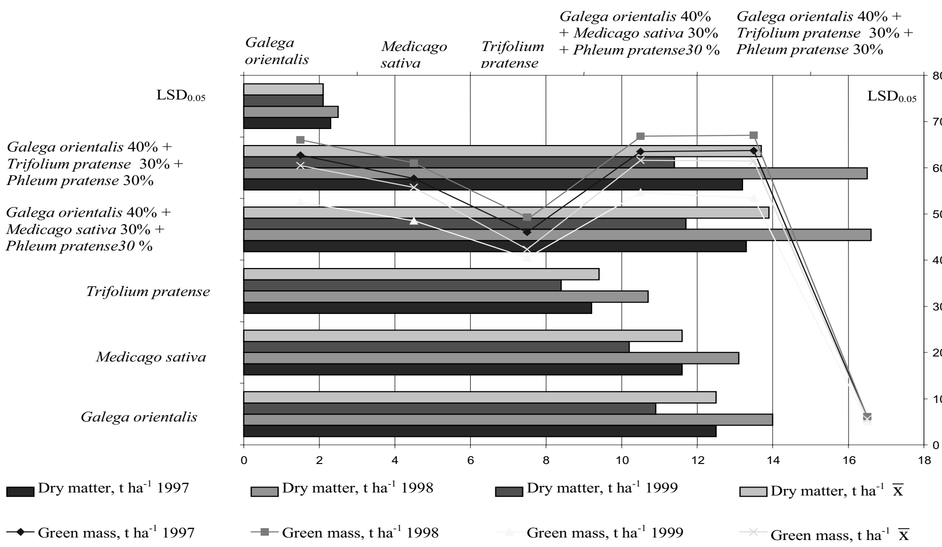

Figure 3. The productivity of three-component mixtures in 1997–1999

Table 1. The chemical composition of perennial legumes and their mixtures

Treatments	Content in DM (g kg^{-1})								DP (g FU^{-1})
	DM	Crude protein	Crude fibre	Crude ash	Crude fat	P	K	Ca	
G. orientalis	211.0	223.2	256.8	95.0	26.8	4.4	10.6	7.2	178.9
M. sativa	214.1	219.4	240.0	106.3	26.5	3.3	10.8	7.6	168.1
T. pretense	212.3	189.8	249.0	91.0	24.4	6.9	15.5	17.2	141.3
G.orientalis 40% + *L. sativa* 30% + *Ph. pratense* 30%	216.4	216.0	270.9	94.2	25.1	8.4	12.6	11.0	149.9
G. orientalis 40% + *T. pratense* 30% + *Ph. pratense* 30%	215.1	194.2	271.0	90.0	25.2	8.6	13.8	13.0	141.4
LSD $_{0.05}$	9.4	7.3	8.5	1.3	1.1	0.7	0.9	2.0	9.0

Conclusions

The new long-term legume fodder galega is suitable for growing in 3-component mixtures with lucerne or red clover and timothy. The density of red clover stands began to decline in the second year and was less persistent than fodder galega and lucerne. The legume-timothy mixtures provided denser and even soil cover than the pure legume crops and are therefore more suitable for growing in ecologically sensitive territories (karstic, hilly, light permeable soils). The mixture of galega (40% of seed rate) with lucerne (30% seed rate) and timothy (30% seed rate) was more productive (12.7 t ha^{-1} DM) and ecologically suitable for providing soil cover than the studied galega-red clover-timothy mixture or pure-sown legumes.

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Performance of a reseeded grassland (*Trisetetum*) in Germany

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Abstract

The aim of this experiment was to reduce the contents of harmful *Trisetum flavescens* by reseeding (two seeds mixtures were compared by direct drilling) and two different management systems. Early cut of primary growth (15 May, at least 3 cuts per year with slightly higher amounts of fertilized nitrogen) and late cut (first cut not before 15 June, at the maximum 3 cuts per year) were compared.
After 6 experimental years the total percentage of grasses was only slightly different between the treatments, but differences between single species existed. Cutting late increases the content of *Dactylis glomerata*, whereas *Poa pratensis* needs to be cut early in order to develop well. *Lolium perenne* could generally be increased by reseeding, but there were no differences between the seeding treatments. At the end of the experimental period *Trisetum flavescens* had less than 20% in all proved variants and is well below the critical content of 40%.
Dry matter yields (2000–2004) and yields of net energy were highest for the early cutting regime. Reseeding resulted in higher DM yields.

Keywords: grassland renovation, *Trisetum flavescens*, utilization management, *Calcinose*

Introduction

On a permanent grassland in South Germany on a basic soil at 700m asl, *Trisetum flavescens* reached nearly 40%, the content reported to be critical for causing calcinose in bovines (Altthaler, 1995).
The methods for reducing its content by different grassland management have been discussed but have not yet been determined (Poetsch and Dubbert, 2002). Our aim was to reduce the percentage of *Trisetum flavescens* under 20 % by reseeding and management.

Materials and Methods

The experiment involved comparison of two utilization management systems (early and frequent cut versus late cut) and three treatments of grassland renovation.
<u>Cutting management</u>
<u>Late cut:</u> Variant (V) 1, V. 5, V. 6: cut of primary growth not before 15 June, next cut 15th of August, max. 3 cuts per year
<u>Early cut:</u> V. 2, V. 3, V.4: early cut of primary growth (15 May), at least 3 cuts per year
<u>Grassland renovation</u>
V.1 and V.2: rejuvenation (after Tiley and Frame, 1991) by use of mineral fertilizer and change of management system (cutting instead of former grazing).
V.3 and V.5: reseeding with mixture NH (25 kg ha^{-1}) (*Lolium per.* 28%, *Dactylis glom*. 16 %, *Phleum prat*. 20%, *Poa prat*. 24%. *Trifolium rep*. 12%).
V.4 and V.6: reseeding with mixture NS2 (25 kg/ha) (*Lolium per*. 48%, *Dactylis glom*. 12%, *Phleum prat*. 12%, *Poa prat*. 16 %, *Trifolium rep*. 12%).
<u>Reseeding as direct drilling</u> in 1999 (with Köckerling slot seeder) after primary growth and after treatment with a rotary harrow.

Fertilisation
Late cut: Variants V.1, V.5, V.6: 115 kg N ha^{-1}; 28 kg P ha^{-1}; 166 kg K ha^{-1}; 21 kg Mg ha^{-1}.
Early cut: Variants V.2, V.3, V.4: 145 kg N ha^{-1}; 35 kg P ha^{-1}; 200 kg K ha^{-1}; 24 kg Mg ha^{-1}.
Determination of net energy by ´Hohenheimer Futterwerttest´ after Menke *et al.* (1979).
Yearly estimation of botanical composition of each experimental plot by the method of Klapp (1949) at the second regrowth in July.
Experimental design was a randomised complete block (3 treatments and 2 factors) with 4 replications, plot size being 25 m^2.

Results

The percentage of grasses in the permanent grassland was only slightly different after 6 experimental years, but individual grass species reacted differently. Late first cut increased the content of *Dactylis glomerata*, whereas *Poa pratensis* required an early cut in order to develop well. *Lolium perenne* could be increased by reseeding, but there was no difference between the reseeding treatments (Table 1).

Table 1. Percentage of various plant species after 6 experimental years in 3rd growth of 2004

Seed variant 1st cut	V.1: nil late	V.2: nil early	V.3: NH early	V.4: NS2 early	V.5: NH late	V.6: NS2 late
Grasses	94.3a	93.5a	89.3a	93.0a	94.0a	94.8a
Dactylis glomerata	37.3a	25.8b	26.5b	28.8b	41.3a	40.0a
Lolium perenne	3.8ab	2.3a	13.0b	13.3b	11.0b	11.8b
Poa pratensis	8.0ab	16.08a	17.05ab	13.5a	8.5b	5.0b
Trisetum flavescens	18.0a	18.08a	12.0b	14.3ab	15.8ab	15.8ab

Data with similar subscript letters within a row do not differ at $p<0.05$

The content of *Trisetum flavescens* decreased during the experimental period under 20% in all experimental treatments, reseeding being particularly effective (Figure 1). Dry matter-yields were influenced by the cutting regime (Figure 2). Late cutting (treatments V.1, V.5 and V.6) gave slightly lower DM-yields than early cutting. Yields were lowest by “late cut without any reseeding” (V.1). Unexpectedly, even in the very dry year 2003 with generally low yields, the early cut treatment had higher DM yields. These effects were similar for the net energy yields. The late cut regime gave lower energy contents and linked with the lower dry matter yields, produced lower amounts of net energy in total. Reseeding had no additional positive effects (Figure 3 and Table 2). Significant differences could not be observed between the two seed treatments.

Table 2. Average net energy contents and yields of DM and net energy of primary growths (2000–2003) (Data with similar subscript letters do not differ at $p<0.05$)

Var		DM yield t ha^{-1}	NEL MJ kg DM^{-1}	Energy yield MJ ha^{-1}
1	Late cut, no seed	4,40	4,6 b	19989 a
2	Early cut, no seed	5,03	5,6 a	28099 b
3	Early cut, NH	4,49	5,6 a	25088 ab
4	Early cut, NS2	4,32	5,7 a	24327 ab
5	Late cut, NH	4,77	4,5 b	21373 a
6	Late cut, NS2	4,44	4,6 b	20407 a
	LSD 0,05	0,998	0,6557	5798

NH = Nachsaatmischung Höhenlage = seed mixture for unfavourable areas
NS2 = Nachsaatmischung Nr. 2 = seed mixture for semi intensive grassland

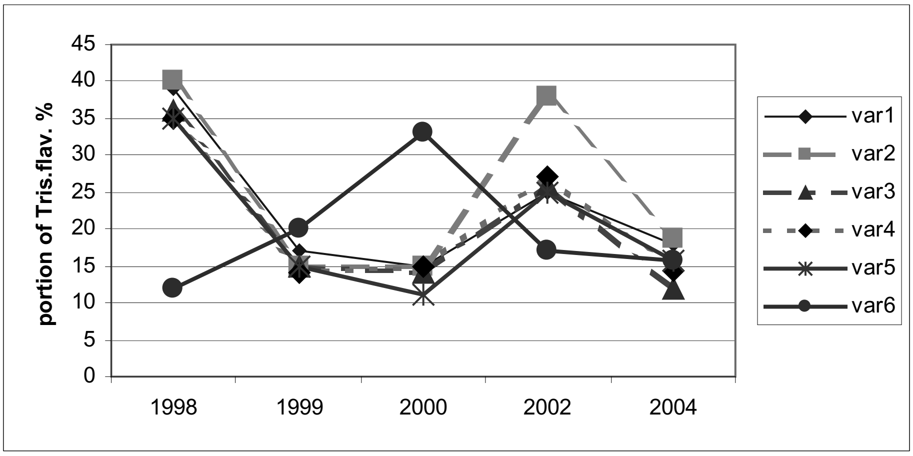

Figure 1. Development of *Trisetum flavescens* from 1998 to 2004 (%)

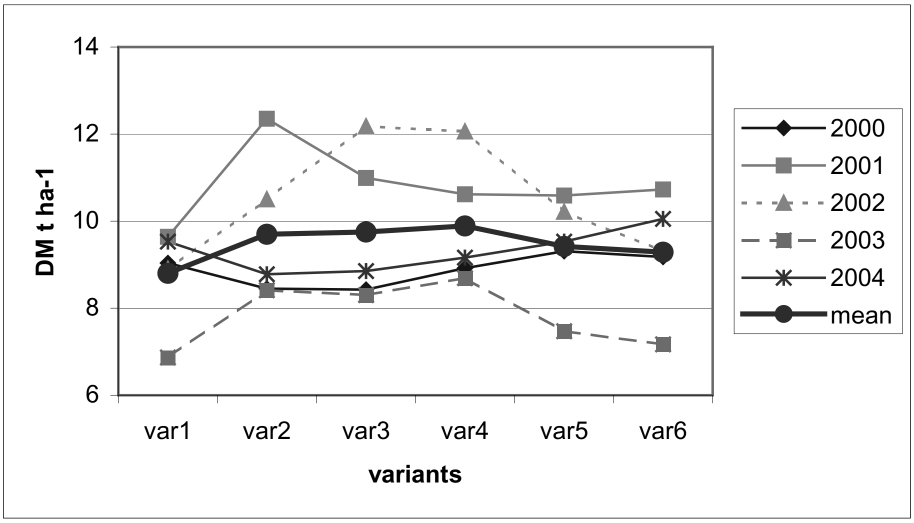

Figure 2. Average DM – yields of experimental treatments (2000–2004)

Conclusion

The experiment shows that the noxious *Trisetum flavescens* could be reduced as well by rejuvenation as by reseeding of the grassland sward. It can be concluded that more than 2 cuts per year are able to reduce *Trisetum flavescens*. Reseeding of the grassland gave no better effects on yields of dry matter and net energy for both utilization systems, but the effects of reseeding on the botanical composition were nevertheless significant. The portions of *Lolium perenne* increased with both seed mixtures and the portions of *Trisetum flavescens* were, caused by higher concurrence, lowest in the reseeded treatments. It could be shown that even the variation in grassland management, so called rejuvenation, is an environmentally friendly method to improve unfavourable permanent grassland. Reseeding after the use of rotary harrows increased the yields only in the first years after application.

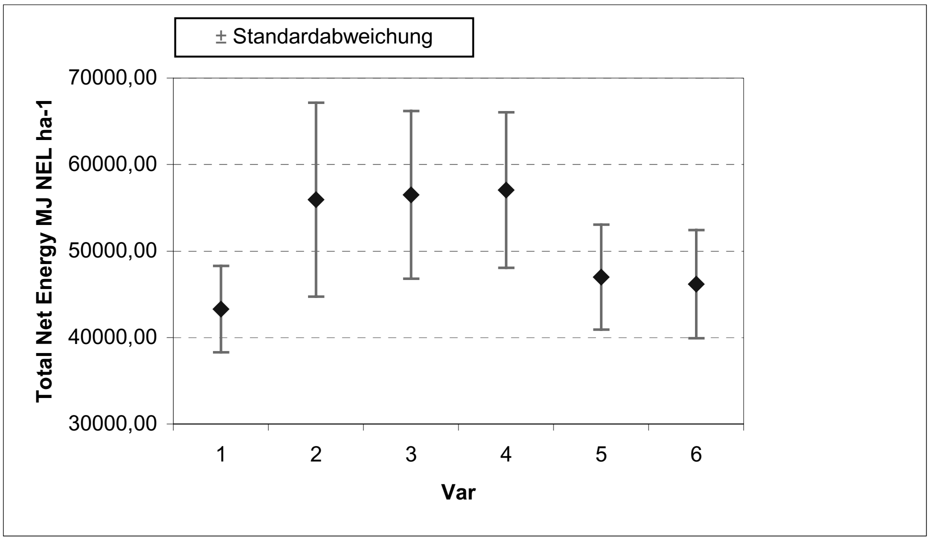

Figure 3. Average amount of net energy (MJ NEL ha^{-1} a) in 2000–2003

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Effect of mineral nutrition on alfalfa forage production

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Abstract

A one-factorial two-year field trial, under conditions of natural rainfall, was undertaken in order to optimize alfalfa (cv. NS-Mediana) mineral nutrition. The effect of phosphorus and potassium fertilizer application on dry matter yield and leaf area index was examined. Fertilizer application rates were determined on the basis of soil supply with the elements concerned and their removal by yield. The soil nitrogen content was 45 kg ha^{-1}. There were three different phosphorus (40, 80 and 120 kg ha^{-1}) and potassium levels (60, 120 and 180 kg ha^{-1}). The total number of treatments was 12. In the first year of study, the highest dry matter yield of 9.06 t ha^{-1} was obtained from the highest PK rate ($P_{120}K_{180}$) followed by $P_{40}K_{180}$ and $P_{80}K_{180}$ treatments (8.87 t ha^{-1} and 8.76 t ha^{-1}, respectively). The lowest yield was recorded on the K_{120} treatment (7.41 t ha^{-1}) and $P_{40}K_{60}$ (7.49 t ha^{-1}). In year 2, the highest yield was obtained by the $P_{80}K_{120}$ and $P_{80}K_{180}$ treatments (13.84 t ha^{-1} and 13.59 t ha^{-1}, respectively) and the lowest in the control treatment (11.46 t ha^{-1}). PK rates affected LAI values.

Keywords: alfalfa, mineral nutrition, yield, LAI

Introduction

Alfalfa (*Medicago sativa* L.) is the most common and important forage crop in the agro-ecological conditions of the Vojvodina Province (Cupina *et al*., 1997).

Plant nutrition management has a vital role in the success or failure of modern alfalfa production. Developing an efficient forage management system provides an opportunity to measure and record positive interaction among the various factors contributing to yield. These include cultivar, soil fertility, cutting schedules, and favorable environmental conditions or, in some regions, the use of irrigation (to achieve higher yields than would be possible with the implementation of any single practices; Lanyon and Griffith, 1988). As a leguminous plant with an ability to fix nitrogen, alfalfa should receive N fertilizer at a rate determined by the supply of N from the soil. Small amounts of N may be recommended at seeding time to aid seedling prior to the development of effective nodulation (Hojjati *et al*., 1978). There is no recent data in the domestic literature concerning the rates of P and K fertilizers required for the production of alfalfa. As a result the rates recommended to farmers are often either inadequate or excessive. Recommendations found in foreign literature cover a wide range of P and K rates. Lanyon and Griffith (1988) reported that alfalfa mineral nutrition is significantly affected by particular soil and weather conditions.

The objective of our two-year study was to monitor the affect of different rates of P and K fertilizers on alfalfa establishment (cv. NS-Mediana) and thus provide optimal recommendations of fertilizer rates in accordance with particular soil type and agro ecological conditions.

Materials and Methods

The field trial was carried out under conditions of natural rainfall during two years using alfalfa swards (cv. NS-Mediana). The trial was established in spring, 2001. The experiment was a randomized block design with four replicates. Soil analyses showed slight acidity

(pH 6.64), medium nitrogen content (0.20 g kg^{-1}) and medium phosphorus and potassium contents of 12.10 and 14.0 mg^{-1} 100 g^{-1} of soil, respectively. Fertilizer rates were determined according to the AL-method based on the soil supply of these elements and their removal by yield (Ubavić, 1996). The soil nitrogen content was 45 kg ha^{-1} (determined by the N-min method). There were three different phosphorus (40, 80 and 120 kg ha^{-1}) and three different potassium levels (60, 120 and 180 kg ha^{-1}). The total number of treatments were 12 (Control, $P_{80,}$ $K_{120,}$ $P_{40}K_{60,}$ $P_{80}K_{60,}$ $P_{120}K_{60,}$ $P_{40}K_{120,}$ $P_{80}K_{120,}$ $P_{120}K_{120,}$ $P_{40}K_{180,}$ $P_{80}K_{180,}$ $P_{120}K_{180}$).
Experimental plot size was 10 m^2. At maturity, dry matter yield (t ha^{-1}) was determined and samples for determining leaf area index-LAI (m^{-2} m^{-2}) were taken. Leaf area was measured with photo-electric system (AREA MATTER LI-3100) and LAI was calculated on the basis of determined coefficient and leaf mass taken from a square meter (Sarić *et al*., 1986). The results were statistically analyzed using analysis of variance, regression and correlation.
Weather conditions. In the first year of study when alfalfa was established, annual amount of precipitation (920 mm) was more than double that of the second year of investigation (420 mm) (Table 1).

Table 1. Monthly precipitation (mm) and average monthly temperature (°C) for 2001 and 2002 (Rimski Sancevi)

Parameter	Year	Month						Winter (X–IV)	Growing season	Annual sum
		IV	V	VI	VII	VIII	IX			
Precipitation	2001	127	75	233	56	30	162	237	683	920
	2002	26	87	27	33	55	46	191	284	465
Long-term average		48	59	83	62	55	39	255	346	601
Temperature	2001	11.2	17.8	18.3	22.3	22.7	16.1	–	18.1	11.9
	2002	11.7	18.1	21.8	23.6	22.2	17.1	–	19.1	14.6
Long-term average		11.3	16.6	19.7	21.4	20.9	16.9	–	17.8	11.0

Results and Discussion

The weather in the growing season has an influence on alfalfa growth and total nutrient requirements (Smith, 1970). In the first year of study, three cuts produced the average dry matter yield of 8.24 t ha^{-1}, while in the second year four cuts produced the average yield of 12.24 t ha^{-1} (Table 2). Regardless of weather conditions in the second year the alfalfa exhibited higher production levels.
In the first year of study, the highest dry matter yield of 9.06 t ha^{-1} was obtained from the highest PK rate ($P_{120}K_{180}$ treatment), followed by $P_{40}K_{180}$ and $P_{80}K_{180}$ treatments (8.87 t ha^{-1} and 8.76 t ha^{-1}, respectively). The lowest yield was recorded on the K_{120} treatment (7.41 t ha^{-1}) and $P_{40}K_{60}$ (7.49 t ha^{-1}). Significant differences were recorded between the lowest yield (treatment K_{120}) and highest yields ($P_{120}K_{180}$ and $P_{40}K_{180}$ treatments).
In year 2, the highest yield was obtained by the $P_{80}K_{120}$ and $P_{80}K_{180}$ treatments (13.84 t ha^{-1} and 13.59 t ha^{-1}, respectively) and the lowest in the control treatment (11.46 t ha^{-1}). Highly significant differences were recorded between the control treatment and treatments 8, 9 and 11.
In all treatments in both years the highest yields were recorded in the first cut (3.85 and 5.15 t ha^{-1}, respectively), then in the second and third (3.20 and 2.93 t ha^{-1}, respectively) and the very lowest in the third i.e. fourth cut (1.17 and 1.51 t ha^{-1}, respectively).

Table 2. Dry matter yield (t ha^{-1}) depending on PK fertilization

Treatment	2001			2002				Total yield	
	Cutting								
	I	II	III	I	II	III	IV	2001	2002
Control	3.51	3.68	1.14	5.01	2.94	2.28	1.23	8.33	11.46
P_{80}	3.71	2.80	1.23	5.10	2.90	2.39	1.45	7.74	11.84
K_{120}	3.51	2.76	1.14	4.92	2.81	2.99	1.54	7.41	12.26
$P_{40}K_{60}$	3.66	2.76	1.07	4.64	2.77	2.71	1.56	7.49	11.68
$P_{80}K_{60}$	3.44	3.17	1.16	4.78	2.81	2.85	1.38	7.77	11.82
$P_{120}K_{60}$	3.88	3.08	1.23	4.83	2.72	2.89	1.45	8.19	11.89
$P_{40}K_{120}$	4.19	3.12	1.28	5.19	2.24	2.99	1.49	8.59	11.91
$P_{80}K_{120}$	4.25	2.31	1.31	5.70	3.16	3.40	1.58	7.87	13.84
$P_{120}K_{120}$	4.28	3.35	1.08	5.42	2.94	3.45	1.56	8.71	13.37
$P_{40}K_{180}$	4.03	3.56	1.28	4.83	2.94	3.03	1.61	8.87	12.41
$P_{80}K_{180}$	4.17	3.45	1.14	5.75	2.90	3.31	1.63	8.76	13.59
$P_{120}K_{180}$	3.60	4.39	1.07	5.61	2.86	2.85	1.71	9.06	13.03
Average	3.85	3.20	1.17	5.15	2.83	2.93	1.51	8.23	12.42
LSD_{005}	1.42	1.31	0.47	1.16	0.73	0.06	0.05	1.40	1.60
$_{001}$	2.08	1.93	0.66	1.73	0.93	0.12	0.10	2.00	1.85

Combining the two study years in the analysis, the highest LAI was obtained in $P_{40}K_{120}$ treatment (9.1), followed by $P_{120}K_{60}$ (8.5) and $P_{120}K_{180}$ treatments (8.2). The lowest LAI was recorded in the $P_{80}K_{180}$ (7.4), followed by K_{120} (7.5) and control and P_{80} (7.6).

Table 3. Leaf area index (m^{-2} m^{-2}) depending on PK fertilization

Treatment	2001			2002				Total yield	
	Cutting								
	I	II	III	I	II	III	IV	2001	2002
Control	4.0	2.2	1.2	4.5	2.5	0.5	0.3	7.4	7.8
P_{80}	4.1	2.7	1.0	4.4	2.6	0.3	0.2	7.8	7.5
K_{120}	4.2	2.3	0.9	4.0	2.7	0.4	0.5	7.4	7.6
$P_{40}K_{60}$	4.3	2.0	1.5	4.2	2.8	0.8	0.6	7.8	8.4
$P_{80}K_{60}$	3.5	2.5	1.6	4.2	2.3	0.8	0.7	7.6	8.0
$P_{120}K_{60}$	3.7	2.1	1.7	4.8	3.0	0.9	0.8	7.5	9.5
$P_{40}K_{120}$	4.4	2.8	1.8	5.0	2.1	1.1	1.0	9.0	9.2
$P_{80}K_{120}$	4.5	2.7	1.2	4.3	1.9	0.5	0.6	8.4	7.3
$P_{120}K_{120}$	4.4	2.3	1.4	4.7	2.0	0.6	0.5	8.1	7.8
$P_{40}K_{180}$	3.7	2.5	1.5	4.7	2.3	0.5	0.8	7.7	8.3
$P_{80}K_{180}$	3.8	1.9	0.8	4.9	2.4	0.7	0.6	6.5	8.3
$P_{120}K_{180}$	3.9	2.3	1.4	4.8	2.5	0.7	0.8	7.6	8.8
Average	4.0	2.3	1.3	4.5	2.4	0.6	0.6	7.7	8.2
LSD_{005}	0.61	0.45	0.21	0.58	0.25	0.51	0.01	0.85	1.70
$_{001}$	0.93	0.61	0.34	0.69	0.71	0.72	0.03	1.12	1.85

The coefficient between LAI and dry matter yield ($r = 0.19$) was not significant. Wolf *et al.* (1976) state effect of LAI on alfalfa dry matter yield.

Conclusions

Regardless of weather conditions in the second year of alfalfa growth there was a higher yield. In the first year of study, three cuts produced the average dry matter yield of 8.24 t ha^{-1}, while in the second year four cuts produced the average yield of 12.24 t ha^{-1}.
In the first year of study, the highest dry matter yield of 9.06 t ha^{-1} was obtained from the highest PK rate. The lowest yield was recorded on the K_{120} treatment (7.41 t ha^{-1}).
In year 2, the highest yield was obtained by the $P_{80}K_{120}$ treatment (13.84 t ha^{-1}) and the lowest in the control treatment (11.46 t ha^{-1}).
Since alfalfa swards can survive for 4–6 years, the trend in the second year of the trial for a higher yield of fodder might continue in further years.
Taking the two study years together, the highest LAI was obtained in $P_{40}K_{120}$ treatment (9.1). The lowest LAI was recorded in the $P_{80}K_{180}$, (7.4).

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Effect of nitrogen fertilization on permanent grasslands productivity in the Vojvodina Province

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Abstract

Regardless soil type, botanical composition and forage yield and quality, the permanent grasslands of the Vojvodina Province receive no cultivation practices. Therefore, forage yields obtained from these grasslands are low. Even under rainfed conditions, appropriate agronomic practices ensure significant increases of herbage yield and quality. A study was carried out for two year (2003–2004), at three locations differing in altitude, soil properties and botanical composition, i.e., grassland yield and quality. The following N treatments (kg ha^{-1}) were applied: control, N_{40}, N_{80}, N_{120}, N_{160} and $N_{leg.}$-under sowing with legumes. The investigation included determinations of botanical composition, dry matter and crude protein yield (t ha^{-1}). Weather conditions (precipitation and temperature) highly affected the number of cuttings and herbage yield. In all three locations, highest dry matter yields were obtained in the treatment with the highest N rate. In all locations, the under sown species did not survive and thus they had not influence forage yield and quality. Correlation coefficient between dry matter and crude protein yield was highly significant.

Keywords: nitrogen fertilization, permanent grassland, productivity

Introduction

In the Vojvodina Province, permanent grasslands cover approximately 200,000 ha, of which area two thirds are pastures. Different soil types affect botanical composition i.e. herbage yield and quality of the permanent grasslands. Allomorphic soil types are common through the grasslands (at about 120,000 ha). They are concentrated in the region of Banat (80 %), where limeless solonetz is the predominant soil type. In upland regions (the Fruska Gora Mountain), there are grasslands (meadows) with satisfactory botanical composition but poor yields. Generally, the climate in the Vojvodina Province, primarily in respect to the rainfall amount and distribution, is not suitable for high forage production. Therefore, forage yields obtained from grasslands are quite low, ranging from 0.5 (pastures) to 2 t ha^{-1} (meadows) (Eric *et al*., 1998). On average, meadows produce one to two cuts per year. Regardless grassland location, i.e., botanical composition and forage yield and quality, they receive no cultivation practices. Even under rainfed conditions, appropriate technological practices ensure 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.
Bearing in mind the above mentioned, the objective of this study was to assess the effect of different N rates and spring harrowing on the yield, quality and botanical composition of permanent grasslands in the Vojvodina Province.

Materials and Methods

The study was carried out under rainfed conditions at three different locations:
- Location 1 – permanent pasture-altitude-80 m (lowland).
- Location 2 – permanent meadow-altitude-120 m (foothills of the Fruska Gora).

- Location 3 – permanent meadow-altitude-170 m (the Fruska Gora Mountain).

Locations differ regarding altitude, soil properties and botanical composition i.e. grassland yield and quality. In the first location, the experiment was established in 2002, while in the second and third location nitrogen rates were applied in 2003. In the first location, no differences between nitrogen treatments were recorded in the first year of study (2002) due to a long-lasting drought and high temperatures. Therefore 2002 were not discussed in the paper.

The following N treatments (kg ha^{-1} yr^{-1}) were applied: Control, N_{140}, N_{80}, N_{120}, N_{160}, and $N_{leg.}$ (under sowing with perennial legume: location 1- birds foot trefoil, locations 2 and 3 – red clover)

Nitrogen was applied early in the spring together with harrowing. The experimental design was a randomized block with three replications. Plot size was 4 m^2.

The investigation included:

- determination of botanical composition (according to Sostaric and Pisasic, 1968),
- dry matter (DM) yield (t ha^{-1}) and crude protein (CP) yield (t ha^{-1}).

Samples for chemical plant analyses were taken from the first cut in the second year of investigation. Statistical data analysis was performed by means of variance analysis, regression analysis, and correlations.

Soil properties. In location 1, the presence of species such as *Statice gmelini* indicated that the soil is saline, differing in wetness, 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 in the spring and it quickly dries afterwards, forming a rock-solid pavement. In location 2, soil samples taken from the fertilized variants differed in relation to the control, particularly in N and P contents (0.30 and 15.7, respectively). The soil in the third location belonged to chernozem type, with good properties for grass growing (Table 1).

Table 1. Soil chemical properties (control and fertilized)

Location	Sample	pH		$CaCO_3$	Humus	Total N	P	K
		KCl	H_2O	g kg^{-1}	g kg^{-1}	g kg^{-1}	mg $100g^{-1}$	mg $100g^{-1}$
1	Control	4.83	6.11	0.33	4.97	0.328	6.8	28.9
2	Fertilized	4.54	5.83	0.16	5.11	0.341	35.3	29.0
	Control	7.08	7.98	8.41	4.00	0.274	7.3	16.8
3	Fertilized	7.09	7.85	8.41	4.69	0.301	15.7	15.9
	Control	6.38	7.15	5.21	3.30	0.218	6.0	22.3
	Fertilized	6.30	6.81	5.21	3.69	0.228	8.5	20.0

Note: Fertilized – average for all applied treatments

Weather conditions. Precipitation sum and mean monthly temperatures (Table 2.) highly affected the number of cuttings and forage yield. In 2003, one spring cut was obtained at each location. In 2004, in consequence to favorable conditions, three cuts and high annual yield were obtained.

Table 2. Sum of monthly precipitations (mm) and mean monthly temperatures (°C) (2003 and 2004, R. Sancevi – Novi Sad)

Month/year	2003		2004		Long-term average	
	Rainfall	Temp.	Rainfall	Temp.	Rainfall	Temp.
I	48	–1.5	54	–1.0	36	–0.6
II	22	–4.7	41	2.5	36	1.2
III	9	5.9	16	6.7	37	5.7
IV	8	10.9	112	12.5	48	11.3
V	23	20.6	89	15.2	58	16.6
VI	31	24.0	80	19.8	83	19.7
VII	60	22.5	63	22.0	61	21.4
VIII	30	24.6	39	21.7	55	20.9
IX	84	17.3	42	16.3	38	16.9
X	142	10.4	–	–	41	11.4
XI	27	8.4	–	–	51	5.9
XII	18	7.6	–	–	50	1.6
Growing season	236	19.9	425	17.9	345	17.8
Winter	266	–	–	–	254	–
Total per year	502	12.1	–	–	600	11.0

* R. Sancevi-Novi Sad is the nearest meteorological station regarding locations

Results and Discussion

Botanical composition of grasslands. In the first location, the prevailing grasses were species from the genus *Festuca* (*F. pseudoovina* – 30 % and *F. ovina* – 20 %). Presence of *Alopecurus pratensis* (20%) was important from the point of herbage quality improvement. Nitrogen application increased the presence of *A. pratensis* and thus improved the herbage quality.

The meadow in the second location was composed of 8 grass species (44%), 6 legumes (36%) and 6 others species (20%). According to its botanical composition and the portion and quality of the species, this grassland was assessed as favorable for forage production, with high feeding value.

In the meadow in the third location, grasses participated with 59% (8 species), legumes with 29% (7 species) and others herbaceous species with 12% (3 species). The dominant species from the families *Poaceae* and *Fabaceae* have very good or excellent feeding value. Birdsfoot trefoil was the dominant species in summer months.

Dry matter and crude protein yield. In the first location in which treatments were established in 2002, DM yield in the control variant was 0.51 t ha^{-1}. However, due to long-lasting drought and high temperatures, it was impossible to assess the effectiveness of N rates.

In 2003, one spring cut was obtained in each of the three locations. The next year, which was favorable particularly regarding rainfall (Table 3), three cuts were achieved. Hence, a significantly lower DM yield was achieved in 2003 compared with 2004. DM yield increased with N rate increase. In all locations and in both 2003 and 2004, highest yields were recorded with the highest N rate (N_{160}), lowest in the control and $N_{leg.}$ treatment (Table 3). Correlation coefficients between N rates and DM yield and DM and CP yield were highly significant. Nitrogen application affected the presence of some useful plant species, thus affecting herbage quality. In all locations, the undersown species did not survive and thus they had not influence on forage yield and quality. Krautzer and Bohner (2002) claim that only endogenous plants should be used for successful undersowing.

Table 3. Effect of N rate on annual dry matter (t ha^{-1}) and crude protein yield (t ha^{-1}) at three studied locations and two years

Year / Location / Treatment	2003						2004					
	1		2		3		1		2		3	
	DM	CP	DM	CP	DM	CP	DM	CP	DM	CP	DM	CP
Control	0.62	0.05	1.62	0.14	0.79	0.07	2.07	0.18	3.36	0.30	4.18	0.38
N_{40}	0.61	0.06	2.38	0.29	1.42	0.14	4.90	0.52	6.16	0.77	8.03	0.83
N_{80}	0.74	0.08	2.60	0.40	1.44	0.16	5.46	0.63	8.11	0.27	9.76	1.38
N_{120}	0.80	0.10	2.69	0.44	1.86	0.23	6.90	0.89	8.03	1.33	9.24	1.20
N_{160}	0.85	0.12	3.18	0.27	1.99	0.29	7.19	1.03	11.14	2.09	13.29	2.02
$N_{leg.}$	0.59	0.05	1.67	0.17	0.89	0.09	3.37	0.48	2.79	0.28	3.63	0.36
Average	0.70	0.07	2.35	0.45	1.39	0.16	5.10	0.44	6.59	0.91	8.01	0.93
LSD_{005}	0.12	0.008	0.35	0.08	0.28	0.03	0.82	0.11	0.93	0.14	1.14	1.33

Conclusions

DM yield increased in proportion to N rate increase. In all locations and both in 2003 and 2004, highest yields were recorded with the highest N rate (N_{160}) and lowest in the control and $N_{leg.}$ treatment.
It is expected that in subsequent years, N fertilization, in addition to yield increase, will have positive effects on the botanical composition of permanent grasslands, i.e., on the presence of better quality grasses and legumes, which will result in higher forage feeding value.

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Effect of nitrogen fertilizer and underseeding on the productivity and chemical composition of *Cynosuretum cristati* type meadows on hilly-mountainous grasslands in Serbia

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Abstract

The research was carried out on the Sjenica-Pester plateau in 2002–2003 on a natural *Cynosuretum cristati* type meadow, at Vrujci, which is 1158 m above sea level. Five nitrogen fertilizer levels (0, 40, 80, 120 and 160 kg ha^{-1}) and red clover and birdsfoot trefoil was underseeded. The data showed a favourable effect of nitrogen fertilizer on increasing DM yield, crude protein, ash and fat content and a negative effect on cellulose content. The maximum DM yield was recorded when 160 kg ha^{-1} nitrogen was applied and the yield amounted to 4.44 t ha^{-1} for two years (increase of 2.03 t ha^{-1} or 85.0% over the control). Increasing the rate of nitrogen increased the protein content, ash, fat, and reduced the cellulose. The DM yield from the underseeded legumes was minimal in the wet year but was significantly higher over the control in the dry testing year. Underseeding did not improved the chemical composition.

Keywords: fertilization, meadow, nitrogen, undersowing, DM yield, chemical composition

Introduction

Natural meadows occupy large areas in the hilly-mountain regions of Serbia. They are of considerable importance for forage and soil utilization and protection. The basic measure for the improvement of meadows and pastures is with fertilization. The use of N fertilizer is an important factor in intensive grass-based dairy farming, as it affects DM yield and the crude protein (CP) concentration of the herbage, and thereby reducing the amount and concentration of supplementary CP fed, and the amount of the N losses through ammonia volatilization, nitrate leaching, nitrous-oxide emission and denitrification (Chamble *et al.*, 1953; Jarvis, 1996; Whitehead, 2000). The results of many tests performed in Serbia show that nitrogen fertilizer had a favourable effect on increasing the yield, crude protein, ash and fat content, and the opposite on cellulose content (Vuckovic *et al.,* 2004). Recommendations for application rates of N fertilizer have been defined at a tactical management level, often as a function of soil and grassland type and climate (Vellinga and André, 1999). The criterion for optimum application rates of N fertilizer was merely economic, for example, a marginal N response of 10–5 kg DM of herbage per kg N (Unwin and Vellinga, 1994; Whitehead, 1995; Reid, 1970; Morrison *et al.,* 1980).

Materials and Methods

The experiment was carried out on the natural meadows in the hilly mountainous region of Serbia – Sjenica-Pester Plateau. In 2002–2003, trials were conducted on a natural *Cynosuretum cristati* type meadow, which is situated 1158 m above sea level. Soil analyses were carried out. The plot experiment was designed as complete blocks with four replications. Five nitrogen fertilizer levels (0, 40, 80, 120 and 160 kg ha^{-1}) were used and red clover and birdsfoot trefoil were underseeded. Fertilization was applied directly on to the surface after the melting of the snow (at the beginning of May). The change in the grass cover was observed by botanical analysis of green herbage. Chemical composition of the DM was represented by CP, ash, fat and cellulose. DM yield was determined on the basis of total DM amount per plot and calculated as DM yield ha^{-1}. Samples were analyzed in the college laboratory, according to the standard methods.

Survey of natural conditions

In 2002–2003 an observation of important meteorological elements was made (Table 1). The mean monthly and annual temperatures were low. The mean annual air temperature was 7.66 °C in 2002, and 6.43 °C in 2003. Late spring frost occured in May and started in fall during September and October.

The amount of precipitation was relatively high in this region (Table 1). Although the amount of precipitation had a great effect on the vegetative productivity of meadows and pastures, it is frequently not well distributed on Sjenica-Pester Plateau. This happens because a rainy period is frequently followed by a marked fall of temperature which retards the growth and development of grasses, and reduces the productivity of the vegetation.

Table 1. Mean monthly temperatures (°C) and total precipitation during 2002 and 2003

Year	Temperatures – °C		Amount of precipitation – mm	
	2002	2003	2002	2003
I	–5.5	–1.8	21.8	133.0
II	2.1	–8.3	31.3	46.7
III	4.3	–0.5	58.4	6.4
IV	6.3	4.9	85.7	52.4
V	12.6	14.2	110.0	64.9
VI	15.7	16.2	21.1	77.1
VII	17.4	16.9	118.0	63.2
VIII	15.7	18.0	73.7	63.4
IX	10.3	10.7	120.0	68.0
X	8.3	7.0	99.4	148.0
XI	5.2	4.8	35.1	31.0
XII	–0.5	–4.9	67.3	49.0
I–XII	7.66	6.43	842.0	803.0

The meadow and pasture vegetation of *Cynosuretum cristati* on Sjenica-Pester Plateau was formed on humus-silicate soil (Ranker). These are shallow to medium deep soils, skeletoid to different degrees, very humic and acidic (Table 2).

Table 2. Chemical properties of the soil

pH_{H2O}	Humus (%)	mg/100 g – soil	
		P_2O_5	K_2O
5.2	7.5	1.1	9.6

Results and Discussion

The effect of nitrogen fertilizers on meadow-pasture vegetation was complex. The grass cover responds not only in yield but also in composition: the ratios between individual species change and with continued use of nitrogen fertilizers, it is possible to get substantial changes in the species composition. The data showed a considerable effect of nitrogen fertilization on natural meadow *Cynosuretum cristati*, especially on yield, quality and on species composition.

Botanical composition of the sward

Data in Table 3 showed the domination of *Poaceae* (48.40–56.04%). Most of grasses were moderate or lower in feeding value. The second most dominate were other species (42.0–34.74%) with no feeding value. *Fabaceae* participate with (9.6%–9.2%), along which *Genista sagittalis*, was very numerous. Other legumes had good feeding value. With increasing of the nitrogen fertilization level, the quantity of higher qulaity grass was improved. The legumes and other herbages were reduced.

Table 3. Botanical composition of the sward

Plants sward in % of mass	2002	2003
Poaceae	48.40	56.04
Other species	42.00	34.74
Fabaceae	9.60	9.20

DM yield and chemical composition

The data showed a favorable response to nitrogen fertilizer on DM yield (Table 4). The maximum yield was obtained by applying 160 kg ha^{-1} nitrogen, amounting to 4.44 t ha^{-1} for two years (an increase of 2.03 t ha^{-1} or 85.0% over the control). This effect varied in 2002 and 2003, depending on the amount of precipitation during vegetation. Although the total yield of DM per unit area was less in the drier year, the percentage above the control was higher in the dry year as compered to the wet year. In 2003 and 2002, the increase in DM yield as compared to the control was 153% and 50%, respectively. These results showed that fertilization not only gives higher yields, but also stabilized fodder production since better nourished grasses use water more economically.

Table 4. The effect of nitrogen fertilizer on the dry matter (DM) yield of the meadow type *Cynosuretum cristati*

Fertilizer N (kg ha^{-1})	2002 (t ha^{-1})	2002 %	2003 (t ha^{-1})	2003 %	Average (t ha^{-1})	Relative yield
0	3.20	100	1.62	100	2.40	100
40	4.02	126	3.35	207	3.68	153
80	4.66	145	3.57	219	4.10	170
120	4.58	143	3.91	241	4.25	177
160	4.78	150	4.10	253	4.44	185
Average	4.24	133	3.30	203	3.77	157
LSD-0.05	0.22		0.35			

Forage quality of natural *Cynosuretum cristati* type meadow was substantially affected by different rates of nitrogen fertilizer (Tables 5 and 6). Increasing the rate of N application resulted in an increase of the protein, ash, fat content and reduced the cellulose content. The DM yield with underseeding was minimum in the wet year, but significantly higher over the control in the dry year. In the dry year 2003, the underseeding yield was higher by 1.07 t ha^{-1}

(66%), while in 2002 which was a wet year, the increase was 0.07 t ha^{-1} (2%). Underseeding did not prove justified for improving the chemical composition. Protein and fat content in both years increased more efficiantly by nitrogen fertilizing than by underseeding.

Conclusions

All levels of nitrogen fertilizers tested showed a favorable effect on DM yield. The maximum yield was obained by applying of 160 kg ha^{-1} nitrogen, amounting to 4.44 t ha^{-1} for two years, which was an increase of 2.03 t ha^{-1} or 85.0% over the control. The fertilizers also changed the botanical composition of the *Cynosuretum cristati* plant association. With increasing nitrogen fertilization levels, the quantity and quality of grass was improved. The legumes and other herbages were reduced.

Increasing the rate of N applied resulted in an increase of the protein, ash, fat content and reduced the cellulose content. The DM yield with underseeding was minimum in the wet year, but significant in the dry year. The chemical composition improvement with underseeding was minimum.

Table 5. Dry matter yield and chemical composition of perennial grasslands as affected by different rates of nitrogen fertilizer and underseeding in 2002

Fertilizer N (kg ha^{-1})	DM (t ha^{-1})	CP	Ash	Fat	Celululose
		(g kg^{-1} DM)			
0	3.20	81.8	55.3	15.9	332.6
40	4.02	96.9	57.2	26.2	311.0
80	4.66	116.4	63.2	29.8	309.5
120	4.58	120.3	67.8	32.3	295.3
160	4.78	146.5	70.1	35.7	277.6
Underseeding	3.27	97.7	57.7	19.1	321.7
LSD_{005}	0.22	4.32	1.52	3.44	7.15

Table 6. Dry matter yield and chemical composition of perennial grasslands as affected by different rates of nitrogen fertilizer and underseeding in 2003

Fertilizer N (kg ha^{-1})	DM (t ha^{-1})	CP	Ash	Fat	Celululose
		(g kg^{-1} DM)			
0	1.62	78.4	53.2	12.3	344.1
40	3.35	88.9	55.8	18.7	331.7
80	3.57	107.6	59.7	24.4	309.7
120	3.91	112.3	66.4	28.6	286.5
160	4.10	124.4	68.1	30.1	280.4
Underseeding	2.69	90.4	55.4	18.1	331.3
LSD_{005}	0.35	5.12	1.10	2.98	8.13

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Performance of lactating dairy cows fed rations with inoculated red clover-grass mixture silage

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Abstract

Low concentrate grass feeding systems for cattle are the most appropriate in Lithuania. Grass and legume forages are the main feeds for dairy cows and beef cattle. First cut red clover-grass mixture silages were ensiled in pits with inoculant (*Lactobacillus rhamnosus + Propionibacterium freudenreichii ssp. shermanii*) or without any additives. Fermentation quality, nutrient losses and aerobic stability of silages were determined. The inoculated silage had no butyric acid, nutrient losses were lowered by 19.4%, and both organic matter digestibility and energy values were higher for the inoculated silage in comparison with the ordinary one. A feeding study was conducted using lactating dairy cows to compare red clover-grass mixture silage inoculated or not inoculated. The lactating dairy cows fed inoculated silage consumed on average 0.89 kg^{-1} DM more compared with feeding non-treated silage. The milk yield tended to increase when the inoculated silage was fed and, the yield of energy corrected milk (ECM) was higher by 2.1 $kg^{-1}day^{-1}$ cow. The output of milk fat and milk protein were higher respectively by 84.8 and by 58.6 g $day^{-1}cow^{-1}$ for cows fed the inoculated silage compared with the untreated silage.

Keywords: grass, red clover, silage, inoculant, fermentation quality, milk

Introduction

Due to the short grazing period and long indoor feeding period in Lithuania, conserved forages play an important role in ruminant feeding. The cheapest and highest-value forages involving the lowest energy inputs can be produced from legume and legume-grass swards (Halling *et al*., 2002). Compared with grass, pure lucerne and red clover, as well as grass-legume mixtures, have a high feeding value because of high intake characteristics, high digestibility and high concentration of protein, Ca and Mg (Campling, 1984). The advantages of legumes as one of the main nitrogen sources and valuable winter forage are still underused. In particular, legume-based systems are known to contribute to sustainable, environmentally-friendly and energy-efficient agriculture (Porqueddu *et al.,* 2003). Opportunities for promoting grassland utilisation are related to the positive health characteristics it gives to animal products. Obtaining good fermentation quality, digestibility of nutrients and high energy and protein value in silages, requires the regulation of the ensilage process, particularly for herbages with the higher values of buffering capacity. Studies (Playne *et al.,* 1966) have confirmed that clovers have approximately twice the buffering capacity of the ryegrass and this is clearly an important factor associated with the difficulties encountered in the ensilage of leguminous crop. The advantages of the use of biological inoculants, recently obtained bacterial additives, thanks to the suitable selection of lactic acid bacteria, have been stressed by many workers, and it is clear from the results that inoculants have a beneficial effect on the improvement of the fermentation quality of silages (Fychan *et al*., 2002; Winters *et al*., 2002; Wrobel *et al*., 2004). An experiment was conducted to compare the effects of ensiling red clover-grass mixture untreated and treated with biological additive on silage quality and to examine the nutritive value of the silages.

Materials and Methods

A legume-grass mixture was used in the experiment (64% to red clover (*Trifolium pratense* L.) cv. Arimaiciai, 12% – timothy (*Phleum pretense* L.) cv. Gintaras, 16% – meadow fescue (*Festuca pratensis* Huds.) cv. Kaita and 8% – others) on second (2) year's use. The sward was cut at the flowering stage of red clover on 14 June, 2003 with the mower conditioner *Kverneland 347*. The crops were allowed to prewilt for approximately 30 h before they were chopped with a chop harvester (E-281). The inoculant (based on two patented bacterial strains: *Lactobacillus rhamnosus* LC 705 (DSM 7061) and *Propionibacterium freudenreichii* ssp. *Shermanii* JS (DSM 7067), Finland) dosage 10^6 cfu g^{-1} was applied using a commercial pump "HP-20" in the chopper. Dry inoculant was mixed with water according to the instruction and applied at the rate 5 l t^{-1}. The grass was ensiled in the period, when the weather was good (temperature 18–21 °C), without rain. The herbages was ensiled in two ferro-concrete pits 100 t each (one – inoculant free, another – with inoculant). During the ensilage, samples of chopped grass were collected to determine its chemical composition. Five control bags of 1 kg weight each were put into each pit to determine dry matter (silage fermentation) losses. Ensiling was finished in a 2 days time and the pressed mass was covered tightly with plastic.

The feed from the pits was offered to animals on 10 December, 2003. After withdrawal and weighing of the control bags, the chemical composition, fermentation quality and dry matter losses of silages were determined. Aerobic stability was measured by changes in silage temperature following exposure to air for 10 days. A representative sample (200 g) of each silage was placed in an open plastic bag that was subsequently placed into a polystyrene box (volume about 1.5 l, and 10 mm wall thickness). There was a 25 mm round opening in the lid of the box through which the rest of the plastic bag was pulled and opened so that air could freely pass. A thermal probe was inserted into the mid point of silage through the opening. Boxes were kept in a room with constant temperature (≈ 20 °C). The temperature of the samples was measured once daily, following exposure to air for 10 days.

Ten dairy cows of the Lithuanian Black-and-White breed were used in the experiment. A three-week pre-experimental period was used in which untreated silage was offered *ad libitum* together with the compound feed. Compound feed (consisting at 75% barley, 10% wheat, 15% soybean meal and vitamin-mineral concentrate *4923 Optima Dairy Extra)* to cows was fed individually according to the milk yield (310g for 1 kg 4% milk). In experimental period (100 days) each group consisting of five cows was fed its respective silage *ad libitum* offered in two meals per day. The weight of the offered silage was determined once weekly on two consecutive days and refusals were weighed back and subtracted when calculating daily intake. The amount of compound feed was recorded at each meal. Milking of cows was performed twice daily in the stable. Milk yield was recorded for two consecutive days every two weeks and aliquat milk samples from morning and evening milk were bulked and content of fat, protein was analysed. The data were analysed by one-way ANOVA, and a mean comparison by Fisher' LSD.

Results and Discussion

The chemical compositions of the herbages and the silages are given in Table 1. The activity of the inoculant was evidenced in this experiment by higher water soluble carbohydrates (WSC) by 18.5g kg^{-1} ($P<0.05$), total acids by 9.81 g kg^{-1} ($P<0.05$) and lactic acid by 21.23 g kg^{-1} ($P<0.01$) and lower acetic acid by 10.41 g kg^{-1} ($P<0.05$), butyric acid by 1.03 g kg^{-1} ($P<0.01$) contents of the inoculated silage compared with the untreated silage. There were found (Driehuis *et al.,* 2001) that silages inoculated with *L. buschneri* plus *Pediococcus pantosaceus* and *L. plantarium* had significantly higher concentrations of lactic acid and lower concentrations of acetic acid. As compared with the untreated silage, the inoculant reduced proteolysis. Lower protein breakdown occurred in the inoculated silage as indicated by the lower (P<0.05) ammonia – N content. Winters *et. al.,* 2002 found that inoculation with *L. plantarium* improved silage quality and reduced the extent of protein breakdown during ensilage of red clover. Due to the higher fermentation quality the nutrient (DM) losses were lower by 19.4% (P<0.01) in the inoculated silage compared with the untreated one. *In vitro* organic matter digestibility of inoculated silage was 760 g kg^{-1} DM and that of the untreated silage 748 g kg^{-1} DM. The inoculation had a positive effect on the nutritional value of silages, however, the digestible energy of the inoculated silage was higher by 0.67 MJ g kg^{-1} DM (P<0.01) compared with untreated.

Table 1. Chemical composition of herbage and silages and fermentation quality of silages

Treatment	Herbage	Silages		$LSD_{0.05}$	$LSD_{0.01}$	S_x
		C	I			
Dry matter, (DM) g kg^{-1}	327.8	318.6	331.5	27.377	39.835	2.582
In dry matter g kg^{-1}:						
organic matter	938.5	933.8	937.5	5.303	7.716	0.174
crude protein	124.4	125.8	130.1	14.872	21.64	3.564
crude fibre	214.2	227.3	221.1	9.03	13.139	1.235
WSC	111.5	28.5	47.0*	17.066	24.833	13.85
NDF	490.8	513.6	502.6	14.352	20.883	0.866
ADF	294.1	335.9	322.0	17.813	25.918	1.66
total acids		67.68	77.49*	6.948	10.109	2.935
lactic acid		40.01	61.24**	8.681	12.631	5.258
acetic acid		26.25	15.84*	9.103	13.245	13.26
butyric acid		1.30	0.27**	0.700	1.018	27.38
Ammonia N, g kg^{-1} total N		39.96	33.18*	4.81	6.999	4.033
pH		4.39	4.23*	0.133	0.193	0.946
ME, MJ kg^{-1} DM		8.21	8.88**	0.233	0.339	0.836
DM losses, g kg^{-1} DM		101.81	82.02**	8.302	12.08	2.77

* and ** denotes significant at level 0.05 and 0.01 respectively

The inoculant was not found to have a negative influence on air stability of the silage (Fig. 1). Both inoculated and untreated samples increased in temperature by more than 3 °C after 3 days from the start. The temperature of inoculated and untreated silages rose above the ambient temperature within 1 day, and the untreated silage had a temperature rise of more than 2 °C within 1 day while the inoculated silage had a temperature rise of more than 2 °C in more than 2 days. Other authors found that some inoculants can improve the aerobic stability in silages by inhibiting the growth of both yeast and molds in silages (Driehuis *et al.,* 2001).

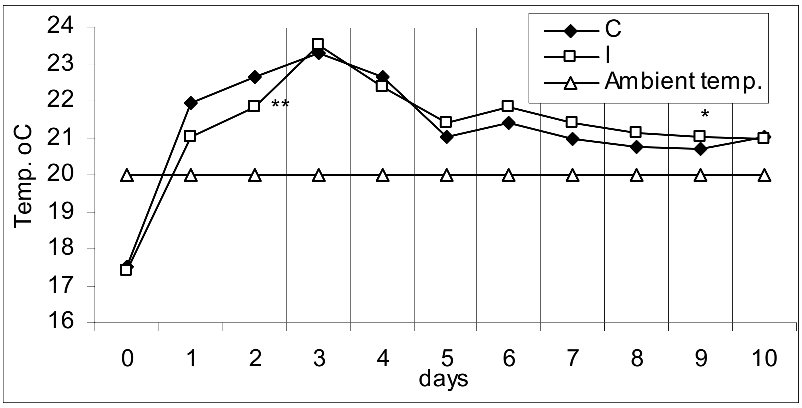

Figure 1. Changes of temperature in silages (* denotes significant at level 0.05.)

As shown in Table 2 inoculation gave the higher (by 0.89 kg cow^{-1} day^{-1}) dry matter intake than the untreated silage. Milk yield was affected due to the higher intake and the higher nutritive value of the inoculated silage. Average milk yield was higher by 13.2% for the inoculated silage diet compared with the untreated silage. Higher silage dry matter intake and better performance of animals were found by Winters *et al.,* 2001. The results showed that milk fat and milk protein did not differ markedly between the treatments. Due to higher milk yield the output of milk fat and milk protein were higher respectively by 84.8 and by 58.6 g day^{-1}cow^{-1} for cows fed the inoculated silage compared with the untreated silage.

Table 2. Intakes, yields and composition of milk of dairy cows fed inoculated and untreated silages

Treatment	Silages		$LSD_{0.05}$	$LSD_{0.01}$	S_x
	C	I			
Silage intake, kg DM cow^{-1} day^{-1}	13.34	14.23	3.769	6.25	6.963
Total DMI, kg cow^{-1} day^{-1}	18.58	19.97	5.30	8.789	7.003
Total ME intake, MJ	175.94	200.31	50.663	84.012	6.859
Daily milk production					
Milk, kg cow^{-1} day^{-1}	15.57	17.67	2.854	4.732	4.373
ECM, kg cow^{-1} day^{-1}	15.92	18.03	4.579	7.594	6.869
Milk composition					
Fat, g kg^{-1}	41.06	41.30	7.782	12.904	4.813
Protein, g kg^{-1}	33.44	32.92	1.902	3.154	1.46
Milk constituent output					
Fat, g day^{-1}	646.2	731.0	232.34	385.28	8.593
Protein, g day^{-1}	521.4	580.0	104.299	172.954	4.819

Conclusions

Inoculation can improve forage quality of legume-grass mixtures and thus create financial economy at farm scale. The quality and nutritive value of the silage and obtained milk yield and milk composition of dairy cows demonstrate that ensilage of red clover-grass mixture with the bacterial additive was a better method of feed preservation than use of no additive when silage making.

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Silage potential of horticultural by-products for the feeding of small ruminants in southern Spain

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Abstract

Almería, a province located in arid south-eastern Spain, has undergone a quite remarkable increase in agricultural production in the last three decades, basically as a consequence of intensive horticultural production. In 2002, 25,000 hectares were cultivated in hothouses, generating enormous economic benefit and a great quantity of vegetable by-products. Disposal of these by-products constitutes a major impact on the environment, and consequently diverse strategies are being applied to reuse them.
These vegetable by-products are essential for the subsistence of the province's 238,000 sheep and 168,000 goats, whose importance is more of a social than an economic nature. In this work we have summarized the different results obtained from the silage of diverse horticultural by-products. Tomato (*Lycopersicon esculentum*), green bean (*phaseolus vulgaris*), aubergine (*Solanum melongena*) and pepper (*Capsicum annum*) plants have been ensiled, as well as tomato, melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*) pulp. In general, the results obtained are most promising, both as regards their nutritive value and their suitability for conservation by silage.

Keywords: vegetable by-products, nutritive value, conservation, diet, sheep, goat

Introduction

The southeast corner of the Iberian peninsula has traditionally been a relatively poor region. However the extraordinary economic boom of recent decades has changed this situation, thanks in the main to intensive agriculture. The following figures give a good indication of the true dimension of this boom: the area of greenhouse crops in the province in 1984/85 was approximately 11,000 hectares, and in 2003/04 the area had increased to 27,000 hectares.
This has naturally resulted in huge quantities of vegetable by-products. Escobar (1998) estimates a total of 935,000 tonnes of fresh vegetable waste matter a year. Such a large quantity of vegetable waste has an obvious impact on the environment, and many methods have been used to recycle or dispose of it. Composting is the most common of these methods.
Small ruminants (sheep and goats) have traditionally been associated with poor regions such as this one. In 2004 there were 238,000 sheep and 168,000 goats in the province (Morcillo, 2004). Although numerous, this livestock is economically insignificant compared to the agricultural sector. Nevertheless, it is our belief that this livestock plays a most important role. They constitute the only way to exploit an enormous area of scant productivity and provide a source of income for many families in rural areas. The semi-arid nature of the area means that the amount of pasture available for these ruminants is highly variable and often scarce at certain times of the year. Owners are often obliged to supplement pasture with forage, and this costly resource makes it harder for them to make a profit.
We therefore consider that vegetable by-products from greenhouses could be conserved for use during future periods of pasture shortage. Due to the high humidity of this waste material, the most recommendable method for this is silage, which consists of the preservation of agricultural by-products by acids which are either added or produced by natural fermentation.

Once the by-products have been collected the material may be chopped or conditioned, additives may be added, and it is then stored in the absence of air so that facultative anaerobic bacteria, present in the forage or added as inoculants, can rapidly convert soluble carbohydrates into acids (Mannetje, 2000). The resulting pH of a well-ensiled product becomes so low that all life processes come to a halt and the material will be preserved for as long as it remains in airtight storage.

For some time the main aim of our research group has been to determine which agricultural by-products are most suitable for preservation while also being of high nutritional value for the livestock.

Materials and Methods

Our research has been developed along the following lines:

- A great variety of by-products was chosen, both for their abundance and for their suitability for silage:
  - Plants (i.e. the whole plant minus the fruit): tomato, pepper, green bean and aubergine
  - Plant clippings: tomato
  - Fruit: tomato, melon and water melon
- Assays have involved the combination of different parameters: composition (using only one by-product or a mixture of several); size (laboratory silo of 1.5 kg, microsilo of 30–40 kg, and silage bags of 200–250 kg); and the use of different natural or chemical additives (formic acid, molasses, salt and straw).
- The vegetable by-products were desiccated and ground in order to determine their nutritional value both before and after silage. Chemical analysis was used to determine the following parameters: dry matter (DM), crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), and ash. The *in vitro* dry matter digestibility (IVD, pepsin/pancreatin) was also determined.
- The evolution and stability of the various silage samples was monitored. Those samples of high water content tend to be less stable than those with a higher content of DM, and it is not therefore known how long they can be stored maintaining perfect nutritional and fermentative characteristics. We should also bear in mind the seasonal nature of these by-products and the fact that a vast quantity becomes available in a relatively short time span. Each of the above-mentioned samples was divided into several bags which were opened at the appropriate moment for analysis.
- The parameters used to determine correct fermentation of the silage were pH and the sensory characteristics, i.e. smell, colour and texture.

Results

As can be seen from Table 1, on the whole the results are most promising, with only a few exceptions.

Table 1. Composition of silage samples

Type of by-product	Silo type	Silage duration (days)	Initial DM	Nutrient composition of silages (%DM)						Effluent
				pH	Ash	CP	NDF	ADF	IVD	
Tomato plant	Laboratory silo (1,5 kg)	50	27,2 ± 1,0	4,2 ± 0,2	23,4 ± 0,9	17,0 ± 0,2	39,7 ± 0,3	32,3 ± 0,2	58,2 ± 1,0	Low
Green bean plant	Laboratory silo (1,5 kg)	50	27,6 ± 1,2	4,4 ± 0,2	21,4 ± 0,5	17,4 ± 0,3	56,1 ± 0,3	31,3 ± 0,0	68,0 ± 1,3	Low
Aubergine plant	Laboratory silo (1,5 kg)	27	34,6 ± 0,9	3,9 ± 0,3	15,5 ± 0,6	n.c. [2]	62,8 ± 0,3	43,1 ± 0,4	53,1 ± 1,1	Low
Pepper plant	Laboratory silo (1,5 kg)	24	24,8 ± 1,0	4,3 ± 0,2	19,3 ± 0,7	19,7 ± 0,3	48,5 ± 0,5	35,1 ± 0,8	46,6 ± 1,4	Low
Tomato plant + aubergine plant	Laboratory silo (1,5 kg)	27	44,5 ± 0,9	3,8 ± 0,3	14,4 ± 0,5	n.c. [2]	63,8 ± 0,9	42,0 ± 1,1	60,3 ± 1,2	Low
Tomato pulp (40%) + clippings (60%)	Laboratory silo (1,5 kg)	30	9,1 ± 0,2	4,1 ± 0,1	12,3 ± 1,1	21,9± 0,9	40,5 ± 1,8	32,7 ± 2,0	58,2 ± 1,2	Medium
Tomato pulp	microsilo (40 kg)	30	7,0 ± 0,1	4,0 ± 0,1	5,9 ± 0,4	10,2 ± 0,9	55,3 ± 1,2	51,8 ± 5,1	44,5 ± 0,8	High
Melon and watermelon pulp	microsilo (30 kg)	30	7,8 ± 1,3	4,5 ± 0,1	10,6 ± 0,5	16,5 ± 1,2	62,4 ± 3,6	56,3 ± 2,6	55,2 ± 2,6	High
Tomato pulp (75%) + wheat straw (25%)	silage bag (250 kg)	60	40,3 ± 2,4	4,3 ± 0,2	16,4 ± 0,7[1]	8,8 ± 0,3[1]	69,5 ± 3,2[1]	45,8 ± 1,0[1]	48,3 ± 0,8[1]	None
Tomato pulp (74%) + Corn silage (9%) + beet pulp (13%)+ wheat straw (4%)	silage bag (250 kg)	90	29,5 ± 1,6	4,0 ± 0,1	11,6 ± 1,0[1]	10,5 ± 0,9[1]	52,0 ± 2,0[1]	29,6 ± 2,4[1]	70,5 ± 1,1[1]	None

[1] pre-silage figures, assays currently in progress; [2] not calculated

Discussion

From the results obtained we consider that greenhouse vegetable by-products show enormous potential for feeding small ruminants:

- Despite the high water content (93% in the case of tomato pulp), the by-products have fermented satisfactorily. Although the recommended water content is between 65 and 70% (Cañeque and Sancha, 1998), this factor does not appear to be of fundamental importance in this type of material. We should also bear in mind the fact that the wettest samples (pulp of tomato, water melon or melon) were the most compact, i.e. they did not allow air to accumulate. They also had high sugar content.
- It would appear that these by-products can be kept in optimum conditions for several months after fermentation. Samples with pulp alone were only tested for 40–50 days due to the lack of available material, but silage in large bags (mixture of pulp and straw) was conserved for at least 3–4 months.
- On the whole the nutritional value is high. Although they cannot be compared to concentrated feed such as cereals, vegetable by-products have proven similar to natural or cultivated forage such as alfalfa hay. All silage samples show values of crude protein (CP) and digestibility (IVD) which are similar to or higher than the above-mentioned forage. Their levels of organic matter are also similar. Generally speaking, vegetable by-products present a higher percentage of fibrous fractions, but this is not a disadvantage as they are intended for consumption by ruminants.
- We believe that silage of these by-products is an economically viable activity, since companies currently exist which are dedicated to their collection and recycling. Growers pay these companies to remove the by-products, and it would therefore be profitable for the companies to develop low-cost silage for animal feed production.

  Nevertheless, a series of drawbacks has been observed, the most important of which are the following:
- The silage of some plants (e.g. tomato, pepper, green bean) has been carried out on an experimental basis, but it is not currently possible on an industrial scale. This is due to the fact that plastic thread is used to guide the growth of these plants, but at present there is no machine available to facilitate the removal of this plastic. Unless a new technique is developed to separate the plastic, or a biodegradable material is used instead, this abundant source of nutrition is likely to continue going to waste.
- Due to the high water content of tomato, melon and water-melon pulp, a great quantity of effluent is produced. In some cases the liquid which is eliminated accounts for 40 to 50% of the initial volume. Companies interested in developing this activity will have to provide a suitable means of storing and dealing with this effluent or of mixing it with absorbent material, e.g. straw.

Conclusions

We consider that vegetable by-products from greenhouses can play a fundamental role in maintaining the extensive livestock which is currently in decline, as they can provide cheap feed supplement at times when natural pasture is scarce, thereby contributing to the profitability of small livestock farms.

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Use of *Festulolium* and *Lolium* x *boucheanum* for forage and seed production

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Abstract

The aim of the research was to study winter hardiness, DM and seed yield and forage quality of seven *Festulolium and Lolium x boucheanum* foreign varieties under the agro-ecological conditions of Latvia. Intergeneric hybrid variety 'Saikava' (*L. perenne x F. pratensis*), developed at the Skriveri Research Center of the Latvia University of Agriculture, was used as a control.
Field trials were carried out on sod – podzolic soil during 2002–2004. Mineral fertiliser rates used were: N 90, N 120 and P – 104, K – 150kg ha^{-1}. The productivity of DM and seeds were dependent on the variety, mineral fertilizer rates and meteorological conditions prevailing in each investigation year. Some parameters were influenced by the genetic characteristics of particular cultivars. The average seed yield of *Festulolium* accounted for 944 kg ha^{-1} at the N fertilizer dose 90 kg ha^{-1}. At the N fertilizer rate of 120 kg ha^{-1} the seed yield increased by 76 kg ha^{-1}. The average seed yield of hybrid ryegrass accounted for 598 kg ha^{-1} at the N fertilizer dose 90 kg ha^{-1}. The increase of N fertilizer to 120 kg ha^{-1} contributed to seed yield increase by 57 kg ha^{-1}. A positive correlation is established between average seed yield and the count of generative tillers at both N fertilizer rates (r = 0.73 and 0.68, respectively).

Keywords: *Festulolium, Lolium* x *boucheanum,* seed production, DM yield, quality

Introduction

Under the conditions of the Latvian climate, forage grasses are the main fodder source in cattle breeding. The productivity of grasslands and pastures mostly depends on cultivated grass varieties.

Sustainability is a measure of our ability to produce food with the maximum of efficiency combined with the minimum of damage to the environment. Grasses that persist from year to year under harsh environments will reduce inputs and costs, and improve predictability and stability of production. Persistency is an essential aspect of sustainability of forage production when environmental conditions are limiting (Ghesquière, 2002).

High quality forage *Lolium* has been bred for intensive systems in benign environments, and have proved to be insufficiently robust to meet many of the environmental challenges in more extreme conditions (Humphreys, 2002). In Baltic climate conditions it is not wide spread for the reason of unsatisfactory wintering. Sometimes crops suffer considerably even in the first winter and thus suffer a decrease in productivity (Nekrošas, 2002). The aim of hybrid ryegrass *(Lolium x boucheanum)* is to combine the best attributes of Italian and perennial ryegrass. It is less winter hardy but higher yielding than perennial ryegrass (Adamovich, 2003; Gutmane, 2004).

Lolium x Festuca hybrids have more persistent, disease resistant and winter hardy than ryegrasses, have better season-long productivity and higher forage quality than fescues (Sliesaravicius, 1997). *Lolium x Festuca* hybrids have good agronomical potential especially in adverse environments (Nesheim, 2000). *Festulolium* hybrids can show completely novel characters, but mostly traits are expressed intermediately and sometimes the traits of one parental species dominate. Some varieties are more like the ryegrasses and some more like fescues, depending on the breeding effort following the cross (Zwierzykowsky, 1980; Hahn, 1999).

Agro-climatic conditions have a very significant role in grass seed production and optimization of mineral nutrition (Havsad, 1998). Much research has been done considering factors influencing perennial ryegrass seed yield. The productivity of DM and seeds were dependent on the variety, on the rate of mineral fertilizer and on the meteorological conditions prevailing in each investigation year (Bumane, 2003). The production of grass seeds is dependent on nitrogen (N) availability. The positive correlation between spring-applied N and seed yield is well documented (Gislum, 2004). The number of generative tillers is a component of potential grass seed yield established during vegetative plant development. Lodging influences the seed yield (Hebblethewaite *et al*., 1980).

The objective of present research was to study forage and seed yield in domestic and foreign cultivars of *Festulolium* and *Lolium* x *boucheanum*. It is of great importance to test already selected cultivars and compare them to those of foreign origin in order to be able to recommend cultivars for use in our country.

Materials and Methods

Field trials were conducted in Latvia on Sod–Podzolic soils (pH_{KCl} 7.1, P – 253, K –198 mg kg^{-1}, organic matter content 31 g kg^{-1} of soils). Swards were composed of: perennial ryegrass 'Spidola'; festulolium – 'Saikava' (*L. perenne x F. pratensis*), 'Perun' (*L. multiflorum x F. pratensis*), 'Punia' (*L. multiflorum x F. pratensis*), 'Lofa' (*L. multiflorum x F. arundinacea*), 'Felina' (*L. multiflorum x F. arundinacea*), 'Hykor' (*L. multiflorum x F. arundinacea*); hybrid ryegrass – 'Tapirus' (*L. multiflorum x L. perenne*), 'Ligunda' (*L. multiflorum x L. perenne*).

The total seeding rate was 1000 germinating seeds per m^{-2}. The plots were fertilized as follows: N $108_{(18+90)}$ P 78 K 90 (at sowing year); P 78 and K 90 kg ha^{-1} and two N fertilizer treatments N $120_{(40+40+40)}$ and N $180_{(60+60+60)}$ (at first and second year of sward use). Swards were cut three times per season. For seed production the seeding rate was 600 germinating seeds per m^{-2}. The rates of mineral fertilisers applied in the seed production year were P104 , K150, N90 and 120 kg ha^{-1}. Dry matter and seed yield were recorded. Analysis of seed yield established during vegetative plant development and other parameters were also recorded.

Results and Discussion

Unfavourable weather conditions in 2002–2003 didn't cause winterkilling of the studied cultivars except for cv. Ligunda.

On both fertiliser backgrounds lodging was observed in all varieties except cv. 'Hykor' and 'Felina' (*L. multiflorum x F. arundinacea*). The rated lodging resistance was only 2.0–2.9 points (in scale from 1 to 9, where 1 – stand is completely lodged, 9 – lodging is not observed).

The produced mean seed yields were comparatively high – 590–1340 kg ha^{-1}. The average seed yield of hybrid ryegrass accounted for 598 kg ha^{-1} at the N fertilizer dose 90 kg ha^{-1}. The N fertilizer dose increased to 120 kg ha^{-1} contributed to a seed yield increase of 57 kg ha^{-1}. *Festulolium* gave higher seed yields. The average seed yield of *Festulolium* accounted for 944 kg ha^{-1} at the N fertilizer dose 90 kg ha^{-1}. The N fertilizer dose increased to 120 kg ha^{-1} contributed to seed yield increase by 76 kg ha^{-1}. The variety 'Lofa' (*L. multiflorum x F. arundinacea*) produced the highest seed yield – 1338 kg ha^{-1} at the fertiliser rate N120.

The 1000 seed mass for the varieties was different ranging from 2.4 to 4.2 g. The coarsest seed was produced by 'Perun' and 'Tapirus' respectively 4.0 and 4.1 g. The length of a flowerhead ranged from 17.6 to 27.4 cm. The mass of flowerheads was 0.44–0.91 g. Seed yield and yield structure data are given in Table 1. Positive correlation was established between average seed yield and the count of productive stems at both N fertilizer rates (r = 0.73 and 0.68, respectively). Increased N rates positive effects on TSW, productive stem number, flowerhaed structure was not observed in our experiments.

Table 1. Seed productivity and yield structure of *Festulolium* and *Lolium x boucheanum*

Nitrogen levels, kg ha^{-1} (F_A)	Varieties (F_B)	Lodging resistance, points	Seed yield		TSW, g	Generative tillers, $p.m^{-2}$	Flowerhead	
			kg ha^{-1}	%			Length, cm	Weigth, g
N 90	Saikava (LV)	2.3	1075	100	3.7	1758	23.4	0.71
	Lofa (DLF)	2.6	1269	118	3.8	1780	24.2	0.76
	Hykor (DLF)	6.3	819	76	2.9	1588	18.2	0.66
	Perun (DLF)	2.9	800	74	4.2	1518	27.4	0.89
	Tapirus (DSV)	2.1	591	55	4.0	1370	22.4	0.74
	Ligunda (DSV)	2.8	606	56	2.9	895	17.6	0.44
	Felina (DLF)	5.8	1019	95	2.4	1555	20.7	0.88
	Punia (LT)	2.9	681	63	3.9	1583	24.1	0.70
N 120	Saikava (LV)	2.0	1134	100	3.6	1678	25.1	0.72
	Lofa (DLF)	2.4	1338	118	3.9	1695	24.1	0.76
	Hykor (DLF)	6.1	931	97	2.8	1510	18.0	0.65
	Perun (DLF)	2.4	878	75	4.0	1440	24.8	0.78
	Tapirus (DSV)	2.1	634	42	4.0	1360	22.1	0.73
	Ligunda (DSV)	2.3	675	25	2.9	890	19.8	0.48
	Felina (DLF)	5.8	1038	23	2.4	1460	20.5	0.91
	Punia (LT)	2.6	800	16	3.9	1635	23.1	0.69
	$LSD_{0.05}$ F_A		36		0.02	62	0.26	0.02
	$LSD_{0.05}$ F_B		72		0.03	123	0.52	0.04
	$LSD_{0.05}$ F_{trial}		101		0.05	174	0.74	0.06

Hybrid ryegrass, perennial ryegrass and *Festulolium* are grasses require high nitrogen fertilisation when grown for high dry matter yield. Increased nitrogen rates resulted to significant increase of dry matter yield.

Average productivity of *Festulolium* accounted for 14.3 t ha^{-1} DM at the N 120 treatment. The N fertilizer dose increase to 180 kg ha^{-1} contributed to a DM yield increase of 2.6 t ha^{-1} or 18%. The average DM yield of hybrid ryegrass accounted for 12.8 t ha^{-1} DM at the N 120 treatment. The N fertilizer dose increased to 180 kg ha^{-1} contributed to a DM yield increase of 3.0 t ha^{-1} or 24 %. The average DM yield of perennial ryegrass accounted for 9.3 t ha^{-1} DM at the N 120 treatment. The N fertilizer dose increase to 180 kg ha^{-1} contributed to a DM yield increase of 2.6 t ha^{-1} or 28 %.

Maximum DM yields were obtained using the highest N 180 fertiliser rate for *Festulolium* cultivars 'Punia' and 'Perun' – 18.2 and 18.0 t ha^{-1}, respectively (Fig. 1). The average DM yields *Festulolium* cultivars was by 5 t ha^{-1} or 47%, but those of hybrid ryegrass of 3.7 t ha^{-1} or 35% were higher compared to perennial ryegrass.

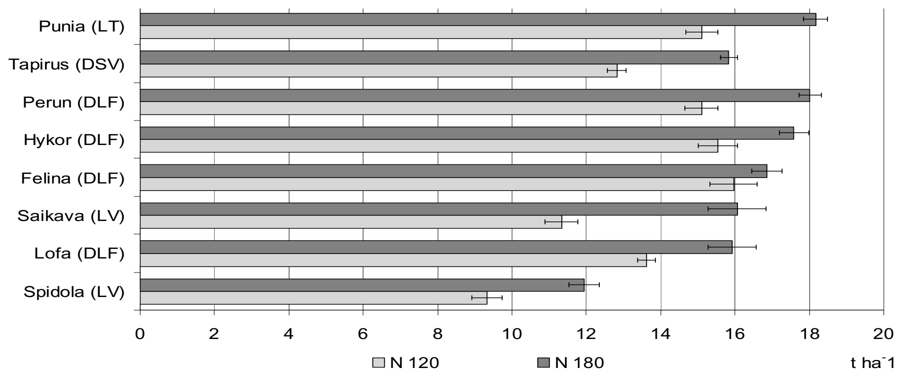

Figure 1. The DM yield of 1st year of sward use, t ha^{-1} (on average for 2003–2004)

Conclusions

Cultivars of *Festulolium* and *Lolium x baucheanum* are prospective forage grasses for growing in the Baltic States and North Europe. Due to its competitive productivity *Festulolium* may be equally ranked with the main forage grasses timothy and meadow fescue grown in the climatic zone of Latvia.

Early heading hybrid ryegrass cultivars are less appropriate for Baltic climate conditions due to the late maturity. Some foreign *Festulolium* and hybrid ryegrass varieties are suitable for seed production under agroclimatic conditions of Latvia.

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Microbiological activity of the soil with different grass-legume mixtures

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Abstract

The number and activity of soil microorganisms, as an indicator of grass-legume mixtures productivity, was monitored on a degraded alluviual soil under different fertilisation and liming treatments.
Microbiological analyses of the soil beneath the grass-legume mixtures (lucerne + orchard grass; red clover + Italian ryegrass; birdsfoot trefoil + meadow fescue; white clover + ryegrass), with differing N rates (60 and 100 kg ha^{-1}) and lime (0 and 5 000 kg ha^{-1}), comprised the total bacteria number (on the soil agar), oligonitrophiles, (on Fjodorov's agar) and proteolytic soil activity determinations (Romeiko's method).
The highest numbers of soil microorganisms were found beneath the mixture of red clover + Italian ryegrass, and the lowest beneath birdsfoot trefoil + meadow fescue, whereas the rate of 100 kg N ha^{-1} was found to have lowered numbers and activity of soil microorganisms, particularly in the treatments without liming.

Keywords: soil, grass-legume mixtures, liming, nitrogen, microorganisms, proteolytic activity

Introduction

Sowing grasses coupled with legume plants can be considered to be a prerequisite for producing good-quality forage. Accordingly, either with or without the application of mineral fertiliser, a higher biomass production with a better protein, carbohydrate and mineral composition may be obtained. Importantly, for maintaining and improving homeostatic soil capacity and an overall biogeocenosis composition, the percentage composition of all the components of the grass-legume mixture under different mineral fertilisers should be determined.
Being the most active part of biogeocenosis, with an expressed ability of hydrolysis, synthesis and accumulation and immobilization of differing pollutants, microorganisms unavoidably indicate soil biological productivity as well as the environmental conditions and plant production quality (Milosevic *et al*., 2004). If inadequately used, N mineral fertilisers and some other human activities may bring about a lower soil biological productivity (quantitative and qualitative microorganism composition, plant yield), a lower quality of the products obtained as well as an array of the environmental and health problems (Djukic and Mandic, 1997).
Liming and the application of organic and microbiological fertilisers, i.e. chemicals, are precluding an adverse impact of the increased mineral fertiliser rates and other potential xenobiotics (Gostkowska *et al*., 1998). This is particularly related to acid soils, which may be a limiting factor of the efficiency in growing forage plants.
Therefore, the paper was aimed at monitoring the number and activity of soil microorganisms under the conditions of applying mineral fertilisers and liming, which would pave the way for choosing the most suitable combinations of grass-legume mixtures for the particular growing conditions.

Material and Methods

The studies were conducted on the trial field of the Centre of Forages in Krusevac. A three-factorial experiment, following the randomized split block design with four replications, was set up in 2001 on the degraded alluvial soil type (pH_{KCl} – 6.4, humus – 1.7%, N – 0.1%, P_2O_5 – 0.068 mg g^{-1}, K_2O – 0.1 mg g^{-1}).

Soil samples for microbiological and biochemical analyses were taken in 2003 from the arable soil layer (35 cm deep). The experimental treatments were, as follows: A – Mixtures: Lucerne + Orchard grass, Red clover + Italian ryegrass, Birdsfoot trefoil + Meadow fescue, White clover + English ryegrass; B – Fertilisation: $N_{60}P_{60}K_{60}$ (N_1), $N_{100}P_{60}K_{60}$ (N_2); C – Liming: no liming (–Ca), liming (+Ca) – slaked lime in the rate of 5000 kg ha^{-1}.

The biological activity of soil was determined through the total number of microorganisms and oligonitrophiles on the appropriate nutritional substrates (for the total number – Pochon and Tardieux, 1962; for oligonitrophiles, Fjodorov's agar – cit.by Govedarica and Jarak, 1993) and soil proteolytic activity (Romeiko, 1969). The data obtained were analysed using the analysis of variance method for the three-factorial experiment, with significance test of the differences performed using LSD test.

Results and Discussion

Statistical analysis of the data showed significant effects of grass-legume mixture, N rates and soil liming to on soil microbiological activity.

As a general indicator of the soil biological activity, the total number of bacteria was highest in the soil treated with the mixture of red clover + Italian ryegrass (Table 1). A somewhat lower number of the bacteria was recorded with lucerne + orchard grass and the lowest number was with birdsfoot trefoil + meadow fescue. Similar results were obtained by other authors growing red clover and various grasses on soils with an acid reaction (Gil *et. al*., 2001), and red clover and lucerne on the variants with and without liming (Jarak *et. al*., 2004).

Table 1. The total number of microorganisms in the soil under the grass-legume mixtures (10^6 g^{-1} absolutely dry soil)

A		Lucerne + orchard grass		Red clover + Italian ryegrass		Birdsfoot trefoil + meadow fescue		White clover + ryegrass		Mean
B		N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	
C	+Ca	150	110	170	160	106	100	150	130	134.6
	–Ca	160	100	140	105	95	88	120	90	112.3
Mean		130.0		143.7		97.4		122.5		
Mean		N_1 136.5								
		N_2 110.3								
LSD		A	B	C	AB	AC		BC		ABC
0.05		8.20	5.60	5.60	11.40	11.40		8.20		16.20
0.01		11.70	7.56	7.56	15.39	15.39		11.70		21.87

Further, higher N rates gave rise to a pronounced decrease in the number of microorganisms, particularly in the variants without slaked lime. Adverse effects of high N rates could be attributed to the changes taking place in the structure of the soil microorganism complex, that is to the activation of toxigenic microorganisms and to an onset of the soil microbe toxicosis (Jemcev and Djukic, 2000). A decreasing negative impact of the high N rates on the variants with liming could be explained by improved agrochemical properties of soil (Gostkowska *et al.*, 1998), particularly when reduced content of mobile Al and Mn forms, exhibiting toxic effects on acid soil microorganisms, is considered.

The number of oligonitrophilic microorganisms was also highest in the soil treated with the mixture of red clover and Italian ryegrass (Table 2). Compared with the rest of the parameters studied, oligonitrophiles exhibited the highest sensitivity to the higher N rates (Jemcev, 2004). The same data presumed that the initially used lower N rates for fertilising legumes might favour the number and activity of soil diazotrophs. However, soon after 30–60 kg ha^{-1} N rates were used, diazotrophs became visibly more sensitive to such N rates, manifested not only in their number, but also in their nitrogen-fixing functioning system.

Table 2. The number of oligonitrophiles in the soil beneath grass-legume mixtures (10^5 g^{-1} absolutely dry soil)

A		Lucerne + orchard grass		Red clover + Italian ryegrass		Birdsfoot trefoil + meadow fescue		White clover + ryegrass		Mean
B		N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	
C	+Ca	93	70	110	81	90	72	71	67	81.75
	–Ca	70	40	60	58	60	46	59	58	56.38
Mean		68.25		77.25		67.0		63.7		
Mean		N_1 75.29								
		N_2 59.67								
Lsd		A	B	C	A×B		A×C		B×C	A×B×C
0.05		4.2	4.80	6.76	3.40		3.40		6.76	9.56
0.01		5.40	6.48	9.13	4.59		4.59		9.13	12.91

The soil treated with red clover and Italian ryegrass is characterised by the highest proteolytic activity, while the soil with the remaining mixtures has a very similar level of activity (Table 3). Most frequently cited explanations connected with a differing mineralisation ability of the soil beneath legumes and grass-legume mixtures focus on the nature of such residues, e.g. low ratio C:N, lignin:N and (lignin+polyphenol):N (Fox *et al.*, 1990).

Table 3. Proteolytic activity of the soil under grass-legume mixtures (gelatinous units g^{-1} air dry soil)

A		Lucerne + orchard grass		Red clover + Italian ryegrass		Birdsfoot trefoil + meadow fescue		White clover + ryegrass		Mean
B		N_1	N_2	N_1	N_2	N_1	N_2	N_1	N_2	
C	+Ca	33	30	40	38	29	29	32	31	32.8
	–Ca	27	26	37	31	26	27	26	24	28.1
Mean		29.0		36.5		27.8		28.3		
Mean		N_1 31.6								
		N_2 29.8								
Lsd		A	B	C	AB		AC		BC	ABC
0.05		2.40	1.80	1.80	3.40		3.40		2.40	5.0
0.01		3.24	2.43	2.43	4.59		4.59		3.24	6.75

In addition, introducing higher mineral N rates caused no change in the proteolytic activity, particularly on the variants with lime. This is in agreement with results of Acosta-Martinez and Tabatabai (2000), suggesting a stabilising effect of calcium on the proteolytic activity in the soil, and those of Fauci and Dick (1994) indicating a decline in proteolytic activity occurring only after the long-term application of the high N fertiliser rates.

Conclusions

The number of microorganisms and soil proteolytic activity depended on the type of grass-legume mixture, the application rate of N and whether or not lime was applied. The highest total number of microorganisms, oligonitrophiles and the strongest proteolytic activity were found in the variant with soil treated with mixture of red clover and Italian ryegrass, and the lowest one in that with birdsfoot trefoil + meadow fescue.

Higher N rates (100 kg ha^{-1}) depressed soil biological parameters, particularly in the variants without liming.

The findings on the biological indicators of soil for the agro-ecological region in this study show that the optimal grass-legume mixture was that of red clover + Italian ryegrass with previously used liming and fertilising with 60 kg N ha^{-1}.

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The influence of different management treatments and soil types on biomass and soil organic carbon

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Abstract

To investigate the possibilities under article 3.4 of the Kyoto Protocol and to determine possible significant increases in soil organic carbon (SOC) concentration, a field experiment was set up on three soil types in Flanders (Belgium). As expected, higher mean SOC contents were found when establishing grassland was compared to original SOC concentrations under previous cropland management. Under agricultural grassland management, SOC concentration increased with on average 14% on the sandy loam soil, 2% on the sand soil and 35% on the clay soil. Under verges, the increases were larger but a significant increase was only found for the sandy loam soil. However, because changes in SOC occur very slowly it is too early to find significant differences in SOC concentrations between and within the various treatments. The removal (or not) of the hay influenced the aboveground dry matter production more than the level of fertilizer used.

Keywords: grassland, SOC concentration, management, aboveground biomass

Introduction

Besides the reduction of greenhouse gasses, countries can also reach their Kyoto targets through enhancing C sequestration in the soil and by trading C credits. Soil C sequestration in croplands, grazing lands, managed forest and land subject to revegetation is included under article 3.4 of the Kyoto Protocol. To investigate the possibilities of article 3.4 for grassland in Flanders (Belgium), a field experiment was set up in 2001 on a sandy loam soil and in 2002 on clay and sand soils. In this experiment, net C accumulation, variability of C sequestration and aboveground biomass production for different grassland types and varying nutrient inputs were studied.

Many studies (for instance Cotrufo and Gorissen, 1997; Bélanger *et al*., 1999; Loiseau and Soussana, 1999) have shown that C sequestration can be affected by the amount of nitrogen fertilizer applied. However, this effect is not always clear.

In our study, clover was also introduced as a factor possibly influencing C sequestration. The effect of clover on C sequestration has already been studied by Elgersma and Hassink, 1997 and Mytton *et al*., 1993. They both found similar OC concentrations under a grass monoculture and under a grass/clover mixture. However, Elgersma and Hassink found a higher above ground production under a grass/clover mixture.

As cropland soils have in general lower SOC contents than grassland soils, it should be possible to determine C accumulation in the soil by our experiment and to determine how long it takes to find significant differences.

Materials and Methods

The experimental fields were located on a sandy loam soil (Merelbeke), clay (Watervliet) and sand soil (Geel) in Flanders (Belgium). All fields on the three locations have for decades been used as cropland. On the sandy loam soil, the experiment was started in spring 2001 and for the clay and sand soils in spring 2002. Two different grassland types were sown i.e. verges and typical grassland for agricultural use. Between different nitrogen levels and different grassland types, there was always a border of approximately 3 m to exclude any influences. On the sandy loam location, the treatments each had 4 replicates whereas due to practical reasons, on the clay and sand locations only 2 replicates were used. Each plot had a net surface of 8.4 m^2.

For the statistical analyses, S-Plus 6.0 was used. To detect significant increases against the starting SOC concentrations and effects of the different factors T-test and Anova were used, respectively. The influence of management on the above ground dry matter production was tested by Anova.

Grassland for agricultural use – The different treatments were: level of fertilisation, cutting regime, grass mixtures and removal of the hay. The fertilizer applications in cutting treatments were 450 kg N ha^{-1}, with 7, 5 and 3 cuts a year; 225 kg N ha^{-1} with 5 and 3 cuts a year and 0 kg N ha^{-1} with 3 and 2 cuts a year. Two different grass mixtures were used. Mixture M1 was composed of *Lolium perenne* 'Ritz' (35%), *Lolium perenne* 'Pandora' (35%), *Phleum pratense* 'Erecta' (15%), *Festuca pratensis* 'Merifest' (10%) and *Poa pratensis* 'Balin' (5%). Mixture M2 was composed of the same grasses but in different quantities of respectively 32.5, 32.5, 15, 10, 5% and also with 5% *Trifolium repens* 'Merwi'. Also removal or non-removal of the hay was an additional factor on the sandy loam soil. On the clay and sand soils, the hay was always removed. Dicotyledons in both plots with M1 and M2 and clover in the plots with mixture M1 were systematically removed through the use of herbicides.

Verges – Three different treatments were applied. The first treatment was the number of cuts; 1 or 2 per year which is also used in practice, depending on the nutrient availability to the vegetation. The second treatment was the grass mixture. Two different mixtures were used. Mixture M3 consisted of *Festuca rubra* 'Bargena' (30%), *Festuca rubra* 'Bargreen' (20%), *Festuca ovina* subsp. *duriuscula* 'Barreppo' (25%), *Festuca ovina* 'Barok' (20%) and *Agrostis tenuis* 'Bent' (5%). Mixture M4 consisted of *Lolium perenne* 'Barrage' (30%), *Festuca rubra* 'Bargena' (40%) and *Poa pratensis* 'Balin' (30%). Natural colonization of dicotyledons was allowed. The last treatment was the removal of the hay. In Flanders, hay must be removed from the verges at the latest 10 days after mowing but in reality, the hay is often not removed. Therefore, at the sandy loam location, the experiment was repeated with and without removal of the hay. On the two other locations, the hay was always removed. No fertilizer was applied on the verges.

Aboveground biomass and soil organic carbon – The aboveground biomass was measured after every cut. The fresh biomass was dried at 75 °C for 3 days. Dry matter was calculated on a yearly basis and as the mean over the years of the experiment. Before the experiment was set up, soil samples were taken at the different locations at 0–10 cm depth. In October 2004 on the three locations, the plots were sampled again. The samples were analysed according to Mestdagh *et al*. (2004).

Results and Discussion

Soil organic carbon – Overall, SOC concentration increased in all treatments for every soil type compared to the starting SOC concentrations. There was no significant effect of the soil type. On the clay soil, there was a significant increase in SOC concentration for nearly all treatments against the starting values (35% higher for agricultural grassland and 15% for verges). On the sandy soil, the increase was much smaller (on average 2% for agricultural grassland and 4% for verges) and so almost no significant increases in SOC were found. Nevertheless, SOC is likely to increase when cultivated soils are planted with permanent grasses or when there is a management for high grass productivity (Post and Kwon, 2000). For both the clay and sand locations, no significant differences between or within the treatments were found.

Table 1 shows the results of the SOC concentration in 2004 after 4 years of experiment on the sandy loam soil. In some cases, the increase in SOC is significant compared to the original concentrations. However, no clear trends were found. Also for this soil type, none of the treatment factors introduced on the grasslands for agricultural use showed a significant effect. Only for the fertilizer regimes 0N and 450N were there significantly higher SOC concentrations under plots with clover and without removal of the hay, respectively. The highly significant increases in SOC concentrations for verges in Merelbeke are explained by the high below ground biomass production compared with grassland for agricultural use (Iantcheva *et al*., 2004).

Table 1. SOC concentrations and original concentrations in g C 10^{-2} g^{-1}dry soil for 0–10 cm and aboveground dry matter production (kg ha^{-1}) at Merelbeke (sandy loam) for the different treatments

Treatment	Soil Organic Carbon No removal of the hay mean	sd	Soil Organic Carbon With removal of the hay mean	sd	Dry Matter Production No removal of the hay mean	sd	Dry Matter Production With removal of the hay mean	sd
Original concentrations	0.99		0.95					
Grassland/450N/7 cuts/M1	1.13 *	0.09	1.02	0.06	12,745	330	16,499	494
Grassland/450N/7 cuts/M2	1.08 *	0.07	1.07	0.05	12,158	504	16,703	358
Grassland/450N/5 cuts/M1	1.17 ***	0.02	1.03	0.04	14,044	225	15,575	395
Grassland/450N/5 cuts/M2	1.14	0.14	1.09 ***	0.05	13,294	618	16,359	229
Grassland/450N/3 cuts/M1	1.12 *	0.08	0.97	0.05	14,660	673	15,071	329
Grassland/450N/3 cuts/M2	1.18 **	0.08	1.04	0.07	13,063	1,074	13,754	716
Original concentrations	0.99		0.95					
Grassland/225N/5 cuts/M1	1.05	0.08	1.04 ***	0.02	13,606	219	12,335	463
Grassland/225N/5 cuts/M2	1.11 *	0.08	1.06 ***	0.02	13,838	583	14,985	363
Grassland/225N/3 cuts/M1	1.03	0.04	1.07 ***	0.02	14,805	699	12,339	237
Grassland/225N/3 cuts/M2	1.11	0.12	1.11 ***	0.04	13,835	485	12,471	1,044
Original concentrations	0.99		0.95					
Grassland/0N/3 cuts/M1	1.13 ***	0.04	1.08 *	0.07	10,701	911	7,843	867
Grassland/0N/3 cuts/M2	1.08	0.09	1.00	0.04	12,022	1,21	9,389	644
Grassland/0N/2 cuts/M1	1.03	0.13	1.08 **	0.05	12,677	766	10,927	1,055
Grassland/0N/2 cuts/M2	1.19 ***	0.05	1.12 ***	0.05	14,406	737	12,354	1,344
Original concentrations	0.86		0.86					
Verges/1 cut/M3	1.06 ***	0.04	1.01 **	0.08	8,593	379	8,902	691
Verges/1 cut/M4	1.07 ***	0.06	1.04 ***	0.01	8,027	1,078	8,874	1,239
Verges/2 cuts/M3	1.05 **	0.07	0.97 **	0.04	11,357	1,063	11,337	1,499
Verges/2 cuts/M4	1.01 ***	0.05	1.07 **	0.08	11,979	558	11,247	1,083

* significant at 0.05; ** significant at 0.01, *** significant at 0.001
sd = standard deviation

That no factor showed a significant effect on the SOC concentration and that significant increases compared to the original values were not always detected is in agreement with the results obtained in the study of Smith (2004). He found that a detectable change in SOC takes 3–15 years (or longer) depending on the increase in C input and the detection power of background SOC. That more significant differences were found on the sandy loam soil is probably due to the longer run of the experiment on this location.

Aboveground biomass – The aboveground dry matter productions for Merelbeke and Geel were of the same order. In Watervliet the production was on average lower than in Geel and Merelbeke. This was confirmed by results from previous experiments at this location. For some treatments in Merelbeke, the standard deviations are rather large, due to variation in emergence of above ground biomass over the years.

For all locations, there was a clear effect of the presence of clover on the above ground biomass for the 0N treatment (however not significant) whereas for the N-fertilized plots this effect was lost. This was expected as the advantage of clover in relation to above ground production disappears with higher levels of N fertilization (De Vliegher and Carlier, 2003). The aboveground biomass at the sandy loam location was comparable for all fertilizer N levels when the hay was not removed (Table 1). When the hay was removed, the production was significantly increased for the 450 N treatments. The aboveground biomass showed an advantage when the hay was kept on the field for the 225 N and 0N treatment. This factor had no effect at all for the verges. In Geel and Watervliet the number of cuts showed a significant effect for all different treatments. In Merelbeke this effect was only significant for the 0N treatment and the verges.

Conclusion

SOC increased for all treatments in grassland after arable land on sandy loam, sand and clay soils, however, not always significantly. For clay and sand soils no significant differences between or within the treatments for SOC were found. On the sandy loam soil, significant differences were found in SOC for the 0N, 450N treatments and for the verges. Because changes in SOC are slow and depending on the number of samples taken, it is recommended that this experiment should be continued.

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BFI – an indicator for the biological quality of soils

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Abstract

An indicator for the biological quality of soils was developed, using Near Infrared Spectroscopy (NIRS) to estimate the potential mineralization of nitrogen as assessed with an anaerobic respiration method (PMN). A good linear relation was found between NIRS and PMN in a dataset with more than 400 soil samples (R^2 = 85%). The estimation by NIRS is used as an indicator for biological fertility (BFI) and a set of reference values for BFI in Dutch grassland soils was developed. BFI was studied in soils as part of the project 'Cows and Opportunities'. Fourteen grassland plots from 7 farms were analyzed for BFI and (potential) mineralization rates of organic matter and nitrogen. Regression analysis showed a good correlation between BFI and the potential N mineralization as measured during 8 weeks in the laboratory (R^2 = 68%). The decomposition rate of organic matter was best predicted by the equation log BFI + C-content (R^2 = 95%). It is concluded that BFI, measured with NIRS, provides a good estimate of PMN, and that BFI has potential as an indicator for the biological quality of soils in terms of nitrogen mineralization and decomposition of organic matter.

Keywords: indicator, soil biological quality, nitrogen mineralization, organic matter

Introduction

In the Netherlands, chemical soil quality is easily assessed with routine analyses. However, methods to assess the biological quality of soils are time consuming and expensive. Potential Mineralizable Nitrogen (PMN) is considered to be one of the best methods for indicating biological quality of soils (Sparling *et.al.*, 2000). As Near Infrared Reflectance Spectroscopy (NIRS) is already used to predict some soil quality parameters, research was conducted to determine whether NIRS could be used to estimate PMN, and to develop reference values for grassland soils. The NIRS estimate is taken as an indicator for the biological fertility of soils (BFI). The use of BFI was demonstrated for agricultural soils in the project 'Cows and Opportunities'. In this project, an annual farm fertilizer plan is made, to reduce nitrogen losses while maintaining forage production. The fertilizer recommendation uses total soil nitrogen to estimate average N mineralization. It was concluded from previous work on the use of fertilizer plans in Cows and Opportunities (Hanegraaf and den Boer, 2003) that further reductions would require information on the biological quality of soils. We hypothesize that BFI can serve as an indicator for rates of nitrogen mineralization and decomposition of soil organic matter.

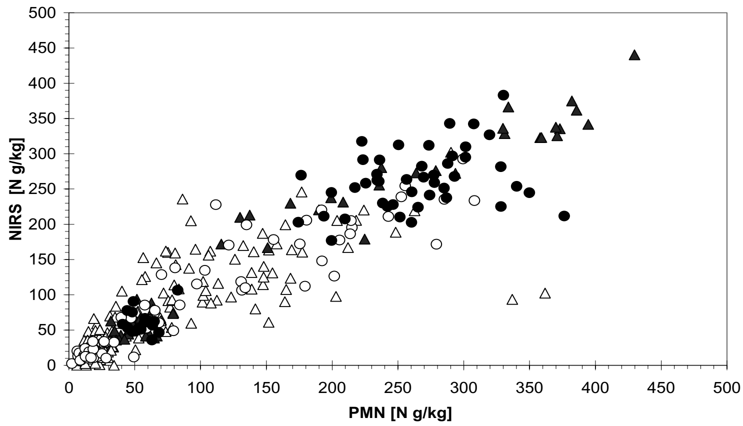
Materials and Methods

For the development of BFI, over 400 samples of grassland (0–10 cm) and arable (0–20 cm) soils from sand, clay and peat regions throughout the Netherlands were taken during June – September 2003 and analyzed for PMN and NIRS. PMN is carried out using a fresh soil sample and an anaerobic respiration over seven days at 40 °C, (Sparling *et al.*, 2000). Ammonium-N is measured after extraction in 2M KCl. For the NIRS measurement an oven dry (40 °C) soil sample is used. NIR-spectra are recorded using a Bomem FT-NIR

spectrometer equipped with a 10W Quartz halogen lamp, a TE cooled InAs detector and a rotating powder sampler (2.5 inch sample containers). The NIR-spectra range from 10000 to 3780 cm^{-1} (1000–2650 nm) with a resolution of 16 cm^{-1}. Regression analysis with Genstat 7 was used to verify the estimate of PMN by NIRS. NIR-spectra are henceforth referred to as BFI. Reference values for BFI in Dutch grassland soils were developed by assuming the lowest value obtained in the dataset of 160 grassland soils as 0%, and the maximum value as 200%. The entire range was subsequently divided into five classes, from very low to very high. It is assumed that both very low and very high values of BFI indicate low biological quality. The use of BFI was demonstrated in grassland plots at seven farms in the project 'Cows and Opportunities'. BFI Measurements were made in two plots per farm. Results of BFI are compared with the results of two soil processes governed by micro-organisms, i.e. nitrogen mineralization and decomposition of organic matter. The relationship between BFI and the potential nitrogen mineralization was studied over an 8 week incubation of 100 g dry weight soil in poly-ethylene bags at 20 °C. At 2, 5, and 8 weeks from the start, $N\text{-}NO_3$ and $N\text{-}NH_4$ contents were determined after extraction in 0.01 M $CaCl_2$ as described in Houba *et al.*, 2003. This method is referred to as PMN8. The decomposition rate of organic matter is estimated from a respiration experiment in which a sample of 100 g. dry weight was incubated at 20 ºC. Measurement of CO_2-emission took place at 2, 5, and 8 weeks after the start of the experiment. Results of the CO_2-emissions were used to calculate the proportion of organic matter remaining at the time of measurement. As a measure of the decomposition rate, the a-value was calculated as formulated by Janssen (1984) in the model 'Mineralization of Nitrogen and Phosphorus (Minip)':
$Y_t / Y_0 = 1 * \exp 4.7[(a+t)^{-0.6} - a^{-0.6}]$, in which:
Yt = amount of C (kg/ha) at time t,
Y_0 = amount of C (kg/ha) at time 0, and
a = a-value of the organic matter.
Soil samples in this experiment consisted of organic matter from the soil as well as from grass roots and organic manure.

Results

Figure 1 gives the results for the PMN and NIR measurements of the 400 samples. Distinction is made in two classes of both clay and organic matter contents.
Regression analysis showed a good correlation between both methods (R^2 = 85 %, mean = 89; s.e. = 36). The NIR-spectra for grassland soils are used to derive reference values for BFI in grassland soils. Results are given in Table 1.
The results of the soil analysis for the seven farms of Cows and Opportunities are given in Table 2, including also the results from PMN8 and a-values.
Table 2 shows that BFI ranges from 25 – 189 in these soils, and that only two grassland soils are considered to be of good biological quality. The potential N-mineralization (PNM8) in the 8-week respiration experiment ranges from 43–292 N kg/ha. Regression analysis showed a good relation between BFI and PNM8 (R^2 = 67%, mean = 125; s.e. 42). The a-values in the soils range from 6–22, indicating large variability in decomposition rates between the soils. Regression analysis between BFI and the a-value showed that the a-value was explained best by the equation log BFI + C-content (R^2 = 95%, mean = 10; s.e. = 1).



Legend:
Δ = claycontent < 15%, organic matter content < 20% ▲ = claycontent < 15%, organic matter content > 20%
○ = claycontent > 15%, organic matter content < 20% ●.= claycontent > 15%, organic matter content > 20%

Figure 1. Results from potential mineralizable N via anaerobic respiration (PMN) and NIRS

Table 1. Reference values for BFI

Soil type	Very low	Low	Good	High	Very high
Sand	< 45	45–89	90–134	135–179	> 179
Peat	< 150	150–219	220–289	290–359	> 359
Other	< 60	60–114	115–169	170–224	> 224

Table 2. Results from biological and chemical soil analyses

Farm/parcel nr.	Soil	$N\text{-}NO_3$ (mg/kg)	$N\text{-}NH_4$ (mg/kg)	C (g/kg)	BFI	Interpretation of BFI	PMN8 (kg/ha)	a-value
1a	sand	11	11	28.1	93	good	94	7
1b	sand	8	5	26.2	78	low	83	7
2a	sand	9	8	28.6	104	good	104	8
2b	sand	10	8	28.3	72	low	80	8
3a	sand	4	4	34.0	69	low	79	9
3b	sand	5	5	55.3	65	low	101	11
4a	loess	6	5	28.1	47	very low	169	7
4b	loess	2	4	19.0	25	very low	83	6
5a	clay	16	3	44.8	69	low	130	9
5b	clay	4	2	37.5	43	very low	78	8
6a	peat	19	18	312.3	173	high	292	22
6b	peat	24	13	215.3	189	very high	260	17
7a	clay	7	6	52.3	91	low	152	10
7b	clay	2	3	31.7	11	very low	43	7

Discussion

The research described in this paper includes two datasets with soil data. A large data set was used to assess the fit between PMN and NIRS. The correlation was considered good enough to use NIR-spectra as an indicator for the biological quality of soils, BFI, and to derive reference values. In this research, sampling was done during late summer and early autumn. Grassland soils are sampled for routine analysis during September – February, and this could have an impact on the result, which should be taken into account in the reference values. It is possible that BFI gives additional information about the N mineralization during the growing season. Therefore, the effect on BFI of temperature and moisture at the time of sampling needs to be investigated.

A small dataset of fourteen samples was used to demonstrate the potential of BFI. Consequently, results from this part of the work need confirmation at a larger scale. The relationship between BFI and the potential mineralization of nitrogen (PMN8) suggests that BFI could be used to improve estimates of nitrogen availability based on total N content. Higher potential nitrogen mineralization than anticipated could be used to lower the nitrogen recommendation, and *vice versa*. BFI appears to be a good predictor of decomposition of organic matter in soils. Calculation was made of the mean annual decomposition in the sandy soils over a 25 year period, using Minip, the a-values and C-contents. Lowest mean annual decomposition was found for plot 1b (1550 kg per hectare), and highest for plot 3b (2100 kg/ha), due to its high initial C-content. This difference, which is of agricultural significance, could not be found with routine soil analyses and could be useful for fertilizer recommendations. For example, at high decomposition rates, the advice could be to use more organic fertilizers and/or add organic matter from other sources. Finally, this study shows that BFI offers potential as an indicator for two soil processes governed by soil flora and fauna, i.e. nitrogen mineralization and decomposition of organic matter. Relations with species, numbers, and activity of soil flora and fauna may also be found, but were not under investigation. The results suggest that reference values for BFI may be derived from relations between BFI and nitrogen mineralization and decomposition of organic matter.

Conclusions

It is concluded that NIRS gives a good estimate of PMN, offering a good and inexpensive analysis of BFI. BFI is potentially a good indicator of biological soil quality in terms of nitrogen mineralization and decomposition of organic matter. However, further research is required on the impact of sampling time and temperature and to improve the reference values.

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Reducing red clover (*Trifolium pratense* L.) diseases in different fertilisation and liming systems

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Abstract

Experiments were carried out in the Vezaiciai Branch of the Lithuanian Institute of Agriculture in 1998–1999 and 2004. The aim of the research was to elucidate the influence of the growing conditions of host-plants on the spread of diseases in red clover. So, soddy medium podzolic sandy loam soil was amended with different amounts of lime (soil pH_{KCl} increased from 3.9 to 6.7), and red clover were fertilized by different amount of mineral fertilizers (according to the following scheme: unfertilized and three incremental rates of phosphorus (P) and potassium (K) fertilizers).
Erysiphe polygoni and *Cymadothea trifolii* damaged red clover by 1.2–1.7 times and *Pseudopeziza trifolii* by 1.4–2.5 times intensive in very acid soil (pH_{KCl} 3.9–4.4) comparing with those grown in the soil with pH_{KCl} 6.3–6.7 in 1998–1999. Different fertilisation had an influence to damage by *Cymadothea trifolii* in 1998 (r = 0.51) and *Pseudopeziza trifolii* in 1998 (r = 0.65) and 1999 (r = 0.70). These agents damaged host-plants in unfertilized soils more intensively.

Keywords: red clover, disease, fertilizer, soil reaction

Introduction

Red clover is an important grassland species. Not in all cases we get desire effect when we use chemical means of plant protection. Hence, it is important to increase the natural persistence of plants against harmful organisms (Anastasios *et al.*, 2005).
Plant diseases develop as a result of the timely combination of three elements: susceptible host plants, a virulent pathogen and favorable environmental condition (Salonen *et al.*, 2001). Fertilization of the cover crop has a big bearing on the amount of damage caused by diseases. Less clover-root is damaged by rot at lower rates of mineral fertilizer, especially nitrogen, because these pathogens multiply at a higher rate in the soils that are rich in nitrogen. Powdery mildew mostly harms red clover growing in soils having a high Ca content (near neutral pH_{KCl}). The spread of powdery mildew is also influenced by the unbalanced fertilization with phosphoric fertilizers and this disease spreads less on red clover, receiving higher rates mineral potassium fertilizers. In the most cases reasons of red clover diseases are unclear. The species red clover is slightly tolerant to acidic soil conditions, but the best growing condition for red clover is in soils with optimal pH_{KCl} between 6.0 and 6.5. Under conditions plants are constantly exposed to attack by pathogenic organisms, especially pathogenic fungi (Salonen *et al.*, 2001). Plants susceptibility to different diseases depend on plants resistant mechanisms (Sigvald, 2000; Salonen *et al.*, 2001; Dufeng *et al.*, 2004).
The aim of the present experiments was to investigate the influence of systematic fertilization with increasing rates of mineral fertilizers and different soil pH_{KCl} on spread of red clover diseases.

Materials and Methods

Experiments were carried out in the Vėžaičiai Branch of the Lithuanian Institute of Agriculture in Dystric Albeluvisol (texture-morain loam) soil. The following crop rotation is applied: 1) fooder beet (*Beta vulgaris*), 2) spring barley (*Hordeum vulgare*) and perennial grasses: red clover (*Trifolium pratense*) 'Liepsna' + timothy (*Phleum pratense*) 'Gintaras II', 3) first year perennial grasses, 4) winter wheat (*Triticum aestivum*), 5) oat (*Avena sativa*). There were two experiments different by square. The area of origin square was 80 m^2 in the first experiment and origin square was 160 m^2 in the second experiment. There were three replications. Soil was limed by different amounts of $CaCO_3$ 92.6%: 1.9, 3.3, 5.8, 14.7 and 49.6 t/ha. After that different soil reaction were observed: pH_{KCl} increased from 3.9 to 6.7. Every square, with different soil reactions, was fertilized by different amount of mineral fertilizers. Increasing rates of mineral fertilizers were applied in both field experiments according to the following scheme: unfertilized, one ($P_{30}K_{30}$), two ($P_{60}K_{60}$) and three ($P_{90}K_{90}$) rates of phosphorus (P) and potassium (K).

Microfungi of aboveground parts of red clovers were investigated in 1998–1999 in the beginning and at the end of the growing season: in a time of stem splitting and blooming and root diseases in 2004 (early in spring). Incidents of foliar diseases are accounted using the number of foliar damaged by diseases expressed by percentage using the formula:

$$P = n \cdot 100/N,$$

where: P – incidence of diseases, by %;
n – number of leafs with diseases by units;
N – amount of checked leafs, by units.

The development of leafs diseases is described using the scale from 0 to 100%. The pathogens were identified by reproductive organs after examination of 10 leaves of red clover from each set (one set 100 leaves) under a microscope. There are investigated 10 plants in 10 places in first experiment and 10 plants in 20 places in second experiment.

The temperature was 12.6 °C and precipitation was 44.5 mm in May 1998. In June, of the same years, the mean temperature was 14.7 °C, it was in line with the standard of several years. There was high precipitation – 87.4 mm. The climate was cool and wet in April in 1999, temperature was 7.9 °C, amount of precipitation was 68.1 mm. At the beginning of May it was even cooler. A rather warm weather and decreased precipitation were characteristic to the month of June. The average of atmospheric temperature in March 2004 was 0.9 ºC and sum of precipitation 61.9 mm, in April was 7.2 °C and 15.8 mm, in May 10.7 ºC and 36.8 mm.

The data was analyzed statistically. Correlation analysis and relations-ships (the Spirmen's coefficient r) were estimated between:

1) disease incidence/development and soil reaction in which host-plants grew;
2) disease incidence/development and norms of mineral fertilizers.

The data was calculated according to a normal distribution (Stewdent's distribution). Distribution of the data was evaluated by calculation of mean values (x), errors of mean (Sx). The results were considered significant, when $p<0.05$.

Results and Discussion

During the investigative period the red clover were harmed by 8 kinds of fitopathogenic microorganisms in total. Northern anthracnose (agent *Kabatiella caulivorum* (Kirchn.) Kar.), common leaf spot (agent *Pseudopeziza trifolii* (Biv.-Bern:Fr.) Fuskel), sooty blotch (agent *Cymadothea trifolii* (Pers.) F. A. Wolf.) and powdery mildew (agent *Erysiphe polygoni* DC.) were prevalent. The incidence and development of northern anthracnose was not influences differences in soil pH_{KCl} of perennial grasses habitats in 1998 and 1999 (Table 1).

Common leaf spot has developed by 2.5 times intensively on the red clover in 1998 that were growing in the soil with pH_{KCl} 3.9–4.4 comparing with those grown in the soil with pH_{KCl} 6.3–6.7. A reverse correlation relation of medial strength has been indicated between the development of common leaf spot (y) on the red clover and the soil pH_{KCl} of their habitat (x): $r = -0.63$, $y = -15.58 + 11.12x - 1.13x^2$. In 1999 the common leaf spot on red clover growing in the soil of pH_{KCl} 3.9–4.4 was 1.5 times higher than red clover growing in the soil of pH_{KCL} 5.7–6.2 (Table 1).

About 20% in 1998 and 10% in 1999 of all red clover was harmed by the sooty blotch. On average the sooty blotch has developed on the red clover which grown in the soil of the most acid reaction comparing to those which were growing in the less acid soil.

During the phase of blossoming red clover were damaged by *Erysiphe polygoni* at the whole crop although not abundantly. Mostly (on average 12% in 1998) of damaged red clover leaves were found in the acid soil in comparison with the number of leaves damaged by this decease in the more neutral soil. The red clover growing in acidic soil was mostly affected by the powdery mildew during the vegetation period of 1999 too. During the whole crop the powdery mildew has been spread by 1.7 times abundantly and developed by 1.5 times intensively in comparison with that in 1998.

In 1998 common leaf spot has incidence by 2.3 and developed by 1.9 times intensively on that red clover which was unfertilized in comparison with the red clover fertilized by the biggest norm of mineral fertilizers: $r = -0.65$, $y = -10.65 + 8.14x - 0.09x^2$ (Table 2). In 1999 development of common leaf spot was 1.7 times as large in unfertilized red clover in comparison with the red clover fertilized by 2 n PK: $r = -0.70$, $y = 12.95 - 2.12x - 0.14x^2$.

In 1998 sooty blotch incidence was more intensive on the red clover that grew in the soil fertilized by three norms of mineral fertilizers, but developed more intensively in unfertilized plants. In 1999 the sooty blotch have expanded and developed rather chaotically in all agrobiocenosis of red clover. The least development of this disease, in average 4.8±0.1, was on that red clover, which were fertilized by the one norm of phosphorus-potassium, and the biggest, average 5.8±0.1, on the red clover, fertilized by the biggest norm of mineral fertilizers. From average of data in the period of investigation show positive influence of increasing of nutritious materials quantity in the soil of host plants habitat for the development of sooty blotch, but it is not possible to suggest one sided about one or another rendition of this disease incidence and development.

Still the most part of red clover in 1998 and 1999 was harmed by powdery mildew more intensively at the end of growing season, in comparison with earlier in the season. In 1999 those red clover were infected by this disease more abundantly which grew in the soil rich with nutrition material in comparison to those plants which were growing in the poor soil. According to the average data the incidence and development of powdery mildew has a little dependence from the fact that red clover has been fertilized by different norms of PK fertilizers.

Table 1. Estimation of incidence and severity red clover diseases in soils with different pH_{KCl} in the end of vegetation in 1998–1999 (x±Sx)

pH_{KCl}	Northern anthracnose		Common leaf spot		Sooty blotch		Powdery mildew	
	Incidence	Development	Incidence	Development	Incidence	Development	Incidence	Development
In 1998								
3.9–4.4	55.5±0.6	18.7±0.04	30.5±2.5	23.5±1.5	20.2±2.1	7.5±0.2	12.0±0.4	8.4±0.01
4.5–5.0	55.2±0.8	21.4±0.2	35.1±3.2	20.1±0.3	24.4±0.8	7.9±0.08	12.8±0.5	7.5±0.04
5.1–5.6	56.6±1.4	19.0±0.5	30.3±0.7	14.4±0.09	22.5±0.6	7.5±0.05	11.6±0.03	8.0±0.2
5.7–6.2	51.2±3.1	20.2±2.2	25.6±0.6	9.2±0.6	20.8±0.7	6.2±0.1	10.5±0.6	6.9±0.5
6.3–6.7	57.0±1.8	20.8±2.0	25.2±1.6	9.5±0.05	20.0±0.5	4.4±0.05	10.2±0.4	7.0±0.5
r*	0.15	0.22	–0.30	–0.63	–0.35	–0.48	–0.40	–0.35
In 1999								
3.9–4.4	35.9±1.5	7.5±0.09	22.4±0.7	10.2±0.04	10.0±1.1	5.5±0.08	19.9±0.5	12.5±0.4
4.5–5.0	40.2±2.2	9.5±0.4	20.5±0.6	10.0±0.5	10.2±0.8	5.7±0.04	20.2±1.6	12.0±0.5
5.1–5.6	35.7±4.1	6.9±0.1	20.1±2.2	9.2±1.1	8.8±1.2	4.5±0.2	20.5±2.1	10.5±1.8
5.7–6.2	36.9±0.9	8.8±0.6	21.5±1.6	6.8±0.2	9.5±0.5	4.2±0.07	17.5±0.9	10.2±2.1
6.3–6.7	35.6±1.6	8.5±0.5	20.8±1.3	7.5±0.5	9.6±0.6	4.2±0.1	17.0±0.4	10.5±0.4
r*	0.22	0.25	–0.28	–0.54	–0.30	–0.35	–0.38	–0.45

Note*: r – correlation between any disease incidence/development and soil reaction in which host-plants grew

Table 2. Estimation of incidence and severity red clover diseases in different fertilization systems in the end vegetation in 1998–1999 (x±Sx)

Norm (n) of mineral fertilizers	Northern anthracnose		Common leaf spot		Sooty blotch		Powdery mildew	
	Incidence	Development	Incidence	Development	Incidence	Development	Incidence	Development
In 1998								
Unfertilized	55.5±0.6	20.0±2.8	35.5±0.6	18.9±0.5	22.2±0.8	7.2±0.08	12.5±1.1	7.0±0.06
1 n PK	56.2±0.8	20.2±1.5	28.5±0.4	15.2±1.2	20.5±3.2	6.5±0.1	10.6±1.2	7.9±0.1
2 n PK	56.6±1.4	20.9±0.6	25.5±1.1	10.5±0.2	22.5±1.8	3.5±0.02	12.6±1.2	8.5±0.1
3 n PK	58.2±3.1	20.5±1.2	15.2±1.2	10.0±0.5	25.1±0.6	3.2±0.02	12.9±0.6	7.5±0.3
r*	0.12	0.20	–0.50	–0.65	0.35	–0.51	0.30	0.35
In 1999								
Unfertilized	41.4±4.5	8.0±0.5	20.2±1.6	11.2±0.5	10.0±0.2	5.0±0.04	20.0±3.2	10.5±04
1 n PK	40.0±2.5	9.5±0.6	20.0±2.5	8.5±0.2	9.8±0.1	4.8±0.1	21.2±1.5	10.0±0.1
2 n PK	38.7±3.5	8.2±0.2	19.5±0.8	6.5±0.8	10.0±0.2	5.5±0.5	22.0±1.2	12.5±0.5
3 n PK	39.5±1.2	8.5±1.5	19.2±1.3	7.0±0.1	10.2±0.5	5.8±0.1	21.5±0.3	12.5±0.5
r*	–0.20	–0.25	–0.30	–0.70	0.15	0.32	0.32	0.40

Note*: r – correlation between any disease incidence/development and norms of mineral fertilizers

Conclusions

The fungal leafs diseases damaged red clover from 3.2 till 58.2% in the different soil reaction and fertilized by different amount of mineral fertilizers at the end of growing season (blooming) in 1998–1999. Northern antracnose, common leaf spot and sooty blotch had more intensive spread in 1998.

Red clover, which grew in very acid soil (pH_{KCl} 3.9–4.4) were more intensive damaged by these diseases: common leaf spot, sooty blotch and powdery mildew. Diseases spreading reduced by 1.7–2.5 times in soil of rather neutral – close to neutral reaction (pH_{KCl} 6.3–6.7). Intensive fertilization by phosphorus and potassium fertilizers significantly reduced the spreading of common leaf spot (r = –0.3–0.7), but it increased the incidence and development of powdery mildew on plants leafs a little (r = 0.3–0.4). Application of different fertilizer and different soil reaction had no significant influence on incidence of *Kabatiella caulivorum.*

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Notes on the floral evolution of the manured meadows in the Sole Valley (Trentino, NE Italy)

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Abstract

To show the evolution of the manured meadows of the Sole valley, 55 floral relevés, already described by Pedrotti in 1963, were compared with 57 relevés surveyed in 1997.
Using the same criterion, the two sets of relevés were classified using a hierarchical clustering method to characterise the past and the present vegetation types. From the comparison, it emerged that the botanical composition of the meadows had changed differently at low altitude compared to high altitude. In general, at low altitude an eutrophication of the meadows was observed with the appearance of new meadow types with less species while, at high altitude, some vegetation forms disappeared. This evolution seemed to be caused by a change in the husbandry activities and, therefore, in the grassland management. These differences were reconstructed with interviews about the past and present management.

Keywords: evolution, meadows vegetation, management, eutrophication, abandonment

Introduction

Vegetation changes may be caused by different simultaneous processes like fluctuation, invasion or disappearance of individual plants, whole populations or plants communities (Wildi and Krusi, 1992). The ecological factors that induce this change can be natural (e.g. fires, climatic fluctuations), or anthropic (e.g. cut, fertilisation, tilling). In particular, grasslands are typical anthropogenetic vegetation influenced strongly by management.
Studies of vegetation changes in time can be done at different spatial and temporal scales. To analyse punctual processes, fixed plots with a standard dimension or nested plots with a variable sampling, in which floristic relevés are measured at different times, have been used. As an alternative, other sources of information, such as cartographies or studies done at different times, can be used to reconstruct the general variation of land use or significant vegetation changes. The latter approach gives less information about the processes that cause variation but it may be useful to have information referred to a wide area.
Using the last method, we compared a past study (Pedrotti, 1963) of the mown meadows of the Sole Valley (only those plant communities are included which belong to the *Arrhenatheretalia* R. Tx. 1931 and *Poo-alpinae Trisetalia* Ellmauer et Mucina 1993) with an actual set of relevés (1997: synthetically published in Scotton *et al*., 2000) taken in the same area. The characteristics of the present and the past management have been reconstructed by interviews.
The principal aim was to describe the changes of vegetation, and to relate them to the management modifications. The discussion is limited to a comparative description of the types of mown meadow at the two epochs.

Materials and Methods

The Sole Valley is placed in NW of Trentino province (NE Italian Alps). The annual rainfall is about 900 mm, mean annual temperature is around 7 °C at 1000 m a.s.l. The climate is continental. The main geological substrates are crystalline or metamorphic.

The first data set comprised 55 relevés surveyed on meadows of the Sole Valley in 1963 by Pedrotti. The second data set was formed by 57 relevés surveyed in the same valley in 1997 (30 of these relevés are taken in the same places as Pedrotti). In the 1997 survey, all sampling plots were 10 m × 10 m; in 1963 some plots had a different size. The relevés were taken with the phytosociological approach using the Braun-Blanquet's scale as a measure of abundance.
The vegetation was classified with a minimum variance clustering method based on the resemblance matrix of a similarity ratio index. Before computing the resemblance matrix, the data were transformed according to the van der Maarel's scale (van der Maarel, 1979). The classification was done with MULVA 5.1 (Wildi and Orlóci, 1996). The phytosociological interpretation followed Poldini and Oriolo (1994) and Ellmauer and Mucina (1997).
The 1997 management was determined by interviews with farmers while the past situation was reconstructed using information given by Pedrotti (1963) or obtained from technicians.

Results and Discussion

In general, the manured grasslands of the Sole Valley can be divided into two main associations: the low altitude *Arrhenatherum elatius* grasslands (*Centaureo carniolicae-Arrhenatheretum elatioris* Oberdorfer 1964 corr. Poldini et Oriolo 1994 or the pseudonym *Arrhenatheretum elatioris* Pedrotti 1964) and the high altitude *Trisetum flavescens* grasslands (*Trisetum flavescentis* Pedrotti 1964 non Brockman et Jerosch 1907 or the pseudonym *Centaureo transalpinae-Trisetum flavescentis* (Marschall, 1974; Poldini et Oriolo, 1994). Here we refer to the associations with the shortened names *Arrhenatheretum* and *Trisetetum*.
In 1963, 2780 ha of meadows and 5150 standard livestock units (SLU) were present in the valley. Considering that about 40% of the farmyard was distributed on potato and cereals fields, the mean fertilisation of the meadows was about 45 kg of N $ha^{-1}y^{-1}$. The management was characterised by a well-balanced cycle of nutrients within the farms. The *Arrhenatheretum* was regularly irrigated and fertilised with manure. There were no fertilisation excesses, because use of extra-farm supplements in the husbandry was not normal and the mineral fertilisation was done at low levels. Moreover, removal of input nutrients from the soil was guaranteed by relatively numerous cuts. Due to irrigation three to four cuts per year were harvested in low altitude meadows. Additionally, at the end of the season, the swards were grazed for 8–10 days. In the *Trisetetum*, the management was generally less intensive, irrigation was absent or less abundant and the fertiliser level was lower. There were one or two cuts per year, but aftermath grazing in autumn was more intense.
In 1997, the meadow total surface was about 1600 ha and the SLU number 3000. Through farmyard fertilisation approximately 180 kg of N $ha^{-1}y^{-1}$ was on average distributed. The actual management was characterised by two principal differences in comparison to the past. At low altitude, several meadows received high levels of manure (over 350 kg N $ha^{-1} y^{-1}$). We also observed an abandonment of irrigation and a decrease in the number of cuts (2 or 3 at most). On the contrary, at high altitude many meadows were abandoned.
To describe the vegetation differences, Table 1 shows a list of vegetation types in 1963 compared to 1997 and the management changes which had occured.
From the classification of Pedrotti's data set, two forms of low altitude grasslands (900–1200 m a.s.l.) emerged: a typical form of *Arrhenatheretum* characterised by good fertilisation and a poor form of the same vegetation characterised by *Avenula pubescens, Festuca ovina* agg. *s.l.* with a group of xerophilous species. Pedrotti (1963) reported a mean productivity for the irrigated *Arrhenatheretum* of about 6.5–8 t of dry matter (DM) $ha^{-1} y^{-1}$.

For the high altitude grasslands (above 1200 m a.s.l.), three form of *Trisetetum* were distinguished: one typical, with good level of fertilisation, one poor with *Poa violacea*, characterised by reduced fertilisation, and a sub-alpine form, in which many species characteristic for low altitude disappeared, replaced by a well defined group of species typical for high altitude. The mean productivity was about 3.5–5.5 t of DM ha^{-1} y^{-1}.

Table 1. List of the vegetation types and management changes from 1963 to 1997

Low altitude grasslands (*Centaureo carniolicae-Arrhenatheretum elatioris*; mountain form)			
Form	1963	1997	Management changes
Typical	present	present	–
Poor form with *Avenula pubescens* and *Festuca ovina agg. s.l.*	present	present	–
Over fertilised form with *Alopecurus pratensis* and *Anthriscus sylvestris* (*Ranunculo repentis-Alopecuretum pratensis*)	absent	present	more intensive fertilisation of the meadows near to the farms
Over fertilised form with *Agropyron repens*	absent	present	more intensive fertilisation of the meadows near to the farms but only 2 cuts
High altitude grasslands (*Centaureo transalpinae-Trisetum flavescentis*)			
Form	1993	1997	management changes
Typical	present	present, but few, relatively low altitude situations (transition to *Arrhenatheretum*)	partial abandonment
Poor form with *Poa violacea*	present	present	–
Sub-alpine form	present	absent	abandonment

In 1997, on the low altitude grasslands, in addition to the two *Arrhenatheretum* forms described by Pedrotti, two new forms were found which were characterised by an impoverished floral composition dominated by few and nitrophilous species: one form with *Alopecurus pratensis* and *Anthriscus sylvestris* and the other form with *Agropyron repens*. The first was an intensively managed grassland (fertilization over 300 kg of N ha^{-1} y^{-1}) present on relatively wet soils; this form can be extensively interpreted as *Ranunculo repentis-Alopecuretum pratensis* Dietl 1983. The second was also very intensive, but it occured on relatively dry soils, and was managed by a low number of cuts (at most 2) and high fertilisation (about 330 kg of N ha^{-1} y^{-1}). These meadows types were the result of the agricultural intensification. They had very low number of species, about twenty relevé$^{-1}$ (often less), with negative consequences for biodiversity. The productivity varied from 7 to 9 t ha^{-1} y^{-1}, significantly exceeding the mean values of the past productivity.

The formation of these two forms of vegetation agreed with the results of Dietl (1995), who observed, in the Swiss Plateau, that the husbandry intensification and the lack of balance between input and removal of nutrients had induced a drastic eutrophication of the site with the formation of vegetation similar to ours in partial replacement of the old ones. For these intensive meadows Dietl (1995) proposed a new alliance (*Trifolio repentis-Lolion perennis* Dietl 1983). This evolution was caused by an increase in fertilisation and a decrease in the number of cuts (not more than 3) caused by the cessation of regular irrigation.

At the high altitude, we found a different situation. Among the three forms of *Trisetetum* deduced from Pedrotti's data set, the ones which were still present in 1997 were the poor form with *Poa violocea* and, partially, the typical form, whereas the sub-alpine one had disappeared. Because of this the highest grasslands (1600–1900 m a.s.l.) were mostly replaced by forests with a substantial loss of floral and landscape diversity. Moreover, the 1997 *Trisetetum* was a transition form between the *Arrhenatheretum* and the *Trisetetum* described by Pedrotti. The *Trisetetum* meadows need good fertilisation and regular cuts but have low productivity (the productivity level at the two epochs are similar) so they have been often abandoned by farmers who prefered to cultivate the more convenient low altitude meadows.

Conclusions

The general evolution of vegetation was caused by two kinds of management changes that produced different negative effects on the floral and landscape diversity.

At low altitude, the more intensive utilisation caused the formation of new meadow vegetation types characterised by a very impoverished floral composition. This change was induced by an imbalance between increased fertilisation input caused by the use of much higher amounts of extra-farm aliments and decreased nutrients removal due to a reduced number of cuts.

The less productive meadows of high altitude were mostly abandoned because their utilisation was no longer profitable. In future, their conservation will only be feasible with monetary compensation or a premium (e.g. by the EU) to motivate farmers to maintain mowing.

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Relationships between management and diversity of permanent grasslands in the Non Valley (Trentino, NE Italy)

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Abstract

The study has the aim to search the anthropic factors that influence the floral composition and the numeric variation of species, considered as a measure of diversity, of meadow vegetation in the Non Valley. The data are the floral, environmental and managerial characteristics of 48 meadows surveyed in 1997.

With a hierarchical clustering agglomerative method 8 vegetation types, based on floral similarity, have been individuated that show the vegetation diversity of the area. Then, with the use of *Principal Components Analysis*, an indirect gradient analysis has been done to underline the factors which influence the floral composition qualitatively. The first two principal components explain more than the third of total variance and the correlation between components and external variables shows that N input and number of cuts are important factors that cause floral variation.

Then, with correlation analysis it has been demonstrated that the number of species has a negative correlation with N input whereas the productivity has an opposite behaviour. So, at this spatial scale, there is antagonism between productivity and diversity of the flora.

Keywords: grasslands, floral diversity, number of species, productivity, N input, cuts

Introduction

The study of grassland diversity can be done from different points of view. Many ecological works have considered the relationships between diversity and productivity of the ecosystems (e.g. Gross *et al.*, 2000) focusing on models of competition that can explain a monotonic or unimodal relationship between these two variables (Abrams, 1995). Others considered in particular the effect of fertilization on species richness (e.g. Bakelar and Odum, 1978; Foster and Gross, 1998; Pyšek and Lepš, 1991) showing that, at reduced spatial scale, nitrogen (N) enrichment increases plant production but reduces species richness. This behaviour is explained by the interspecific competitive exclusion hypothesis which assumes that mortality is not equal among species and that interspecific competition is the principal cause of decreasing in species richness in fertile grasslands (Stevens and Carson, 1999). This kind of analysis considers the effects of some treatments on the number of species in short term and at a small spatial scale.

On the contrary, the diversity of vegetation is normally faced at regional level with a phytosociological approach with studies that describe qualitatively the floral composition of the vegetation. Some works of this kind interest the permanent grasslands of NE Italian Alps (e.g. Pedrotti, 1963; Poldini and Oriolo, 1994; Scotton and Rodaro, 2000).

Here, we regard two aspects of the grassland diversity of the area: floral composition of vegetation and species richness in relation with management. These relationships are studied choosing plots among different communities present at regional scale.

Therefore the objectives of the study are: 1) to describe briefly the meadow vegetation diversity of the area with a phytosociological approach, 2) to understand the effect of N input and number of cuts on the floral variation of vegetation, 3) to comprehend the interrelationships between number of species, productivity and N input.

Materials and Methods

The Non Valley is placed in the NW of Trentino province in the NE Italian Alps. The prevalent geological substrates are carbonatic. The mean annual rainfall is about 900 mm, the annual mean temperature 9.3 °C at 900 m a. s. l. and 7.1 °C at 1350 m a. s. l.
48 survey areas were chosen in the summer of 1997. The choice of the plots was done with a systematic sampling, stratified for intensity of management and geomorphology. The quadrates cover the entire vegetation variability. The units of sampling are squares of 10×10 m with homogeneous vegetation, in which floral relevés were made using the Dietl's scale of percentage biomass estimation for each present species (Dietl, 1995). For each surveyed meadow, number of cuts, number of species, N input, productivity and some simple environmental variables (altitude, slope and exposure) were determined.
On the basis of the obtained data, the vegetation was classified with the *minimum variance* clustering method based on the resemblance matrix of the *similarity ratio* index. The phytosociological interpretation follows Poldini and Oriolo (1994) and Mucina *et. al* (1997).
To understand the relationship between floral composition and management intensity an indirect gradient analysis has been done using the results of *Principal Component Analysis* (*PCA*) basing on the variance-covariance matrix of the floral data transformed into the binary scale of presence/absence and centered by species. The scaling method chosen preserves the euclidean distance between samples. Four surveys of over fertilized grasslands with *Agropyron repens* were excluded from ordination because they hadn't floral continuity with the others. After the extraction of the principal components, a correlation analysis was done using as variables the first two components, N input, number of cuts, productivity and number of species. Cluster analysis and PCA were executed with MULVA 5.1 (Wildi and Orlóci, 1996). Then the interrelationships between number of species, productivity and N input were considered.

Results and Discussion

With the classification, eight vegetation types have been recognized. The eight types can be organized into four principal categories of vegetation and can be described as follows (in brackets, for each type mean number of species, N fertilization and productivity (dry matter) are added):
1. *Bromus erectus* grassland (*Bromion erecti* Koch 1926): this type of grassland is characterized by soils poor in nutrients, one cut year^{-1}, low productivity but high floral diversity:
1a. Primitive of high slope (50; 50 kg ha^{-1} y^{-1}; 4.1 t ha^{-1} y^{-1}).
1b. Evoluted of low slope (45; 50 kg ha^{-1} y^{-1}; 4.9 t ha^{-1} y^{-1}).
2. *Arrhenatherum elatius* grassland of low altitude (*Centaureo carniolicae-Arrhenatheretum elatioris* Oberdorfer 1964 corr. Poldini et Oriolo 1994): *Poaceae* as *Arrhenatherum elatius*, *Trisetum flavescens*, *Dactylis glomerata* or *Agropyron repens* dominate this grassland. This is the more widespread type in the area, cut 2–3 times year^{-1}. The floral structure is quite simplified. Four types have been distinguished:
2a. Typical, normally fertilized form (38; 125 kg ha^{-1} y^{-1}; 7.6 t ha^{-1} y^{-1}).
2b. Form with *Bromus inermis*, probably originating from a past re-sown with commercial mixtures containing the species (33; 250 kg ha^{-1} y^{-1}; 8.6 t ha^{-1} y^{-1}).
2c. Highly fertilized and wet form with *Alopecurus pratensis* and *Anthriscus sylvestris* (25; 250 kg ha^{-1} y^{-1}; 8.4 t ha^{-1} y^{-1}).

2d. Over fertilized form with *Agropyron repens* (29; 350 kg ha^{-1} y^{-1}; 8.5 t ha^{-1} y^{-1}).
3. *Agropyron repens* grassland: on drained soils, highly fertilized but cut only twice yearly and characterized by the lowest species number (15; 350 kg ha^{-1} y^{-1}; 7.3 t ha^{-1} y^{-1}).
4. *Trisetum flavescens* grassland (*Centaureo transalpinae-Trisetum flavescentis* (Marschall 1974) Poldini *et* Oriolo hoc loco 1994): grassland above 1100–1200 m a. s. l. without *Arrhenatherum elatius* and characterized by a clear and well-defined group of species typical of the high altitude. It is less intensively managed than the previous ones because more distant from the farms (39; 90 kg ha^{-1} y^{-1}; 5.7 t ha^{-1} y^{-1}).

In Figure 1 the ordination of the relevés is presented. The first two principal components explain respectively 19.7 and 10.9% of the total variance. The ordination diagram also shows a good separation of the principal categories of vegetation described before. It can be observed that the forms of highly or over-fertilized grasslands of low altitude are plotted in a narrow area. This arrangement is caused by the use, in the procedure of ordination, of the presence–absence data instead of the abundance data which are, on the contrary, important in discriminating the vegetation types in the cluster analysis.

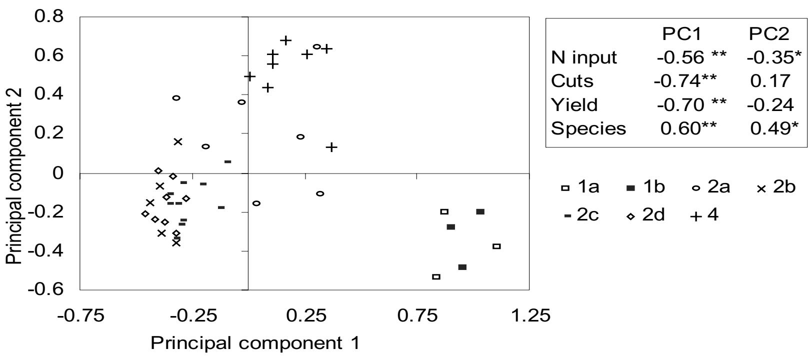

Figure 1. Ordination of the floral surveys with *PCA* against the first two principal components. The different symbols used for plotting the surveys refer to the seven vegetation types indicated in the legend and described in the text. In the associated table the correlation indices between the first two principal components (PC1 and PC2) with N input, number of cuts (Cuts), productivity (Yield) and number of species (Species) are presented (significance level: *, $p<0.05$; **, $p<0.01$)

Observing the indices in Figure 1, there is a negative correlation between the first component and two principal anthropic factors of management: N input and number of cuts. Therefore this component can be interpreted as representative of a decreasing gradient of intensity of management. This result indicates that the management influences the floral composition and that an important part of the total variance is explained by the above-mentioned factors. Moreover, it can be observed that the change of the vegetation types along the first component, from the more to the less intensive, is correlated negatively with the productivity and positively with the number of species (see Figure 1). This behaviour is caused by the progressive decrease of fertilization and, as consequence, of the soil fertility.

Figure 2 shows the interrelations among number of species, productivity and N input. The number of species has a negative correlation with N input and productivity. Moreover, N input and productivity are positively correlated. These results agree with many studies conducted at a field scale (e.g. Bakelar and Odum, 1978; Foster and Gross L., 1998; Wilson and Tilman, 1991) and confirm the antagonism between productivity of ecosystems and species richness.

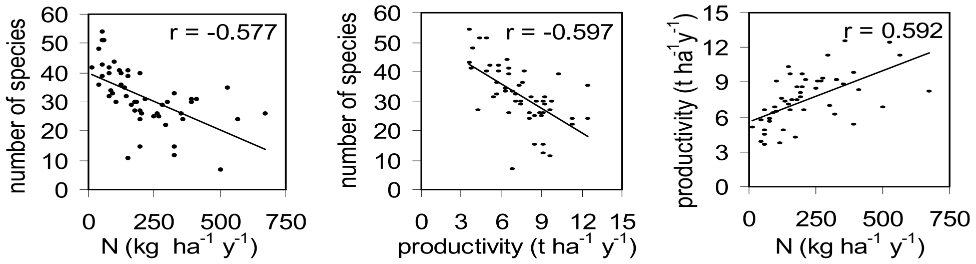

Figure 2. Relationships between number of species, productivity and N input (all correlation coefficients are significant at the $p<0.01$ level)

Conclusions

The study confirms that there is a strict relation between intensity of management and the two levels of diversity: floral composition and species richness. In particular the high fertility selects a low number of species that build a community whose structure excludes the less competitive species. At the same time the fertility seems to determine the formation of different vegetation types as consequence of the fertilization level.

Therefore, transforming extensive grassland into an intensive one, many species can be lost and also the floral structure becomes more simplified. This consideration is much more important while deciding the management intensity of grasslands located in Natural Parks or *Natura* 2000 Sites where the conservation of diversity has particular importance.

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Berseem-annual ryegrass intercropping: effect of plant arrangement and seeding ratio on N_2 fixation and yield

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Abstract

Various agronomic factors can affect the productivity and the efficiency of legume-grass intercropping systems. This research was carried out in a Mediterranean semi-arid environment (37°30'N; 13°31'E; 178 m a.s.l.) with the aim to study on berseem clover- annual ryegrass mixture (*Trifolium alexandrinum* L. – *Lolium multiflorum* Lam subsp. *wersterwoldicum*) the effects of different plant arrangement (sowing of the two components in alternate rows or in the same row) and seeding ratios (100:0; 75:25; 50:50; 25:75; 0:100) on forage yield, nitrogen content and nitrogen fixation. The experimental design was a split-plot with four replications. The ^{15}N isotope dilution technique was used to estimate nitrogen fixation by berseem clover. All plots were cut four times (first cut 85 DAS; rest period of four weeks). The DM yield of mixtures and pure stand clover were similar; annual ryegrass in pure stand produced the lowest yields. No significant differences for DM yield were observed due to the plant arrangement and seeding ratio in the mixture. Intercropping berseem had always a significant higher percentage of Ndfa than monocropped berseem. The %Ndfa of mixed berseem was not influenced by plant arrangement but gradually decreased when proportion of berseem in the mixture increased.

Keywords: berseem clover, annual ryegrass, mixture, plant arrangement, seeding ratio, nitrogen fixation

Introduction

Intercropping is the growing of two (or more) crops together on the same area of ground and often produces an advantage in terms of more yield and less variation in yield than comparable areas of sole crops (Willey, 1979; Bulson *et al.*, 1997). The most commonly accepted reason explaining why it is possible to obtain better yields with crop mixtures is that the component crops can use more efficiently the limiting resources differing in their growth requirements. Systems which combine grass and legume crops are highly regarded because of their potential for replacing fertilizer N with symbiotically fixed atmospheric N_2 and the economic and environmental benefits which may result from this (Stern, 1993). However, in the literature there are few data available on biological nitrogen fixation by annual forage legumes in Mediterranean environments. As well as few data is available on the contribution of biological nitrogen fixed by annual legume to the nitrogen nutrition of a non-legume grown in mixed stand and on the effects of intercropping with grass on the quantity of N_2 fixed by forage legume component. Moreover the productivity and efficiency of grass-legume intercrop system are affected by various agronomic variables such as component crop density, plant spacing and arrangement, time of sowing of component crop, N fertilization (Ofori and Stern, 1987).

The aim of this research was to evaluate on berseem clover – annual ryegrass mixture the effects of different plant arrangement and seeding ratios on forage yield, nitrogen content and nitrogen fixation in a typical rain-fed Mediterranean environment.

Materials and Methods

The research was carried out during 2002/03 in a hilly area of Sicily (37°30'N; 13°31'E; 178 m a.s.l.) on a *Vertic haploxerepts* soil and with wheat as previous crop. The topsoil (0–40 cm) had the following characteristics: 38% clay, 25% silt, 36% sand, 8.4 pH (in water), 1.27% organic matter, 0.85‰ total nitrogen.

The experiment was set up in a complete randomized block design with four replications. Treatments were: berseem (*Trifolium alexandrinum* L. cv Lilibeo) in pure stand (B); annual ryegrass (*Lolium multiflorum* Lam. subsp. *wersterwoldicum* cv Elunaria) in pure stand (R); and their mixture with different plant arrangement [sowing of the two components in alternate rows (BR_{AR}) or in the same row (BR_{SR})] and seeding ratios (B_{25}-R_{75}; B_{50}-R_{50}; B_{75}-R_{25}). Pure stands were seeded at 50 kg seeds ha^{-1}. Mixed and pure stands were sown by hand on 16 December 2002. No herbicide treatments were used; all plots were kept free of weeds by hand-weeding.

The ^{15}N isotope dilution technique was used to estimate nitrogen fixation by clover. ^{15}N fertilizer [$(NH_4)_2SO_4$ with an isotopic composition of 10 atom% ^{15}N] was uniformly applied in a liquid form, following the application procedure described by Hogh-Jensen and Schjoerring (1994). ^{15}N fertilizer (8 kg N ha^{-1}) was applied to a 2.88 m^2 microplot in the middle of each plot at the emergence of the crops and again two days after the 1st and 2nd utilizations. The rest of the plot outside the ^{15}N-labelled area received a top-dressing of ammonium sulphate in an amount equivalent to the microplots. After each application of labelled fertilizer an irrigation of all plots was used in order to avoid the retention of ^{15}N fertilizer on the plant leaves.

All plots were cut simultaneously at 85d after sowing and defoliation frequency of 28d was used (4 times). All plots were harvested by hand at 5 cm stubble height and total fresh weight was determined. At each harvest, a sample of plant material, taken in the centre of microplots, was hand-disaggregated into its botanical components (B, R), dried at 60 °C for 36 h, weighed and ground to a fine powder (sieved using a 0.1 mm mesh size) in a fast running mill and analysed by the Iso-Analytical laboratory (EA-IRMS technique) for ^{15}N enrichment and total N content.

Data on ^{15}N enrichment of biomass were used to calculate the percentage of clover nitrogen derived from symbiotic N_2 fixation (%Ndfa) according to Fried and Middleboe (1977).

The GLM procedure of the Statistical Analysis System (SAS) was used to analyze the variance. Least significant difference (LSD at $P \leq 0.05$) was used to make comparisons among treatments.

Results and Discussion

During growing season total rainfall was close to the long-term mean (532 mm vs 550 mm) and distribution was generally favourable for crop growth.

Dry matter yield (kg ha^{-1}) for annual ryegrass and berseem clover in pure and mixed stands in relation to the different plant arrangement and seeding ratio are reported in Table 1.

The yield of sole-cropped berseem was significantly higher than ryegrass in pure stand (9449 *vs* 4826; $P<0.0001$). The DM yield of mixture and pure stand clover were similar. No significant differences for DM yield were observed due to the arrangement of plants and to the different seeding ratio in the mixture.

The legumes competed very well in the mixed stands, producing on average 80% of the total yield. Both seeding ratio and plant arrangement had small effects on %clover on DM basis.

Annual ryegrass intercropped with berseem consistently had a higher nitrogen concentration in the dry matter than ryegrass grown in pure stand ($P<0.001$). This is in agreement with the reports of Jorgessen *et al*. (1999) and Malhi *et al*. (2002). Moreover, mixing the components within the row, compared to sowing in alternate rows, significantly increased the N content in annual ryegrass.

On the contrary, the N concentration of berseem was much greater in pure stand than in mixture; similar results have been found by Scarpello (2003) for berseem clover intercropped with annul ryegrass in a Mediterranean semi-arid environment.

In the mixture the N concentration (g kg^{-1} DM) of berseem and ryegrass forage increased significantly with increase in berseem portion of stand.

Table 1. Dry matter yield (kg ha^{-1}), N concentration (g kg^{-1} DM) and percent of N uptake derived from atmospheric nitrogen fixation (%Ndfa) for annual ryegrass and berseem clover in pure and mixed stands as affected by plant arrangement (alternate rows – BR_{AR}; same row – BR_{SR}) and seeding ratio

	Dry matter yield (kg ha^{-1})			N concentration (g kg^{-1} DM)		Ndfa (%)
	Berseem	Ryegrass	Total	Berseem	Ryegrass	Berseem
Berseem (B)	9449	–	9449	35.0	–	73.3
Ryegrass (R)	–	4826	4826	–	20.6	–
BR_{AR} (B_{25}-R_{75})	6746	2000	8746	31.6	29.9	81.1
BR_{AR} (B_{50}-R_{50})	7083	1707	8790	32.6	29.2	80.7
BR_{AR} (B_{75}-R_{25})	6948	1718	8666	33.5	31.3	78.8
BR_{SR} (B_{25}-R_{75})	6824	2458	9282	31.4	28.4	84.1
BR_{SR} (B_{50}-R_{50})	7980	1266	9246	33.7	33.3	80.2
BR_{SR} (B_{75}-R_{25})	8258	1438	9696	33.9	33.6	78.8
$LSD_{0.05}$	*970*	*852*	*811*	*1.3*	*2.5*	*3.0*
Mean effect of plant arrangement						
Alternate rows	6925	1809	8734	32.6	30.1 b	80.2
Same row	7688	1721	9409	33.0	31.8 a	81.0
Mean effect of seeding ratio						
BR (B_{25}-R_{75})	6785 b	2228 a	9013	31.5 b	29.1 b	82.6 a
BR (B_{50}-R_{50})	7531 a	1487 b	9018	33.1 a	31.2 a	80.4 ab
BR(B_{75}-R_{25})	7603 a	1579 b	9182	33.7 a	32.5 a	78.8 b

Different letters within the columns indicate significant different at the P≤0.05 level

On average, *Trifolium alexandrinum* achieved a higher proportion of its N from nitrogen fixation when grown in mixture with ryegrass than when it was grown in monoculture ($P<0.0001$). In mixture ryegrass has been found to be stronger competitor for soil nitrogen (data not shown), and berseem relied more on N_2 fixation as N source. Similar observations were made by Papastylianou (1988), Loiseau *et al.* (2001), Carlsson and Huss-Danell (2003) and Stringi *et al.* (2004). This suggests that nitrogen competition plays a key role in intercropping legume-nonlegume systems and its knowledge can enable to manage better N inputs in order to make the intercropping system more efficient.

No significant differences for %Ndfa were observed due to the arrangement of plants in the mixture. The percentage of nitrogen derived from N_2-fixation decreased with increase in berseem portion of stand. Such result seems related to the increase of soil N uptake by

ryegrass as its density increased in the mixture; this, on turn, encouraged the legume to obtain a greater proportion of its nitrogen through biological fixation.
The apparent transfer of fixed nitrogen from clover to grass was negligible in all treatment. In fact, no significant lower values for % atom ^{15}N of intercropped annual ryegrass compared to monocropped were observed, indicating that transfer of the nitrogen from legume to grass was marginal or nonexistent (Cowell *et al*., 1989). This is in agreement with the reports of Peoples and Herridge (1990), Danso *et al*. (1993) and Stringi *et al.* (2004) that highlighted how in annual grass-legume intercropping N transfer may not be common phenomena.

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Variability of dry matter yield and quality of lucerne genotypes depending on geographic origin

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Abstract

Dry matter yield and quality are the two main and increasing goals of lucerne breeding. Genotype variability is almost as important in lucerne selection as the breeding methods used in the process. In 2002, a trial with 15 cultivars was established to study the variability of yield and quality in lucerne genotypes of different geographic origin. Two of the cultivars are from Serbia, five from Greece, five from Bolivia, one from Ukraine and three from Estonia. They are biologically divergent (12 of the cultivars are *Medicago sativa* ssp. *sativa* and three *Medicago sativa* ssp. varia. Forage and dry matter yields ranged from 33.6 t ha^{-1} to 78.4 t ha^{-1} and from 8.0 t ha^{-1} to 20.4 t ha^{-1} respectively. Regrowth after cutting and plant height ranged between 15.1 and 34.7 cm and 36.4 and 71.2 cm, respectively. Leaf contribution to yield varied significantly among the *M. sativa* genotypes and did not depend on geographic origin. The largest contribution of leaves and hence best quality were found in the cultivars Pella and Bolivia 2000.

Keywords: dry matter yield, cultivar, geographic origin, quality

Introduction

Lucerne is the most important forage crop in the world, not only because of high yields of forage and hay, but also for their high nutritive value in ruminants feeding. Yields of forage and hay depend on genotype, ecological conditions and biological factors. Cultivars developed for specific local ecological conditions are more adapted, and therefore have higher yields (Julier, 1996). Cultivars from more distant regions are less adapted and have lower yields (Katić *et al*., 2004a). Quality, that is digestibility, depends on crude protein content (Rotili *et al.,* 2001; Julier *et al.,* 2001), which is positively correlated with the content of leaves and negatively correlated with dry matter yield (Katić *et al*., 2000). Crude cellulose content is negatively correlated with quality, that is digestibility (Julier *et al.,* 2001). The aim of this paper was to assess the variability of yield and quality in lucerne genotypes of different geographic origin.

Materials and Methods

Field experiments were conducted in the period 2002–2004 in Novi Sad. The soil in the field is a chernozem, with neutral reaction (pH_{KCl} 7.25). The average annual temperature for Novi Sad is 11.0 °C, the total annual rainfall is 597 mm. Of *Medicago sativa* ssp. sativa, threre were two cultivars developed at the Institute (NS Banat ZMS II and NS Mediana ZMS V), four from Greece (Hyliki, Cheronia, Dolichi and Pella), five from Bolivia (Bolivia 2000, Riviera, UMSS 2001, Altiplano and Repaan), and one from Ukraine (Sinskaja). Of Medicago *sativa* ssp. *varia* cultivars, threre were three from Estonia (Jõgeva 118, Karlu and Juurlu), All of them were tested using a random block design in five replications.
The plot size was 5 m^2 (5 m × 1 m). Four cuts were made in 2003 and in 2004. Plant height and the number and length of internodes were measured in samples consisting of 30 shoots per replication. The portion of leaves in the yield of dry matter was determined by manually separating leaves and stems. Regrowth rate was measured 15 days after cutting. Crude

cellulose content, crude protein content, mineral substances, oil and N-free content (NFE) were determined by standard chemical analyses.
The two-factorial analysis of variance was used with cultivar as factor A and cut as factor B. The LSD test was used for testing the significance of differences.

Results and Discussions

The yields of green forage varied from 33.6 to 78.4 t ha^{-1}, the yields of dry matter from 8.0 to 20.4 t ha^{-1} (Table 1). The domestic cultivars and those from geographically close regions (the domestic cultivar NS Banat ZMS II, the Greek cultivars Hyliki, Dolichi and Pella) had higher dry matter yields than the cultivars from distant regions. The cultivars *M. sativa* were higher yielding than the cultivars *M. varia* (Katić *et al.,* 2004b). The highest yielding cultivars, those from Greece, Serbia and Ukraine (Sinskaya) had tall plants, good regrowth after cutting and high adaptation to the local conditions. Tallest plants came from cultivars from geographically close regions and they were also close biologically. Those were the domestic cultivar NS Mediana ZMS V and the Greek cultivars Dolichi and Cheronia. Plant height of the Bolivian cultivars was less than that of the Serbian and Greek cultivars. The Estonian cultivars from the subspecies *M. varia* had shortest plants. Mutual relationship was established between regrowth rate and dry matter yield. The cultivars with high regrowth rate had high yield of dry matter (Katić, 2001).

Table 1. Forage yield (t ha^{-1}), dry matter yield t ha^{-1}), plant height (cm), regrowth rate (cm) and portion of leaves (g kg^{-1}) in lucerne cultivars during 2003–2004

Cultivar	Forage yield	Dry matter yield	Plant height	Regrowth rate	Portion of leaves
1. NS Mediana ZMS V	68.0	17.2	68.9	31.9	480
2. NS Banat ZMS II	74.8	20.4	67.4	33.4	490
3. Hyliki	76.4	20.0	68.9	33.7	480
4. Cheronia	71.2	18.8	71.1	34.7	490
5. Dolichi	78.4	20.0	71.2	33.2	460
6. Pella	76.0	20.0	66.4	34.0	510
7. Sinskaya	71.2	18.4	60.3	25.5	530
8. Bolivija 2000	48.8	13.2	57.9	28.0	500
9. Riviera	48.0	13.2	61.4	27.7	490
10. UMSS 2001	55.2	14.8	62.4	31.2	500
11. Altiplano	51.6	13.2	64.2	27.1	500
12. Repaan	52.0	14.0	62.8	27.5	490
13. Jõgeva 118	40.0	9.2	41.4	16.9	570
14. Karlu	33.6	8.0	42.6	16.0	580
15. Juurlu	36.8	8.8	36.4	15.1	630
Average	58.8	15.3	60.2	27.7	510
LSD 0.05	3.6	1.0	2.5	1.60	0.58
LSD 0.01	4.7	1.2	3.3	2.10	0.77

Significant differences were observed in regrowth rate between *M. sativa* and *M. varia* genotypes. The highest regrowth was exhibited by the Greek cultivars (Cheronia, Pella and Hyliki), the domestic cultivar NS Banat ZMS II and the Bolivian cultivar UMSS 2001. The Estonian cultivars Juurlu, Karlu and Jõgeva 118 had the lowest regrowth, about half of the maximum values measured. The portion of leaves is an indirect indication of high quality of dry mass (Katić *et al.,* 2000). The portion of leaves was higher in *M. varia* cultivars (570–630 g kg^{-1}) than the highest values of *M. sativa* cultivars, such as Sinskaya and Pella.

The studied cultivars differed significantly in chemical composition. *M. varia* cultivars from Estonia had the highest content of crude proteins and the lowest content of crude cellulose (from 244.1 g kg^{-1} in Karlu to 250.3 g kg^{-1} in Juurlu). Among *M. sativa* cultivars, the highest contents of crude proteins were founds in NS Mediana ZMS V (205.4 g kg^{-1}) and Sinskaya, and (204.6 g kg^{-1}), respectively.

As can be seen in Table 2, the results confirmed also a significant relationship between protein content and the portion of leaves in total yield (r = 0.91).

Table 2. Chemical composition (g kg^{-1}) in lucerne cultivars during 2003–2004

Cultivar	Fibre	Proteins	Mineral substances	Oil	NFE
1. NS Mediana ZMS V	346.0	205.4	84.4	15.6	344.8
2. NS Banat ZMS II	350.0	188.1	80.4	15.9	361.4
3. Hyliki	353.5	194.4	81.2	17.0	351.5
4. Cheronia	368.1	188.0	77.1	12.8	351.7
5. Dolichi	354.0	188.5	76.3	11.3	362.5
6. Pella	350.5	190.6	78.2	13.6	360.3
7. Sinskaya	316.0	204.6	88.9	16.8	369.3
8. Bolivija 2000	311.6	202.1	92.3	16.9	373.5
9. Riviera	346.7	196.7	86.5	16.5	351.2
10. UMSS 2001	343,8	199.6	86.5	20.0	348.5
11. Altiplano	337,2	196.9	84.4	17.2	360.7
12. Repaan	348.8	204.4	77.8	19.6	343.6
13. Jõgeva 118	293.9	244.4	79.7	25.5	348.0
14. Karlu	274.3	244.1	84.6	23.0	366.0
15. Juurlu	267.0	250.3	92.7	25.4	356.5
Average	330.8	206.5	83.4	17.8	356.6
LSD 0.05	36.48	11.19	11.87	13.47	24.11
LSD 0.01	49.16	16.04	16.,00	18.16	32.50

The highest yielding cultivars had a lower portion of leaves and crude protein content. This finding confirmed previous ones on the existence of a negative correlation between dry matter yield and quality.

The highest contents of crude cellulose were found in the highest yielding cultivars from Greece, Cheronia and Dolichi, (368 g kg^{-1} and 354g kg^{-1} respectively). Reduced content of crude cellulose is an indication of better quality, i.e. better digestibility (Ray *et al.,* 1999). The lowest contents of crude cellulose were found in *M. varia* cultivars from Estonia. Among *M. sativa* cultivars, the lowest contents of crude cellulose were found in the Bolivian cultivar Bolivia 2000 and in the Ukrainian cultivar Sinskaya.

The content of mineral substances was highest in the cultivars Juurlu, Bolivia 2000, and Sinskaya. The oil content was 17.8 g kg^{-1} on average. It was significantly higher in *M. varia* than in *M. sativa* cultivars. The highest oil contents among the latter cultivars were registered in UMSS 2001 (20 g kg^{-1}) and Repaan (19.6 g kg^{-1}). The only statistically significant differences in oil content are between Dolichi and the Estonian cultivars Jõgeva 118 and Juurlu. The portion of N-free matter indicates the content of sugar in alfalfa. The average N-free content for the experiment was 356.6 g kg^{-1}. The highest contents of N-free matter were registered in *M. sativa* cultivars Bolivia 2000 (373.5 g kg^{-1}) and Sinskaya (369.3 g kg^{-1}). The lowest contents were registered in the Bolivian cultivar Repaan (343.6 g kg^{-1}) and in the domestic cultivar NS Mediana ZMS II (344.8 g kg^{-1}).

The results indicated that the yield and quality of dry matter varied significantly depending on the geographic origin of the cultivar. The domestic and Greek cultivars had high yield of dry matter but their contents of crude protein were below those of the Bolivian cultivars. Improvements in yield capacity and dry matter quality may be achieved by crossing geographically close cultivars (from Serbia and Greece) with exotic germplasm (Bolivian cultivars). *M. varia* cultivars are less adapted to the climatic and soil conditions of Serbia and they produce lower yields of green forage and dry matter than *M. sativa* cultivars. They have better quality (increased portion of leaves in dry matter yield, increased content of crude protein and decreased content of crude cellulose), and they are recommended for use in programs of breeding for improved quality.

Conclusions

Genetic variability of forage and dry matter yield between cultivars is significant. The highest yields of forage and hay were found in cultivars from Serbia (NS Banat ZMS II), and in cultivars from countries with similar environmental conditions (Dolichi, Pella and Hyliki from Greece). When breeding lucerne for higher dry matter yield, promising culivars are the domestic ones and those from Greece and Ukraine, while of the Bolivian cultivars the most promising is UMSS 2001. These cultivars should be used as parents in hybridisation. The highest crop growth rates and the tallest plants were monitored in *M. sativa* cultivars. On the other hand, *M. varia* cultivars from Estonia had a higher crude protein content, higher portion of leaves in dry matter yield and lower content of crude cellulose.

When breeding lucerne for better quality, *M. varia* cultivars, especially Jõgeva 118, can be used as gene donors for better quality in hybridisation with the best Serbian cultivars and those of close geographic origin and environmental conditions (Greece and Ukraine).

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Effect of defoliation management and plant arrangement on yield and N_2 fixation of berseem-annual ryegrass mixture

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Abstract

The research was carried out in a Mediterranean semi-arid environment on berseem clover, annual ryegrass and their mixture to study the effect of defoliation management [date of first cut (FC) 85, 119, 140, 169 days after sowing] and different plant arrangements (sowing the two components in alternate rows or in the same row) on yields, N content, N_2 fixation and N transfer. The experimental design was a split-plot with four replications. The ^{15}N isotope dilution technique was used (8 kg N ha^{-1} as ammonium sulphate at 10 atom% ^{15}N excess) to evaluate the N_2 fixation. Total seasonal DM yield was, on average, significantly higher for FC119 and FC140 (approx. 12.3 t ha^{-1}) than for FC85 and FC169 (approx. 10.6 t ha^{-1}). Plant arrangement did not significantly influence total yield of the mixture. However, the legume yield was higher (+20%; $P<0.0001$) in the same row than in alternate rows arrangement. N content of ryegrass was significantly higher in the mixtures than in pure stand and in the 'same row' plant arrangement than in the 'alternate rows'. Intercropped berseem always had a significant higher % of Ndfa than the monocropped one (on average 74.7% and 57.7% respectively). The apparent transfer of fixed N from berseem to ryegrass was not detected in either plant arrangement.

Keywords: Berseem clover, annual ryegrass, nitrogen fixation

Introduction

The traditional forage systems of semiarid rain-fed Mediterranean areas are based mainly on grazing land (pasture and rangeland) and annual forage crops (vetch, oat and berseem clover in either pure or mixed stands). Many authors consider the annual grass-legume mixture system an effective alternative to pure stands due to several advantages over monocultures. These include improvement in quantity and quality of forage production, improved forage yield stability and seasonal distribution and more efficient use of the resources, which gives a reduction in costly inputs (Carr *et al*., 2004; Fukai and Trenbath, 1993; Mooso and Wedin, 1990; Sengul, 2002). Nitrogen economy and the success of the grass-legume intercrop in low input systems depend on the effectiveness of N_2 fixation and on the current N transfer from legume to the non-legume companion (Jørgensen *et al*., 1999). However, little data is available about the effects of crop management on symbiotic nitrogen fixation by annual forage legumes in Mediterranean environments and on the contribution of their N_2 fixed to the N supply of a non-legume grown in mixture.

The main aim of this study, carried out under field conditions in a semi-arid Mediterranean environment, was to estimate the effect of different defoliation managements on dry matter yield and symbiotic nitrogen fixation by berseem clover in pure stand and in mixture with annual ryegrass and to quantify the N transfer from legume to grass.

Materials and Methods

The research was carried out in 2003/04 at Pietranera farm (Agrigento, Italy; 37°30′N, 13°31′E; 178 m a.s.l.) on a deep, well-structured soil (0.38 clay, 0.25 silt, 0.37 sand; pH in water 8.4; 1.27% organic matter and 0.85‰ total N). The previous crop was wheat. The soil was ploughed at a depth of 25 cm in summer and harrowed in autumn. Before harrowing, all plots received 69 kg P_2O_5 ha^{-1}. The experiment was set up in a split-plot design with 4 replications. Main plots consisted of berseem (*Trifolium alexandrinum* L. cv Lilibeo) in pure stand (B), annual ryegrass (*Lolium multiflorum* Lam subsp. *Wersterwoldicum* cv Elunaria) in pure stand (R) and their mixture arranged either in alternate rows (BR_{AR}) or in the same row (BR_{SR}). Sub-plot treatments were defoliation management: 1) FC85, first cut at 85 days after sowing (DAS), and subsequent cuts at 119, 140, 169 and 198 DAS; 2) FC119 first cut at 119 DAS, and again at 140, 169 and 198 DAS; 3) FC140, first cut at 140 DAS and again at 169 and 198 DAS; 4) FC169, first cut at 169 DAS and again at 198 DAS. Sub-plot size was 4.0 m x 2.6 m (13 rows spaced every 0.2 m, length of row 4 m). Plots were hand-sown on 16 December 2003 using 1300 germinable seeds m^{-2} for pure stands and a 0.5:0.5 ratio for mixed stands. All plots were hand-weeded. The ^{15}N isotope dilution technique was used to estimate nitrogen fixation by clover. ^{15}N fertilizer [$(NH_4)_2SO_4$ at 10 atom% ^{15}N excess] was applied to a microplot (2.88 m^2) in the central area of each plot, following the procedure described by Høgh-Jensen and Schjoerring (1994); the total amount of labelled fertilizer (8 kg N ha^{-1}) was split at crop emergence and after defoliations. On the same dates, the rest of the plot outside the ^{15}N-labelled area received an equal amount of ammonium sulphate.

At each harvest, plants were cut at 5 cm stubble height and the total fresh and dry weights were recorded. A forage sample, from the central area of the microplot (0.80 m^2), was separated into botanical components (B, R), dried to a constant weight at 60 °C, ground to a fine powder (sieved through a 0.1 mm mesh) and analysed by the Iso-Analytical laboratory (EA-IRMS technique) for ^{15}N enrichment and total N content.

Data on ^{15}N enrichment of biomass was used to calculate the percentage of clover nitrogen derived from symbiotic N_2 fixation (%Ndfa) according to Fried and Middleboe (1977). The fraction in the associated grass of atmospherically derived nitrogen transferred from clover (%Ntrans) was calculated using the formula reported by Ta and Faris (1987).

The GLM procedures of the Statistical Analysis System (SAS) were used to analyse the variance (version 8.1, SAS Institute, Cary, NC). The Least Significant Difference (LSD at $P \leq 0.05$) was used to make comparisons among the treatments.

Results and Discussion

Total rainfall during the growing season was higher than normal (690 mm *vs* 550 of the long-period average) and well distributed and resulted in high DM yields.

On average, berseem in pure stand and mixtures yielded about 20% more DM than ryegrass in pure stand ($P<0.01$) (Table 1). The response to defoliation management varied greatly according to the sward type (interaction significant for $P<0.0001$). Total DM yield of ryegrass in pure stand increased as first cut was delayed (and number of defoliations was reduced). On the contrary, berseem increased the total DM production when it was subjected to several defoliations (i.e. bringing forward the date of first cut). However, when the first cut was done very early (T1) the total DM yield was decreased as the crop did not accumulate adequate reserves for prompt regrowth at the first defoliation, and the interval between successive cuts was not sufficient to recover the initial gap. In mixed stands the effect of defoliation management on total DM production resulted intermediate compared to the two pure stands and no significant differences were observed between the two plant arrangements. However, compared to sowing berseem and ryegrass in alternate rows, the legume content on the total DM increased significantly ($P<0.0001$) when sowing the two components in the same row.

In the mixed stands, also the frequency of defoliation had a significant effect on the proportion of the two species. Berseem content on dry matter basis of the harvested herbage showed a trend similar to that observed for the DM yield of the pure stand.

Table 1. Total above-ground dry matter yield (kg ha^{-1}) of berseem clover (B), ryegrass (R) in pure stand and their mixtures ($BR_{(AR)}$ alternate rows; $BR_{(SR)}$ same row) for the defoliation treatments (first cut at 85, 119, 140, 169 DAS)

Defoliation treatment	Dry matter yield (kg ha^{-1})				
	B	$BR_{(AR)}$	$BR_{(SR)}$	R	Mean⁺
FC85	11822	11489 (65.5)§	11607 (77.9)	7692	10653 b
FC119	14180	13310 (86.7)	13826 (89.2)	8365	12420 a
FC140	12739	12417 (70.7)	12893 (84.3)	11026	12269 a
FC169	9394	10383 (38.5)	9829 (63.0)	12413	10505 b
Mean⁺	12034 a	11900 a	12039 a	9874 b	
Interaction	P<0.0001; $LSD_{0.05}$ = 899				

⁺ Mean followed by the same letter are not different at P≤0.05; ‡ ns = not significant
§In brackets the proportion of berseem (%) on total DM production

Berseem content was always higher than that of ryegrass except when the first cut was delayed up to 179 DAS (T4) and plants of both species were arranged in alternate rows. According to Fukai and Trenbath (1993), such results highlight the importance of crop husbandry practices and management on relative competitive abilities and hence on the yields of the component crops.

When first cut was delayed, the mean N content in the above-ground biomass of both pure stands decreased (Table 2). N content of ryegrass was always significantly higher in the mixtures than in pure stand, as observed by several authors studying grass-legume intercrops (e.g. Høgh-Jensen and Schjoerring, 1994; Jørgensen *et al*., 1999). In ryegrass mixed with clover, the 'same row' plant arrangement gave higher N contents compared to the 'alternate rows'. This result was not due to a higher N uptake from the soil (data not shown) but may be related to the lower DM production recorded for ryegrass in 'same row' arrangement.

The stronger competitive ability for N of ryegrass in mixed stand did not affect the N content in berseem and, in fact, no significant differences were observed either between pure and mixed stand or between the two different plant arrangements. The depletion of soil N, due to the ryegrass uptake, forced the legume to increase the N_2 fixation to meet its own needs. In the berseem grown in mixed stand, the amount of N_2 fixation was, on average, significantly higher than in pure stand, and slight differences (but significant at P<0.05) were observed between the plant arrangements (Table 3). For berseem in pure stand, %Ndfa decreased significantly when the first cut was delayed from early March (T1; 66.9%) to late April (T3; 49.7%) and increased again when the first cut was done at the end of May (T4; 58.8%). As well as a delay of the first cut, a progressive reduction of %Ndfa was observed in the mixed stands even though the variations were lower compared to those of pure stand.

Table 2. N concentration (g kg^{-1} DM) of above-ground biomass of berseem clover and annual ryegrass in pure stand and in mixtures (AR alternate rows; SR same row) for the defoliation treatments (first cut at 85, 119, 140, 169 DAS)

Defoliation treatment	Berseem				Ryegrass			
	Pure stand	Mixture		Mean+	Pure stand	Mixture		Mean+
		AR	SR			AR	SR	
FC85	35.4	33.6	32.4	33.8 a	21.3	30.0	32.9	28.1 a
FC119	30.5	29.9	30.2	30.2 b	19.3	32.6	35.9	29.3 a
FC140	28.2	26.7	28.0	27.6 c	16.4	26.0	34.2	25.5 b
FC169	24.8	23.2	22.4	23.5 d	11.6	16.9	23.2	17.3 c
Mean+	29.7	28.4	28.3		17.2c	26.4b	31.6 a	
Interaction	*ns*‡				P=0.0012; $LSD_{0.05}$ = 2.53			

+ Mean followed by the same letter are not different at P≤0.05. ‡ ns = not significant

Table 3. Percentage of N_2 fixation (%Ndfa) in above ground biomass of berseem and atom % ^{15}N excess in above ground biomass of ryegrass in pure stand and in mixtures (AR alternate rows; SR same row) for the defoliation treatments (first cut at 85, 119, 140, 169 DAS)

Defoliation treatment	%Ndfa				Atom % ^{15}N excess			
	Berseem				Ryegrass			
	Pure stand	Mixture		Mean+	Pure stand	Mixture		Mean+
		AR	SR			AR	SR	
FC85	66.9	85.7	82.9	78.5 a	0.1624	0.1979	0.2343	0.1982 b
FC119	55.4	75.9	70.6	67.3 b	0.1330	0.2715	0.3365	0.2470 a
FC140	49.7	74.3	69.6	64.5 b	0.1558	0.1784	0.2383	0.1909 b
FC169	58.8	70.2	68.6	65.9 b	0.1580	0.1581	0.1846	0.1669 b
Mean+	57.7 c	76.5 a	72.9 b		0.1523 c	0.2015 b	0.2484 a	
Interaction	P = 0.0212; $LSD_{0.05}$ = 5.7				P = 0.084; $LSD_{0.05}$ = 0.06061			

+ Mean followed by the same letter are not different at P≤0.05. ‡ ns = not significant

Atom % ^{15}N excess of ryegrass was significantly higher in mixed stands than in pure stand (Table 3). This is not unusual and is probably due to dissimilar N uptake patterns by plants in pure or mixed systems (Danso *et al.*, 1993). On the whole, our data suggests that N transfer from berseem to ryegrass did not occur. Also Peoples and Herridge (1990), in their review, commented that N transfer in annual legume to non-legume may not be a common phenomenon.

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Adaptability of galega (*Galega orientalis* Lam.) in Hokkaido region of Japan

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Abstract

In the Hokkaido region of Japan, the new forage crop galega (*Galega orientalis* Lam.) cv. 'Gale' was investigated for growth characteristics and adaptability under monoculture and mixture cultivation, in comparison with alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.). Galega showed almost the same yielding ability as alfalfa, and it showed very good persistency under quite severe conditions through wintering in Hokkaido. In the case of a pasture mixture of galega and timothy (*Phleum pratense* L.), the botanical composition of the legume was more stable over a six-year period than those of alfalfa and red clover. Galega seeds have been supplied to farmers in Japan since 2002. The recent cultivation area of galega in Hokkaido is about 350ha and it is increasing year on year.

Keywords: adaptability, galega (*Galega orientalis* Lam.), Japan, persistency, rhizome

Introduction

The legume composition in pasture is related to the yield and quality of forage. To maintain the percentage of legumes is very significant for increasing the self-sufficiency of forage. The average botanical composition of legumes is only 10% in the Hokkaido region of Japan. The growth of timothy (*Phleum pratense* L.) which is used in more than 70% of fields in Hokkaido is often suppressed by competition with alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.). On the other hand, these legumes do not have good persistency under the quite severe conditions through the winter in Hokkaido. At present they have not been sufficiently improved by breeding. Therefore it is necessary to find new legume forages with good persistency and compatibility with timothy (Fairey *et al*., 2000).
The legume galega (*Galega orientalis* Lam.) originated in the Caucasus, and was developed in Estonia as new forage (Raig *et al*., 2001). It is a perennial and winter-hardy legumine that can spread widely by rhizomes. Varis (1986) reported that it persisted in pasture fields for seven to fifteen years in temperate condition such as Nordic countries.
The present study was conducted at several sites in the Hokkaido region of Japan to compare the growth characteristics and productivity of galega with the traditional legumes alfalfa and red clover.

Materials and Methods

This study was conducted at four sites in north, east and central Hokkaido with latitude in the range of 43°N to 45°N. The experimental sites in Hokkaido have quite severe conditions in winter as compared to Tallinn (59°N) in Estonia (Table 1). The experimental plots were established by the randomized block method with three replications in June 1999. The materials were 'Gale' galega that was bred by the Estonian Research Institute of Agriculture, and 'Makiwakaba' alfalfa and 'Hokuseki' red clover which were bred for Hokkaido Region of Japan. The seeding rate of each legume in mono culture was 30kg ha^{-1} for galega was at and 15kg ha^{-1} for the other species. In the mixture cultivation with 'Nosappu' timothy which is early heading type, the rate of galega was 30 to 45kg ha^{-1}, alfalfa was 10 to 15kg ha^{-1} and red clover was 3kg ha^{-1} respectively. Timothy seeds were sown at a rate of 10 to 15kg ha^{-1}. The trials in mono cultivation were harvested two or three times per year, adjusting to the early flowering stage of each legume. In mixture cultivation, all treatments followed the harvesting schedule of timothy.

Table 1. Latitude and enviromental conditions of experimental sites

Site	Latitude	Annual precipitation (mm)	Minimum and maximum monthly temperature (°C)			
			Minimum		Maximum	
			January	July	January	July
Kunneppu	43°47'N	810	–15.8	14.1	–3.9	23.1
Nakashibetsu	43°34'N	1225	–13.5	12.6	–2.1	20.7
Hamatonbetsu	45°07'N	1187	–10.4	13.3	–4.1	19.4
Sapporo	43°00'N	957	–11.1	15.2	–1.9	23.6
Tokyo (Japan)	35°41'N	1407	1.0	22.0	9.0	28.0
London (U.K.)	51°09'N	754	0.0	11.0	7.0	22.0
Tallinn (Estonia)	59°23'N	564	–6.0	13.0	–2.0	20.0

Growth characteristics and yielding ability of galega were evaluated compared with the traditional legumes. An assessment of the forage quality of galega was carried out for the plant material of the third year at the Kunneppu site. Samples were prepared at five-day intervals from the end of May to the middle of July, and crude protein (CP), acid detergent fiber (ADF) and natural detergent fiber (NDF) were analyzed by enzyme methods.

Results and Discussion

In the Hokkaido region of Japan, the flowering date of galega at the first cutting stage was 7 to10 days earlier than that of alfalfa and red clover, and it was later than others at the second cutting stage. The degree of leaf diseases and lodging for galega was significantly less at each site. Raig *et al.* (2001) showed the same results in Estonia. However, it is necessary to investigate the details for some diseases continuously, because galega is new forage in Japan (Iwabuchi *et al*., 2004). Although the growth of galega in the first year was less than other legumes, the winter survival was distinctly superior to alfalfa and red clover. Galega was not damaged by physical heaving of roots and snow mould (*Typhula isikariensis* Imai) disease which are caused frequently by severe winter conditions in Hokkaido. Some reports on alfalfa showed that many of the lateral root type variety have good resistance to physical winter damages (Avendano *et al*., 1986). The vigorous rhizomes of galega under the ground might also be effective against physical winter stress. The leaves and stems of galega do not remain above ground before wintering, and this might protect it from the invasion of snow mould disease.

In monocultures of legumes for three years, the dry matter yield of galega tended to be slightly lower than that of alfalfa, and higher than that of red clover (Fig. 1-A). In mixture cultivation with timothy, the total dry matter yield of a mixture of galega and timothy was higher than another combination except at Konsen (Fig. 1-B). The percentage cover of galega continued at about 20% averaged over all sites through the growing season, although the percentages were 73% for alfalfa and 55% for red clover, on average (Fig. 1-C). These results indicate that galega has good compatibility with timothy. This main factor of compatibility in galega might be related to the growing trait of plant height. Fig. 2 shows the changes in plant height after first cutting of galega and alfalfa. The height of galega in the early term after cutting progressed very slowly, compared with that of alfalfa.

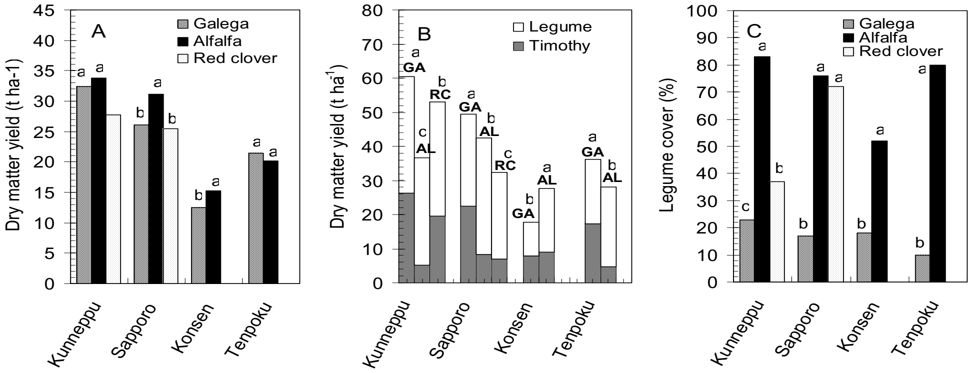

Figure 1. Dry matter yield and legume percentage for three years of three legume species under mono and mixture cultivations in some sites in Hokkaido, Japan. A, C– Mono cultivation of legume, B – Mixture with legume and timothy. a, b, c – Values with different superscripts are significantly different (P<0.05)

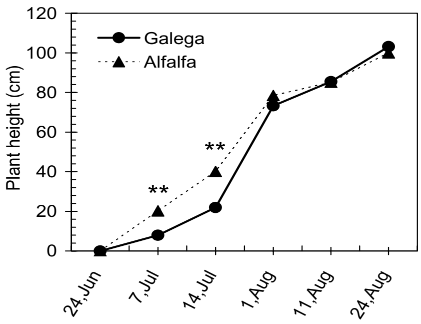

Figure 2. Changes in plant height after first cutting of galega and alfalfa. ** P<0.01

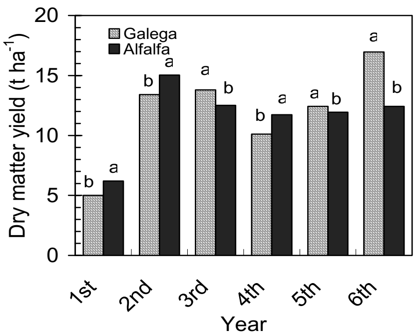

Figure 3. Dry matter yield for six years of two legume species under mono cultivation in Kunneppu. a, b, c – P<0.05

Fig. 3 shows the changes in dry matter yields for six years of galega and alfalfa in monocultures in Kunneppu. Alfalfa showed higher performances in the first, second and fourth years. On the other hand, galega demonstrated excellent yield production in the third, fifth and sixth years. Comparing with an indication of persistency that was calculated as (dry matter yield in 6th year) / (dry matter yield in 2nd year) × 100%, it was estimated at 126% for galega and 83% for alfalfa.

The changes in forage quality of galega and alfalfa are shown in Fig. 4. CP of galega was lower than that of alfalfa before the first flowering stage, but after that it remained at a high percentage relative to alfalfa. ADF and NDF of galega did not change greatly and were stable for a long period, although those of alfalfa increased gradually. Thus, galega is as high quality a leguminous forage, at least, as alfalfa.

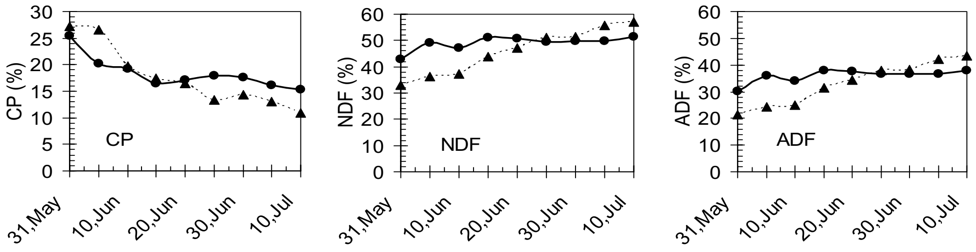

Figure 4. Changes in CP, NDF and ADF percentages of galega and alfalfa up to first cutting. ● – galega, ▲ – alfalfa

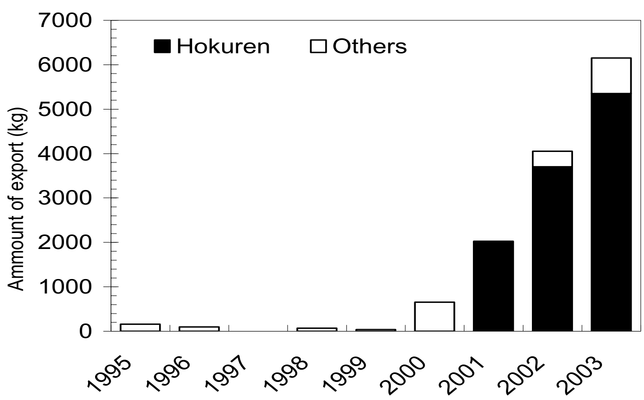

Figure 5. Changes in amount of galega seeds exported from Estonia

Fig. 5 shows the amount of galega seed exported from Estonia from 1995 to 2003. It was very low until 1999, but it increased drastically after 2000. The majority was exported to the Hokuren Federation of Agricultural Cooperatives in the Hokkaido region of Japan. Galega seeds have been supplied to farmers since 2002 in Japan. The recent cultivation area of galega in Hokkaido is about 350ha and it is increasing year on year.

Conclusions

In the Hokkaido region of Japan, the new forage crop galega showed almost the same yielding ability as alfalfa. The winter survival of galega was distinctly superior to alfalfa and red clover. In mixture cultivation with timothy, galega has good compatibility with it. Galega is as high quality a leguminous forage, at least, as alfalfa, for CP, NDF and ADF. Galega seeds have been supplied to farmers since 2002 in Japan, and the cultivation area in Hokkaido is increasing year on year.

Acknowledgements

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Effect of timothy sowing ratio on yield and nutritive value of alfalfa/timothy bi-crops

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Abstract

The experiment aimed at determining the optimal proportion of timothy in an alfalfa mixture, and at investigating respective changes in nutritive value and in protein quality of forage. The experiment was carried out in Juuliku Experimental Farm. Two hybrid alfalfa (*Medicago varia* Mart.) and two high-quality alfalfa (*Medicago sativa* L.) varieties were cultivated in unmixed and mixed sowings with timothy. The yields were measured and herbages' chemical compositions were determined for each cut of monocultures and mixtures from 2000–2003. The dry matter yields of bi-crops were higher than those of monocultures. The increase of timothy's sowing norm was accompanied by plausible decrease of crude protein content in the first cut harvests. The variations in the timothy's sowing norm had no impact on the contents of metabolisable energy in the dry matter yields. The harvests of the alfalfa-timothy mixtures had positive protein balance values (PBV) in the rumen. These values decreased with the increase of timothy's sowing norm. In the harvest of the third cut the PBV was 2-3 times higher than in the previous cuts and the effect of timothy's sowing norm was reduced.

Keywords: dry matter yield, crude protein, metabolisable energy, protein balance value

Introduction

Alfalfa is a forage culture characterised by large yields and high protein content. Alfalfa varieties with greater fall dormancy ('Jõgeva-118', 'Karlu') tend to grow slower after cutting than less dormant varieties ('WL-252HQ', 'WL-326HQ'); considerable growth-rate variability exists within a dormancy group. Alfalfa's maturity has a considerable influence on the quality of harvested forage. Declining quality is associated with marked decreases in the quality of stems while little change occurs in the leaves (Albrecht *et al.,* 1987) The decrease in alfalfa quality associated with advancing maturity is strongly influenced by temperature and is greater in summer than in spring and in autumn (Kalu and Fick, 1983). Whereas it is recommended to grow alfalfa in pure sowings, its mixtures with grasses have provided higher dry matter yields, facilitated preventing lodging, and reduced harvesting losses. The results of feeding the alfalfa-grasses silage were better than those of feeding the silage based on unmixed sowings (Tamm *et al*., 2003). Timothy has been proven to fit into alfalfa mixtures as it is resistant to cover crop, it has low competitiveness in the case of low content in mixture, it is not fastidious to growth conditions, and it develops relatively slowly. The nutritive value and the protein quality of alfalfa differ from those of timothy. Alfalfa has higher protein content and also contains more non-protein substances than timothy. Alfalfa's protein also degrades faster and more completely in rumen and part of the nitrogen released in the process remains unused in formation of microbial protein. Excess ammonia derived from the well-degradable protein increases the carbamide content of milk, which has been impossible to normalise by additional concentrate feeding (Rihma and Kärt, 2000). This effect may manifest when cows are grazed on alfalfa pastures or when alfalfa silage are fed *ad libitum*. Adding timothy to alfalfa mixtures has a potential to mitigate this effect and therefore it became the subject of this study.

Materials and Methods

The experiment aimed at determining the optimal proportion of timothy in mixtures with alfalfa and at investigating respective changes in nutritive value and in protein quality of forage was carried out in Juuliku Experimental Farm on the soddy-calcarous loam soil from 2000–2003. The trial soil was neutral – pH_{KCl} 7.2, humus 3.3%; available phosphorus 81–110; mobile potassium 106–118; magnesium 177–187; boron 1.3–1.6 and copper 3.2–3.4 mg kg^{-1}. The hybrid alfalfa (*Medicago varia* Mart. – 'Jõgeva 118' and 'Karlu') bred in Jõgeva and the high-quality alfalfa varieties (*Medicago sativa* L. 'WL-252HQ' and 'WL-326HQ') imported from the United States were cultivated in unmixed and mixed sowings with timothy (2, 4 or 6 kg ha^{-1}). The hybrid alfalfa varieties were compared with the high-quality alfalfa varieties on the same calendar date. The weather conditions did not favour the growth of alfalfa in springs of 2000 and 2003. The first harvests of the three-mowing utilisation were grown under droughty and cool weather conditions. Dry periods prevailed during the summer of 2002. Plants suffered from drought from mid-August and growth was decreased due to night frost on 21 September in 2002, for that reason the third cut was not carried out. The forage samples were analysed for dry matter (DM), crude protein (CP), crude fibre (CF), crude ash and minerals P, K, Ca. The digestibility of organic matter was determined *in sacco*. Nutritive value of forage – metabolisable energy content (ME), metabolisable protein content (MP) and protein balance value (PBV) – was calculated on the basis of parameters obtained through application of Weende's analysis scheme (Oll and Tölp, 1997; Kärt, *et al.*, 2002). The results of the experiment were analysed by dispersion and by regression methods.

Results and Discussion

The average dry matter yields of bi-crops were higher (by 17.0% and 22.9% respectively in the *Medicago varia* and *Medicago sativa* mixtures) than these of monocultures (Table 1). *Medicago sativa* bi-crops had higher DM yields (in average 10.6% higher) compared with *Medicago varia*. The differences in DM yields occurred in the third cuts. The third cut harvests constituted 8% of the total annual harvests in the case of the hybrid alfalfa varieties, and 19.4% in the case of high-quality alfalfa varieties.

Table 1. Dry matter yields (DM t ha^{-1}) produced with different alfalfa species and timothy's seeding rates

Timothy kg ha^{-1}	2000	2001	2002	2003	Average
Medicago varia					
0	6.20	12.76	6.07	8.71	8.43
2	8.15	15.00	7.67	11.14	10.49
4	8.51	14.72	6.67	9.85	9.94
6	7.27	13.38	6.45	9.54	9.16
Medicago sativa					
0	7.36	13.60	5.69	7.46	8.53
2	10.16	16.12	7.36	11.37	11.26
4	8.91	16.33	6.89	9.99	10.53
6	8.07	14.90	5.81	9.90	9.67
LSD 0.05	0.64	0.75	0.61	0.68	0.69

The harvests of the first cut of the mixed sowings contained 60–90% of alfalfa and 7–37% of timothy. The harvests of the second and third cuts contained 6–20% of timothy. The effect of timothy's sowing ratio on the botanical composition was smaller in the harvest of the second and the third mowing.

The high-quality alfalfa varieties grew from 5–6 days faster than hybrid alfalfa varieties under favourable conditions. In the first cut no plausible difference in the nutritive value was observed between the forages of the different alfalfa species. Whereas the high-quality alfalfa varieties started to grow earlier in spring, they were damaged by night frost and their growth was halted for a week. The CP content of the DM depended on the sowing norm of timothy (Table 2). The increase of the timothy's sowing norm was accompanied by a decrease of the CP content in the first cut ($r = -0.41$, $P<0.05$). The decrease was most extensive in the case of the imported alfalfa and timothy's maximum sowing norm. The influence of timothy was not visible in the forages of the second and third cuts ($r = -0.22$ and $r = -0.17$, $P>0.05$). The CF content was not related to the timothy's sowing norm ($r = 0.19$, $P>0.05$), but to the alfalfa's development differences at the cutting moment. The first and second cuts were carried out in the initial phase of flowering. The CF content of the second cut harvests of the mixed sowings was higher than that of the first cut harvests (281–292 g kg^{-1} for the second cut, see Table 2 for the first cut CF values) due to warmer weather. The second cut harvests of the high-quality alfalfa bi-crops had on average 10 g kg^{-1} higher CF content than the respective harvests of the hybrid alfalfa-timothy mixtures. However, the difference was not plausible.

Table 2. The nutritive value of the first cut of alfalfa forages (average 2000–2003)

Timothy kg ha^{-1}	*Medicago varia*					*Medicago sativa*				
	CP g kg^{-1}	MP g kg^{-1}	CF g kg^{-1}	ME MJ kg^{-1}	PBV g kg^{-1}	CP g kg^{-1}	MP g kg^{-1}	CF g kg^{-1}	ME MJ kg^{-1}	PBV g kg^{1}
0	182	80	251	10.2	35	181	80	240	10.2	39
2	180	82	254	10.1	33	178	82	235	10.2	32
4	162	83	248	10.1	18	163	82	249	10.1	18
6	162	84	254	10.1	14	156	83	257	10.0	8

The DM Ca-content of the hybrid alfalfa was 13.7–20.3 g kg^{-1} and that of the imported alfalfa 15.0–23.0 g kg^{-1}. The increase of the timothy's sowing norm was accompanied by a plausible decrease of the Ca-content in the harvest of the first cut ($r = -0.58$, $P<0.05$). The increase of the timothy's sowing norm had no effect on the P-content (2.6–2.9 g kg^{-1}) and K-content (23.0–25.2 g kg^{-1}). The differences between the P- and K-contents of the hybrid and the high-quality alfalfa varieties were not plausible. The four-year average organic matter digestibility (OMD) was 640–660 g kg^{-1} in the first cut and 610–620 g kg^{-1} in the second cut harvests. It did not depend on the alfalfa species and on timothy's sowing norm ($r = 0.16$, $P>0.05$). The OMD of the third cut harvests ranged from 690–720 g kg^{-1}. The dry matter's ME contents were 9.8–10.2 MJ kg^{-1} in the first cut and 9.3–9.8 MJ kg^{-1} in the second cut. Greater alfalfa development during summer growth periods compared with spring or autumn growth periods might account for the lower forage quality in summer. In addition, changes in cell-wall chemistry associated with higher temperatures also contributed to the lower forage quality in summer (Sanderson and Wedin, 1988). Nutritive values of the third cut harvests were highest 10.9–11.1 MJ kg^{-1} and 10.4–10.6 MJ kg^{-1} in the cases of the hybrid and imported alfalfas, respectively. The variations in the timothy's sowing norm had no impact on the content of ME in DM ($r = 0.13$, $P>0.05$). In the feeding process of ruminants the MP and the protein balance value (PBV) were used for the evaluation of the fodder protein quality. The experimental results showed the first cut MP content of 80–84 g kg^{-1} and that of 77-80 g kg^{-1} in second cut. The third cut resulted in highest MP contents: 85 and 96 g kg^{-1} for the hybrid and imported alfalfas, respectively. The PBV calculated on the basis of experimental data was positive (Table 2). The increase of the timothy's sowing ratio decreased the PBV and it was close to zero in the case of 25–37% proportion of timothy in the harvest of the first cut (1.1 and 0.4 respectively for *Medicago varia* and *Medicago sativa* in 2000, and 7.6 and 1.8 respectively for *Medicago varia* and *Medicago sativa* in 2002). Timothy's share from 25–37% in the alfalfa mixture fodder reduced considerably its PBV value ($r = -0.66$, $P<0.05$). This is explained by timothy′s lower protein content and by lower degradability of proteins in the rumen. Our results indicate that slower morphological development of *Medicago varia* varieties does not account for the higher quality of these varieties.

Conclusions

Sowing the investigated alfalfa varieties in mixtures with timothy increased the dry matter yield and influenced the nutritive value. The presence of timothy had only limited influence on the nutritive value on the forages of mixed sowings. This was due to the different development phases of legumes and grasses, and the slow development of timothy's aftergrass. The most visible changes of the nutritive value occurred in the harvests of the first cut. Adding timothy (2, 4, 6 kg ha^{-1}) to the pure alfalfa sowings reduced the protein contents of harvests, especially in first cut. The changes in the CF content did not depend on the timothy's sowing norm. The differences between the cuts' CF content and OMD were caused by the development differences of plants. The Ca-content were higher in the case of the *Medicago sativa* varieties. The increase of timothy's sowing norm reduced the Ca-content in the first cut. Simultaneously, the P- and K-contents did not change. The harvests of alfalfa-timothy mixtures had positive PBV values in the rumen. The significant degrease of the PBV was observed at timothy's sowing norms of 4 kg ha^{-1} and higher. The PBV of the harvest of the third cut was 2–3 times that of previous cuts and the effect of timothy's sowing ratio was absent.

Acknowledgments

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Formation of yielding ability and cold resistance of three red clover and alfalfa cultivars

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Abstract

The goal of this study was to investigate cold tolerance, morphological characteristics and productivity of alfalfa and red clover varieties, that differed in hardiness.. The following varieties of red clover Ilte, Mars, Barfolia and of alfalfa Karlu, WL 324 and Medina were used. Seeding year yielding ability was connected foremost with genetic qualities. The highest partial DM yield (cv. Mars-4.49 and WL 324-3.22 t ha^{-1}) was obtained in the medium winter-hardiness varieties. Differences (P<0.001) in total DM yield between cv. Ilte and other red clovers are caused by there heading types. In harvest year yielding ability of red clover and alfalfa increased up to 2.8 times and differences between varieties enlarged. After favourable over-wintering, the highest partial DM yield (10.46–10.60 t ha^{-1}) was obtained in cv. Mars and WL 324 sward. Heavy winter damage resulted in degradation and diminishing yielding ability of cv. Medina.

The most sensitive to cold were Barfolia red clover and Medina alfalfa (LT_{50} = –9.8 and –8.5 ºC, respectively in 2003 and –8.8 ºC in alfalfa in 2004). In the harvest year, red clover was infected by root rot. That additional biotic factor caused a large dispersion of LT_{50} data.

Growing ability of the surviving plants (after freezing) was rather different and connected with freezing temperature. However, morphological features are important as well. There was a correlation between the diameter of taproot and regrowth (P<0.05 in red clover and P<0.001 in alfalfa).

Keywords: red clover, alfalfa, low temperatures, taproot diameter, DM yield

Introduction

The main limitation in plant growth, productivity and distribution is winter injury in the colder climates of northerly areas. Cold and dry winters and fluctuation of temperatures in autumn and spring characterize unstable climate in Estonia. Legumes developing in such climate are periodically subjected to a combination of stresses. Several factors that are related to weather, soil or legumes management may contribute to cold tolerance.

Minimum and maximum air temperatures during winter strongly influence the development of cold hardiness of red clover (Sunde, Skelvag, 1996). Northern ecotypes of red clover have a greater response to photoperiod compared with southern types, especially at lower temperatures (Lunnan, 1989). Longer photoperiod gave higher DM yields for red clover and therefore northern types would be more responsive to this factor (Pulli, 1988). Aim of this work was to study cold tolerance, morphological characteristics and productivity on alfalfa and red clover varieties that differed in hardiness and genetic qualities.

Materials and Methods

The field experiment with different winter hardiness, pure seeded red clover and alfalfa varieties (cv. Ilte, Mars, Barfolia and cv. Karlu, WL 324, Medina, respectively) was established at Experimental Station of Estonian Agricultural University (58º21´N, 26º40´E) in 2003. Randomized block design, in four replications, was used on Albeluvisols (WRB classification) soil (pH_{KCl} 6.2, content of available phosphorous and potassium were 164 and 208 mg kg^{-1}, respectively). The alfalfa seeds were inoculated with *Rhizobium meliloti* and both forages were broadcast at seed rates of 15 kg ha^{-1} on 21 May 2003. The yield was harvested twice in sowing year and three times in productive year at 8–10 cm height of cutting. Before each harvest the subsamples were taken for botanical analysis. Red clover or alfalfa, grasses and herbs were separated, dried and weighted. DM content of samples was determined by oven drying at 105 ºC for 6 h during each cut. According to herbage yield, DM content and botanical composition, the partial DM yield of red clover or alfalfa was calculated.

Cold tolerance of alfalfa and red clover were determined in lab using plants dug from the field at the end of October. The plants were washed with cold water to remove excess soil. Roots and shoots of the plants were clipped to length of 8 cm below and 4 cm above the crown and the diameter of the taproot at the crown-root juncture was measured in two positions. Six-plant bundles (14 plants in bundles) of each entry were placed into boxes (one box for each temperature level), filled with vermiculite and placed in controlled freezing chamber. The plants were tested between –2 to –16 ºC, lowered at a rate of 4 ºC h^{-1}, whereby desired temperature held constant for 1 h. At the end of each temperature plateau, boxes were removed from the freezer and thawed at +2 ºC for 24 h. After thawing, the plants were transplanted into fertilized neutralised peat substrate at +24 ºC light temperature and +19 ºC dark temperature for 2 weeks. Cold injury was estimated visually according to 1–6 point-system (1 = undamaged plant, 6 = dead plant) and shoot regrowth of each plant was weighted.

The data was analysed by programme STATISTICA 7 (www.statsoft.com) using linear regression analysis; ANOVA, followed by Turkey HSD test, at that the input data was checked by normal distribution.

Results and discussion

Yielding ability

The results of the field experiment indicated that DM yield of red clover and alfalfa depends on many factors. Seeding year yielding ability was connected foremost on genetic qualities, which expressed in different developmental rhythms. Local varieties developed slower and stopped growth earlier in autumn than that of introduced varieties. The highest partial DM yield (cv. Mars-4.49 and WL 324-3.22 t ha^{-1}) was obtained in growing of medium winter-hardiness varieties (Table 1).

Winter-sensitive varieties have usually higher yielding in the sowing year than the more winter-hardy (Huarte & Arnold, 2002). Results of previous investigations with alfalfa indicated prostrate branching or rosette-like growing type of regrowth in hardy varieties connected with slower regrowth after cutting (McKenzie *et al*., 1988). Hardy cv. Karlu is a vegetative spreading type and its shoot formation starts predominantly from the crown, while in case of others varieties they form from the stubble buds (Bender, *et al*., 2000). Differences ($P<0.001$) in DM yield between cv. Ilte and other red clovers are caused by their heading types. Late heading types of red clover (like cv. Ilte) achieve lower rates of photosynthesis and dark respiration than early flowering type (like cv. Mars and Barfolia; Frame *et al*., 1989), that resulted in lower productivity. However, in growing of winter-sensitive alfalfa cv. Medina was observed depletion of partial DM yield, obviously as a result of higher requirement for radiation. Next year yielding ability of red clover and alfalfa increased up to 2.8 times and differences between varieties enlarged. After over-wintering, the highest partial DM yield (10.46–10.60 t ha^{-1}) was obtained in cv. Mars and WL 324 sward. Heavy winter damages resulted degradation and diminishing yielding ability of alfalfa cv. Medina. Thereby winter-sensitive Barfolia of red clovers had ability to increase yield, despite of low population, by quicker regrowth, its yielding ability restored during the growing period (data not shown).

Table 1.Yield ability and winter-hardiness on varieties of red clover and alfalfa

Variety	Partial DM yield, t ha^{-1}	LT_{50}, ºC	Partial DM yield, t ha^{-1}	LT_{50}, ºC
	Sowing year – 2003		1st productive year – 2004	
		Red clover		
Ilte	3.12	–11.7	8.36	–9.6
Mars	4.49	–12.0	10.46	–13.0
Barfolia	3.98	–9.8	9.56	–12.4
P	<0.001***	<0.01**	<0.01**	X
LSD_{05}	0.31	1.30	0.72	X
		Alfalfa		
Karlu	2.33	–13.00	7.80	–10.6
WL 324	3.22	–11.00	10.60	–11.3
Medina	2.81	–8.50	5.32	–8.8
P	<0.001***	<0.001***	<0,01**	P >0.05; ns
LSD_{05}	0.13	0.20	1.38	1.13
*P<0.05	**P<0.01	***P<0.001	P>0.05; ns-non-significant	

X-the plants were infected by root rot.

Cold resistance

According to expectations cold resistance depended on variety characteristics. The most sensitive to cold were red clover cv. Barfolia and alfalfa cv. Medina (LT_{50} = –9.8 and –8.5 ºC, respectively in 2003 and –8.8 ºC in alfalfa in 2004). The difference between medium winter-hardy and winter-hardy varieties were comparatively small and in most of cases non-significant. In the second year (2004), red clover was infected by root rot. The infection was spread strongly in roots of local cv. Ilte. That additional biotic factor had a strong impact on cold resistance, which caused a large divergence of LT_{50} data.

Growing ability of survived plants (after freezing) was rather different and connected with freezing temperature. However, morphological features are important as well. The widest crown (11.23±0.02 mm; $F (2; 219) = 10.05$; $P<0.001$) and the highest regrowth had red clover cv. Barfolia (estimated after freezing; $P<0.05$; Figure 1).

In case of alfalfa no differences between taproot diameter and variety were found (Karlu-5.20 mm, WL 324-5.27 mm, Medina-5.60 mm). Whereby differences ($F (2; 181) = 5.54$; $P<0.05$) in regrowth were significant between Karlu (0.26±0.02 g $plant^{-1}$) and WL 324 (0.50±0.06 g $plant^{-1}$). There was found correlation between diameter of taproot and regrowth ($r = 0.38$; $N = 222$; $P<0.05$ in red clover and $r = 0.49$; $N = 184$; $P<0.001$ in alfalfa). Greater shoot regrowth have been occurred for plants with high levels of root N, whereby taproot protein concentrations increase during hardening (Li *et al.,* 1996), independent of taproot TNC (total non-structural carbohydrate) concentrations (Volenec *et al*., 1996).

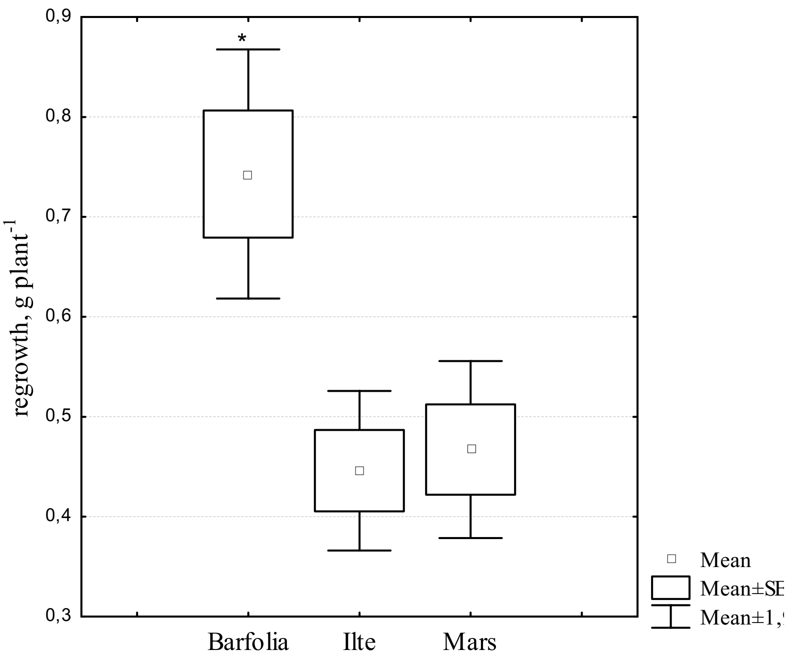

Figure 1. The regrowth (after freezing process) on different varieties of red clover. Means followed by the mark (*) is significantly different (P<0.05)

Conclusions

The highest partial DM yield in the sowing year was obtained in growing of medium winter-hardiness varieties. Differences in DM yield between cv. Ilte and other red clovers were caused by their heading types and different developmental rhythms. In harvest year yielding ability of red clover and alfalfa increased up to 2.8 times and differences between varieties enlarged. The highest partial DM yield was obtained in cv. Mars and WL 324 sward. Heavy winter damages resulted degradation and diminishing yielding ability of cv. Medina.
The most sensitive to cold were Barfolia red clover and Medina alfalfa in the sowing year. Next year (2004) was red clover infected by root rot. The infection was spread strongly in roots of local cv. Ilte. That additional biotic factor had a strong impact on cold resistance. The morphological features were important as well. The widest crown and the highest regrowth had red clover cv. Barfolia. In case of alfalfa no differences between taproot diameter and variety were found.

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Growing corn as an extra energy crop in grassland based forage systems in Latvia

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Abstract

The aim of this study was to demonstrate the potential of a range of corn hybrids (*Zea mays* L.) for making energy dense silage in Latvian conditions, which are marginal for corn growing. Field trials were carried out at the Research and Study Farm 'Vecauce' (latitude: N 56° 28′, longitude: E 22° 53′) from 2002 to 2004. Altogether 33 different corn hybrids according to their earliness bred in the Ukraine were evaluated. Two hybrids bred in Germany ('Loft', 'Anna') were used as checks. Hybrids were grouped according to earliness and characterised by FAO number from 140 to 350. Year effects on results were substantial hence demonstrating that the main factor in Latvian conditions determining good results is temperature (2002 – the best suited year; average DM yield – 16.0 t ha^{-1} with a high density of corn-cobs – 510 g kg^{-1}; 2004 – the worst results due to a cool season – DM yield 8.77 t ha^{-1}, corn-cob density 315 g kg^{-1}). Lack of precipitation could affect quality of forage substantially in very few years (2003; average DM yield – 14.03 t ha^{-1} with the density of corn-cobs only 337 g kg^{-1}), too. Effect of hybrid earliness was more important in unfavourable years. To avoid poor harvests in such years one should recommend specific hybrids for use in Latvian conditions. Despite some difficulties, especially in cool seasons for bulk yield, we can sustain recommendation to grow corn in Latvia for energy dense silage making.

Keywords: corn, hybrid, earliness, yield, quality, meteorological conditions

Introduction

Corn or maize (Zea mays L.) provides forage that complements rations based on legumes and grasses (which provide higher crude protein (CP) concentrations) with relatively higher net energy. Compared to other forages, corn has a relatively high fibre concentration, as measured by neutral or acid detergent fibre (NDF and ADF, respectively), but low lignin concentrations (Coors, 1994). At the same time corn contributes to overall farming systems because it fits well into a wide range of crop rotations (Wilkins and Kirilov, 2003). Corn silage is a popular fodder not only for its high energy density, but also because it requires less intensive harvest management, if compared with legumes and grasses, as corn for silage is harvested only once yearly. The bulk of the corn is produced between latitudes 30° and 55°, with relatively little grown at latitudes higher than 47° anywhere in the world. Latvia is located between the North latitudes 55° and 58°. Breeding has produced new hybrids exhibiting much improved yields, cold tolerance, lodging and pest resistance and early maturing, so that it is now possible to grow corn in areas previously classed as unsuitable. During the last decade early maturity corn hybrids from different parts of the world became available for researchers, and many of them already for farmers use, too, in Latvia. Since Latvia geographically could not be included in traditional corn growing areas, a suitable corn hybrid has to be high in early vigour, cold tolerant in spring, and early enough to reach at least dough stage of maturity (dry matter (DM) content 250 g kg^{-1}) (Gaile, 2000), even if growing conditions are not good during all the vegetative season. Corn-cob content in the whole plant DM yield should be 400 to 600 g kg^{-1}. These are not easily achievable aims every year in Latvia. Proper hybrid selection is very important in any corn growing strategy. There is very little published information on the performance of modern, early maturing corn hybrids in Latvia and very few publications on corn quality taking into account individuality of season. The work reported here was designed to provide such data.

Materials and Methods

Field trials were conducted at the Research and Study farm 'Vecauce' of Latvia University of Agriculture (latitude: N 56° 28′, longitude: E 22° 53′) in 2002–2004. Altogether 33 different corn hybrids according to their earliness bred in Ukraine were tested. Two hybrids bred in Germany ('Loft', 'Anna') were used as checks. Hybrids, according to earliness, were included in groups characterised by FAO number from 140 to 350. Original seed was used. Trials were arranged in four replicate randomised blocks with plot size 16.8 m^2. Yield was measured from 8.4 m^2. Row width was 0.7 m. Planted population density was 82000 plants per ha to achieve a plant density at harvest of 60000 up to 80000 plants per ha. Soil was sod podzolic loam with plant available P 198–253 mg kg^{-1} of soil; plant available K 198–224 mg kg^{-1} of soil; pH_{KCl} = 6.3 – 7.1, humus content 15–31 g kg^{-1}. The previous crop was spring barley. Traditional soil tillage was used: mould-board ploughing in the previous fall, cultivation and rototilling before sowing in spring. Fertilisers: 34 kg ha^{-1} P, 75 kg ha^{-1} K and 148 kg ha^{-1} N (18+70+60). Planting was carried out by hand handled planter at 3–4 cm depth. Corn was planted appropriately early for each specific year: on May 6, 2002, May 13, 2003 and May 12, 2004. Weeds were controlled by spraying herbicides (metil-primisulfuron 0.04 kg ha^{-1}+ dikamba 0.1 l ha^{-1}) and mechanically. Harvesting was done on September 19, 2002, September 25, 2003 and October 6, 2004. The following observations were carried out: entering of phenological phases – germination and flowering (tasseling and silking), stand density before harvest in plants per ha, plant height (PH) before harvesting, (m), green and dry matter (DM) yield, t ha^{-1}. The following quality analyses for every hybrid were carried out using standard methods: content of DM of whole plant and corn-cobs, (%). Only for 4 to 6 hybrids quality was analysed in more detail to include: CP, NDF and ADF, in g kg^{-1} of DM, ash, Ca, P, in g kg^{-1} of DM (data are not presented). Three plants were taken randomly for each sample at the time of harvesting. Some parameters were calculated in addition: digestible dry matter DDM g kg^{-1} = 889 – (0.779 × ADF); net energy for lactation NEL MJ kg^{-1} of DM = (0.00245 × DDM – 0.12) × 4.184; DMI g kg^{-1} of cow body weight = 12000/NDF.

Meteorological conditions were variable across years, and the main indices, average daily temperature and precipitation, are characterized in Table 1.

Table 1. Temperature and precipitation compared with meteorological norm during 2002–2004

Month	Average daily air temperature, °C				Precipitation, mm			
	2002	2003	2004	Norm	2002	2003	2004	Norm
May	14.5	12.0	10.2	11.2	16	16	43	43
June	15.8	14.3	13.3	15.1	100	49	118	51
July	18.8	19.7	15.8	16.6	174	44	116	75
August	19.5	16.1	17.3	16.0	0	115	69	75
September	12.2	11.9	12.3	11.5	35	36	82	59

Spring frost after corn emergence occurred only in 2002 (min –2.1 °C), the corn was damaged, but not frost-bitten. Fall frosts before corn harvesting were not observed. Each year had a distinct weather pattern. In summary the best year for corn growing was 2002, following by 2003, and the worst year was 2004. Results were statistically analysed using ANOVA procedures, correlation and regression analyses.

Results and Discussion

On average during 3 experimental years quite high DM yields of corn were obtained –12.24 t ha^{-1} and average DM content was 251.19 g kg^{-1} that covers least demand. Yield of corn hybrids as well as quality was strongly affected by year and hybrid ($p<0.05$) (Table 2). The best average dry matter (DM) yield per ha was obtained in 2002 when the latest maturity hybrid (EURO 401CB, characterising with FAO 380) gave the best DM yield and quite appropriate quality (Table 2). The worst DM yield, and with poor quality was obtained in 2004. Comparing together all the experiments with corn since 1994 in Vecauce (Gaile, 2000; Gaile, 2004) 2004 was the worst year for corn growing with extremely low air temperature during nearly the whole season.

Table 2. Corn DM yield, DM content of whole plant at harvesting and density of corn-cobs in DM yield depending on hybrid and year, 2002–2004

Hybrid	FAO num.	DM yield, t ha^{-1}			DM content, g kg^{-1}			Corn-cobs density in DM yield, g kg^{-1}		
		2002 n=11	2003 n= 17	2004 n=21	2002 n=11	2003 n= 17	2004 n=21	2002 n=11	2003 n= 17	2004 n=21
Loft – check	170	16.04	13.46	x	381.4	294.7	x	549	321	x
Anna – check	210	x	13.51	8.03	x	306.9	214.6	x	368	480
Mais – 125	140	x	13.65	7.39	x	269.1	192.5	x	284	430
Mais – 140	150	12.08	11.40	6.84	392.6	300.9	231.7	639	456	490
Mais 199	200	x	14.18	8.58	x	246.8	197.2	x	404	350
Dneprovskij 228 MB	220	16.53	13.24	8.32	405.1	259.8	208.0	546	250	370
Souz	320	x	x	8.19	x	x	143.1	x	x	241
Euro 401 CB	380	19.28	14.09	x	301.6	216.4	x	348	207	x
Average per trial	x	16.08	14.03	8.77	351.9	257.9	193.0	510	337	315
Min	x	12.08	11.40	4.68	301.6	216.4	143.1	348	207	90
Max		19.28	16.90	12.82	416.2	306.9	228.3	639	456	490
$LSD_{0.05}$	x	2.46	1.41	1.77	x	x	x	84	126	61

Substantial positive correlation was found over the three year period between plant height (PH) and DM yield and between the plant density before harvest and DM yield (Fig. 1).

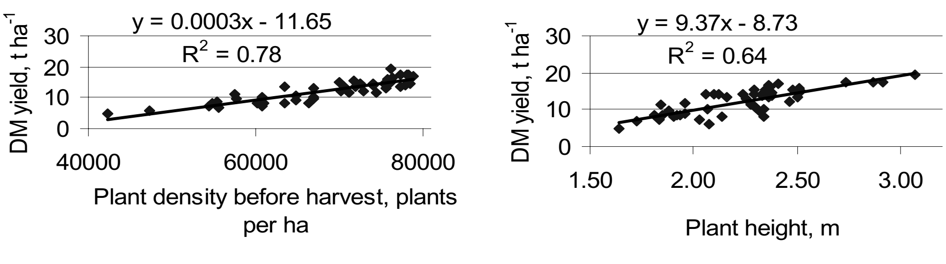

Figure 1. Correlation between DM yield and plant density before harvest and plant height before harvest ($p<0.01$)

PH was generally greater for later maturity hybrids and in warmer years. PH in our experiment was on average 2.59 m, 2.25 m and 2.04 m in 2002 to 2004, respectively. Advised plant density at harvest for good DM yield in Latvia is from 60000 to 80000 plants per ha. Although, the minimum was exceeded in all the years (in average 76247, 73232, 60119 plants per ha in 2002, 2003, 2004, respectively) still the plant density cut side to other factors in the worst year (2004) affected yield significantly.

For years, the first criteria of good nutritional value of corn hybrids for silage was equated with their grain content and dry matter content at harvest (Darby and Lauer, 2002) (Table 2). On average during the 3 years density of corn-cobs in the whole plant DM yield was 364. 41 g ka^{-1}, that is below the required minimum – 400 g kg^{-1} in Latvia. In Latvian conditions the main problems could arise due to very cool growing season (2004; looking back until 1994, cool, but not so were 2000 and 1998, too), inappropriate hybrid selection or incorrect growing manner, including planting and harvesting dates (Gaile, 2004). 2003 was the only year when quality was diminished by the lack of moisture mainly during the silking that caused decrease of grain set. Higher DM content at harvest and corn-cob density in the yield leads to higher quality, including energy density of forage (Table 3). A decline in fibre concentration with increasing maturity can be attributed to the dilution effect created by increasing content of grain as corn matures (Coors, 1994).

Table 3. Average quality of some corn hybrids in research years, 2002–2004

Year	Content of DM, %	Average quality indices on the basis of the DM					
		CP g kg^{-1}	NDF g kg^{-1}	ADF g kg^{-1}	NEL MJ kg^{-1}	DDM g kg^{-1}	DMI g kg^{-1*}
2002 (n=4)	360.73	72.45	445.10	250.25	6.61	694.06	27.22
2003 (n=5)	267.78	75.40	530.82	289.30	6.30	663.64	22.64
2004 (n=6)	195.75	82.90	530.10	307.72	6.15	649.29	22.66

*g onto 1 kg^{-1} of cow body weight

Corn does not contain enough CP for animal needs. Corn, if it has reached at least the stage of soft dough (DM content at least 250 g kg^{-1}), could be energy source very well utilised together with grasses rich in CP. Darby and Lauer (2002) reported CP concentration in corn 72–138 g kg^{-1}, but our results show range from 72.45 to 82.90 g kg^{-1} (Table 3).

Conclusions

Generally, our experiments with Ukrainian corn hybrids certify possibility to grow corn for energetically dense silage making in Latvian conditions despite of several cool seasons. Certainly, proper hybrid selection is very important and results of research maintain previous recommendation to choose for growing hybrids characterised with FAO number not higher than 220 as quality is highly important. If the season is warmer later maturity hybrids show the best performance and in addition – good quality (2002). If the area is cool – one should choose an earlier maturing hybrid for good performance and satisfactory quality (2004).

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Variability of agronomic characteristics in eight lucerne (*Medicago sativa* L.) genotypes

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Abstract

A trial, including eight lucerne genotypes selected from hybrid populations, was conducted between 2001 and 2003 at the Experiment Field in Mačkovac. The greatest plant height was found in genotype 11 (75.5 cm), while the greatest number of tillers per plant was found in genotype 12 (55.3). Genotype 8 had the smallest plant height (57.0 cm) and also the smallest number of tillers per plant (36.5). The greatest number of lateral branches per plant was in genotype 9 (12.7), while the least was in genotypes 10 and 13 (11.1). The greatest leaflet length was found in genotype 8 (26.1 mm), while the smallest was found in genotype 13 (20.5 mm). Leaflet width was the greatest in genotype 14 (9.4 mm) and the smallest in genotype 10 (7.8 mm). The largest plant mass was in genotype 11 (277.66 g), while the smallest plant mass was in genotype 13 (180.91 g). Wide genetic variability of agronomic traits in eight lucerne cultivars provides a good basis for the creation of new cultivars with great potential for high and quality yields of forage and hay.

Keywords: agronomic characteristics, genotype, lucerne, variability

Introduction

With a growing area of about 30,000,000 ha worldwide (Michaud *et al.*, 1988) and 210,000 ha in Serbia and Montenegro (Đukić, 2002), lucerne (*Medicago sativa* L.) is one of the most important forage crops, cultivated mainly for green forage, hay, silage, haylage and for drying (Vučković, 1999).

One of the basic goals of modern lucerne breeding programmes is the development of new cultivars that have a great potential for highquality and stable yields of both forage and hay (Riday and Brummer, 2002). Moreover, such cultivars need to be tolerant to prevailing diseases and nematodes, resistant to lodging and must have a good ability for utilisation in associations with grasses (Đukić, 1995). In that way, they will be able to respond to the increased needs of animal husbandry, as well as to play a significant role in diverse environmental conditions and farming systems (Lukić, 2000). In order to achieve this, remarkable progress has been made recently towards deeper understanding of relations between forage production and single agronomic characteristics (Huyghe and Julier, 2003).

The aim of our trial was to determine genetic variability of agronomic characteristics in eight lucerne genotypes, as well as to evaluate their breeding potential as gene donors in the development of new lucerne cultivars.

Materials and Methods

A trial with variability of agronomic characteristics in lucerne was conducted between 2001 and 2003 at the Forage Crops Centre Experiment Field in Mačkovac. It included eight different experimental lucerne genotypes selected from various hybrid populations. The genotypes were sown in early April 2001, with every genotype in a separate row and with 60 cm between rows and 60 cm between plants of one genotype. Samples of twenty plants of each genotype for the analysis of agronomic characteristics were taken at the beginning of flowering of each cutting (Bošnjak and Stjepanović, 1987), eleven times during three years, with three cuttings in 2001 and four cuttings in 2002 and 2003.

Since many morphological traits often represent yield components, we monitored plant height (cm), number of tillers per plant, number of lateral branches per plant, length of middle leaflet (mm), width of middle leaflet (mm) and plant mass (g).

The results were processed by the analysis of variance with the LSD test applied.

Results and Discussion

As one of the most important components of yield of green forage (Katić *et al.*, 1998), the average plant height ranged between 57.0 cm in genotype 8 and 75.5 cm in genotype 11 (Table 1). There were significant differences in plant height among all examined genotypes as in the research undertaken by Milić *et al.* (2004), with a lower value of coefficient of variation than was reported by Radović *et al.* (2003).

A characteristic in high correlation with green forage yield, not only in lucerne (Lugić *et al.*, 2001), the number of tillers per plant varied from 36.5 in genotype 8 to 55.3 in genotype 12 and was at the upper limit of the species' average (Erić *et al*., 1996).

Table 1. The average plant height, number of tillers per plant, number of lateral branches per plant, length of middle leaflet and width of middle leaflet of eight lucerne genotypes during 2001–2003

Genotype	Plant height (cm)	Number of tillers per plant	Number of lateral branches per plant	Length of middle leaflet (mm)	Width of middle leaflet (mm)
8	57.0	36.5	11.3	26.1	8.5
9	68.6	49.8	12.7	24.7	8.2
10	74.5	46.0	11.1	24.8	7.8
11	75.5	48.5	12.1	24.1	8.7
12	70.4	55.3	12.2	22.4	8.7
13	62.9	52.9	11.1	20.5	8.0
14	65.3	41.2	12.1	21.1	9.4
15	73.9	55.2	11.7	22.7	8.6
$LSD_{0.05}$	3.2	3.8	0.7	1.6	1.0
$LSD_{0.01}$	4.2	5.0	0.9	2.1	1.4
CV (%)	6.67	15.17	8.95	8.85	15.39

The number of lateral branches per plant ranged between 11.1 in genotypes 10 and 13 and 12.7 in genotype 9, and was rather lower than found by Radović *et al.* (1996).

The greatest average length of middle leaflet was found in genotype 8 (26.1 mm), while the smallest was found in genotype 13 (20.5mm), in agreement with Ivanov (1980). Genotype 14 had the widest middle leaflets (9.4mm), while genotype 10 had the narrowest middle leaflets (7.8mm).

Plant mass is a resultant of all yield components and together with number of plants per area unit is directly responsible for yield of green matter and hay. The largest average plant mass was measured in genotype 11 (278 g), while the smallest plant mass was measured in genotype 13 (181 g). As related to the average values of cuttings during all three years, it varied from 86.72 g in genotype 8 in the fourth cutting to 306.13 g in genotype 9 in the second cutting (Table 2), similar to the results obtained by Ivanov (1980). There were significant differences in plant mass between eight examined lucerne genotypes. The plant mass of all genotypes was greatest in the second cutting, except for genotype 14 (largest plant mass in the third cutting) and genotype 15 (largest plant mass in the first cutting). The smallest plant masses of all genotypes were in the fourth cutting.

Table 2. The average plant mass (g) of eight lucerne genotypes during 2001–2003 as related to cuttings

Genotype	Cutting				
	I	II	III	IV	Mean
8	183	204	163	87	184
9	254	306	215	116	265
10	253	265	191	138	260
11	276	289	209	162	278
12	241	261	194	142	242
13	193	184	137	104	181
14	164	166	180	103	193
15	283	254	228	143	272
$LSD_{0.05}$	32.30				
$LSD_{0.01}$	42.66				
CV (%)	21.20				

Conclusions

Significant differences in agronomic characteristics between eight examined lucerne genotypes indicate the existence of wide genetic variability. Cultivars with optimal relationship between yield components and good distribution of yield of both green forage and hay as related to cuttings can be successfully used as donors of genes for desirable traits in future breeding work. This should lead to the creation of new cultivars with a high adaptability to the prevailing environmental conditions and high and quality yields of forage and hay.

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Increasing the diversity of forage crop communities

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Abstract

We are trying to verify the possibility of increasing the diversity of forage crop communities by including new wild species of the family *Fabaceae*. Our aim is to collect seeds of wild species, to test possibilities for their cultivation, their seed production and also to test their characteristics in sown multi-component communities. The results of observing growth phases, seed characteristics, resistance to pathogens and persistence of the species in mixed swards are presented in this paper.

Keywords: *Fabaceae*, forage crops, wild species, biodiversity, agronomic characteristics

Introduction

Forage crops from the family Fabaceae are very important in agriculture and in landscape diversity. Agroecosystems with judicious representation of perennial forage crops are stable in their biomass production and the crops provide multi-harvests during the vegetation period. They help biodiversity in the landscape and are important natural filters e.g. for water purification. They also have anti-erosion functions in ecosystems, especially in undulating landscapes.

Modern plant breeding requires searching for the new donors of important characters among wild plant species. For example, in the USA and in Canada Astragalus cicer was introduced into cultivation (Townsend, 1990).

In the Research Institute for Fodder Crops, Ltd. in Troubsko in last 15 years a major effort has been dedicated to collecting wild species from several families including Fabaceae. The assembling of these species was done by individual collecting or by expeditions in the Czech Republic (Zapletalová and Pelikán, 2001) and abroad (Nedělník *et al*., 2003). Some important species have been studied and described in detail (Gottwaldová *et al*., 2003, Vymyslický *et al*., 2003).

Materials and Methods

In the year 2003 twenty-six species of the family *Fabaceae* were selected for field trials (see Table 1). After determining the germination, purity and weight of a thousand seeds, sowing rates were calculated. As control species *Medicago sativa* and *Trifolium pratense* were used. The field trials were established in 2004. In the first year growth phases of each species were evaluated and seeds were collected if possible. During the vegetation period the health state of growths and any infestation of pests were evaluated.

Parallel field trials with a standard grass mixture were established, and into the mixture 50 seeds of 21 species of the family *Fabaceae* were added (see Table 2). During the year the persistence of the studied species was evaluated.

For the characteristics beginning of flowering, full flowering, start of podding and ripening of pods, the number of days was counted from the date of a cleaning cut except for the annual species, where the number of days was counted from their germination in the field (there being no weed cleaning cut).

During the germination the infestation of weevils (*Sitona* spp.) was studied at several places in the 5m^2 plots. The first evaluation was done at the beginning of May. On the species that germinated later, another evaluation was done on 25th May. Evaluated plants were divided into 4 groups according to their loss of leaf area: 1 – no infestation, 2 – loss from 0 to 20%, 3 – loss from 20 to 50% and 4 – loss from 50 to 100%.

Results

The results of observation of growths of individual species are presented in Table 1. The fastest germination occurred with species *Medicago sativa, Trifolium pratense*, *Vicia tenuifolia* and *Trifolium medium*. The first genuine leaflet appeared first in *Vicia cracca* and *Lathyrus tuberosus*.

The beginning of flowering and full flowering was the fastest for perennial species *Lupinus polyphyllus* and *Galega officinalis*. For annual species the fastest beginning of flowering was recorded by the species *Vicia angustifolia* and *Trifolium campestre*. In the year of establishment, *Lupinus polyphyllus* showed the fastest setting of the pods and the beginning of ripening of pods. For annual species the fastest setting of pods and the beginning of ripening of pods was recorded for the species *Vicia angustifolia*.

Erysiphe polygoni was the most distributed pathogen on species *Lupinus pollyphyllus, Vicia villosa* and *Vicia tenuifolia*. Another identified pathogen was *Peronospora* spp., occurring in different degrees on species *Lathyrus sylvestris, Astragalus cicer* and *Galega officinalis*. The occurrence of *Pseudopeziza* spp. was recorded on species *Vicia angustifolia* and *Trifolium fragiferum*.

Two main species of weevils were found: *Sitona lineatus* – 90% of the infestation and *S. macularius* – 10% of the infestation. Table 1 presents the percentage of infested plants. Some species were not infested but some species were strongly damaged. Species of the genus *Vicia*, *Trifolium* and *Melilotus* were most damaged. Weak infestation was observed on the species *Dorycnium herbaceum* and *Trifolium montanum.* On the species *Trifolium dubium*, *T. campestre, Lathyrus sylvestris*, *L. tuberosus, Astragalus onobrychis, A. lasiopetalus* and *Lotus uliginosus* no infestation by weevils was recorded.

The persistence of studied species in the grass mixture was evaluated at four different times and mean numbers of plants represented in the mixture are presented in Table 2. The highest persistence in the first year was by the species *Vicia villosa, Lupinus polyphyllus* and *Vicia angustifolia*.

Discussion and Conclusion

After the first year of the trials it could be concluded that species *Vicia villosa, Lupinus polyphyllus, Vicia tenuifolia, Vicia angustifolia, Trifolium medium, Trifolium alpestre, Vicia cracca* and *Galega officinalis* showed good characteristics and could be suitable for potential use in forage crop communities. For some species their potential in forage crop communities could be assumed, because in the past they were extensively used in agriculture. *Lupinus polyphyllus* was cultivated at forest margins as food for wild animals, *Vicia villosa* was cultivated together with rye for green matter for feeding domestic animals and *Galega officinalis* is still used as medicinal plant. Other species (*Vicia tenuifolia, Trifolium medium, Trifolium alpestre* and *Vicia cracca*) are important constituents of natural meadow communities in the Czech Republic (Moravec *et al.,* 1995), and so they also show good potential for forage crop communities.

Table 1. The basic characteristics of studied species observed at different growth stages. Mean numbers counted from 3 replicates

Species	The beginning of germination	The first genuine leaflet	The beginning of flowering	Full flowering	Start of podding	The ripening of pods	Recorded plant pathogens	Plants infested by *Sitona* sp. (%)
Lupinus polyphyllus	17	9	20	30	40	60	*Erysiphe polygoni*	0
Lathyrus sylvestris	24	9	–	–	–	–	*Peronospora* spp.	0
Lathyrus tuberosus	31	4	55	65	65	80		0
*Vicia villosa**	12,5	13	35	48	50	60	*Erysiphe polygoni*	0
Vicia pisiformis	34	4	50	60	65	–		0
Vicia cracca	24	2	49	57	63	62		50.0
Vicia tenuifolia	12	12	40	50	51	–	*Erysiphe polygoni*	100.0
*Vicia angustifolia**	20.7	7	80*	93*	100*	105*	*Pseudopeziza* spp.	100.0
Astragalus cicer	19	7	41	54	63	72	*Peronospora* spp.	87.9
Astragalus excapus	26	10	55	65	70	–		0
Lotus uliginosus	24	8	36	44	51	60		0
Medicago falcata	17	11	36	48	51	58		83.3
Melilotus officinalis	20.7	11	41	53	58	–	*Erysiphe polygoni*	100.0
Trifolium rubens	14.3	11	41	53	63	65		41.4
*Trifolium dubium**	14.3	12	85*	100*	105*	110*	*Erysiphe polygoni*	0
Trifolium fragiferum	17	14	46	53	57	70	*Pseudopeziza* spp.	50.0
*Trifolium campestre**	19.3	8	80*	95*	100*	110*	*Erysiphe polygoni*	0
Trifolium medium	12	16	44	57	63	75		75.9
Trifolium montanum	31	14	48	53	70	85		6.7
Trifolium alpestre	12.7	20	44	53	63	75		76.9
Galega officinalis	19	13	28	35	44	53	*Peronospora* spp.	83.3
Astragalus lasiopetalus	29	14	–	–	–	–		0
Dorycnium herbaceum	24	8	63	75	75	-	*Peronospora* spp.	5.6
Astragalus onobrychis	24	6	–	–	–	–	*Peronospora* spp.	0
Chamaecytisus albus	30	6	–	–	–	–		0
Chamaecytisus virescens	34	4	–	–	–	–		0
Medicago sativa "Palava"	11	14	40	52	53	65	*Pseudopeziza* spp.,*Uromyces striatus*	50.0
Trifolium pratense "Start"	11	12	30	40	40	55	*Erysiphe trifolii*, *Kabatiella caulivora*	50.0

* marks annual or overwintering species – number of days is counted from the germination date. For other species the number of days is counted from the day of a weed cleaning cut.

The occurrence of annual species in the grass mixture was much higher than the persistence of perennial species in the first year (Table 2). It is assumed that in future years hard seeds of perennial species will germinate and their performance will be much better. The occurrence of annual species in later years will be promoted by lower cover of the vegetation layer, the presence of gaps and their natural dynamics of growth.

Table 2. The number of plants of each species found in the grass mixtures. Mean numbers counted from 3 replicates

Species	40 days after sowing	60 days after sowing	12 days after first cutting	14 days after second cutting
Lupinus polyphyllus	7.7	11	6.7	5.7
Lathyrus sylvestris	0.3	0.3	0	0
Lathyrus tuberosus	0	0	4.5	0
*Vicia villosa**	12	25	11	7.3
Vicia pisiformis	0	0	0.3	0
Vicia cracca	1	7	1.7	1.7
Vicia tenuifolia	0	0	19	3.3
*Vicia angustifolia**	5.3	11	8.7	5.7
Astragalus cicer	0.3	1	0.3	1
Astragalus excapus	0.5	0.5	0.5	0
Lotus uliginosus	0.7	1	1	0
Medicago falcata	0.5	1.5	0	0
Melilotus officinalis	2	5	3	2
Trifolium rubens	3.3	4.3	0.7	0
*Trifolium dubium**	1	2	2.3	2.7
Trifolium fragiferum	0.7	0.7	2.3	1.7
*Trifolium campestre**	1.7	4.3	3	2.3
Trifolium medium	1.7	1.7	0	0.3
Trifolium montanum	0	0.3	0	0
Trifolium alpestre	1.7	1.7	1	0.3
Galega officinalis	0	0	0	0.3

* marks annual or overwintering species

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Production and quality of grassland forage in relation to stocking rate and cutting frequency

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Abstract

The paper evaluates small-plot trials at two sites in the Czech Republic which were established in 2004 according to the methodology of BAL Gumpenstein, Austria. The aim of the trials was to determine the influence of cattle load on forage production and quality. The following parameters were investigated: three levels of fertiliser inputs from stocking rates of 0.9, 1.4 and 2.0 LU per ha, which provided inputs of 54, 84 and 120 kg ha^{-1} N. Grassland dry matter production reached 6.43 t ha^{-1} at the site in Jevičko in a dry year, and 4.07 t ha^{-1} at the site in Vysoké nad Jizerou in a normal year. The highest DM production was obtained at both sites after the use of mineral fertilisers. When manure was used, yields decreased at both sites. A model for sustainable farming indicated that stocking rates of 0.9 LU ha^{-1} would provide 6.66 tonnes of forage in dry matter per LU, a stocking rate of 1.4 LU ha^{-1} would be in balance with a consumption of 4.65 t LU^{-1} and with a stocking rate of 2 LU ha^{-1} would not produce sufficient forage, i.e. 3.39 t LU^{-1}. The forage quality from both sites has similar nutritive value, i.e. concentration of CP, crude fibre, DM and energy concentrations in terms of NEL (net energy of lactation) and NEV (net energy of fattening) and was not dependent on whether mineral and organic fertilisers had been used. Higher stocking rate combined with higher utilisation intensity increases CP concentration, decreases crude fibre concentration in forage and slightly increases concentration of energy in forage.

Keywords: grasslands, intensity of utilisation, fertilisation, forage quality

Introduction

Permanent grasslands cover an area of 950 thousand ha in the Czech Republic (CZ), i.e. 22.2 % of farmland. The decrease of cattle stock from 1236 thousand heads of cows in 1990 to 590 thousand heads in 2003 caused deterioration of grassland management and utilisation (803 thousand ha were harvested in 2002 according to data from the Czech statistical bureau). The decrease of cattle numbers means lower load per ha and thus lower production of farm manure which influences the production potential of grasslands. Buchgraber and Pötsch (1994) reported that dry matter yield decreased with increasing utilisation frequency at the same fertilisation level. However, insufficient data are available on the production and quality of forage under different stocking rates with cattle which would result in different organic fertiliser inputs.

Materials and Methods

The scientific research was carried out at the experimental stations of RICP Prague, Research Station of Grassland Ecosystems in Jevíčko (site A) and Liberec, at the site of Vysoké nad Jizerou (site B), in a form of small-plot trials which were established on permanent grassland (PG) in 2004 with different cutting regimes (two, three and four cuts) as well as stocking rates (0.9, 1.4 and 2.0 livestock unit (LU) ha^{-1}), and fertilised with a) manure + dung-water, b) beef cattle slurry, c) mineral fertilisers (Table 1).

The Jevíčko site is located in a temperate climatic region which is 335 m above sea level with an annual average temperature 7.5°C and annual long-term average of rainfall 629 mm. In 2004 the average monthly temperature in the vegetation season was 13.5 °C (average of 50 years 13.0 °C), total rainfall 251.1 mm (average of 50 years 397.0 mm). The experimental site at Vysoké nad Jizerou is situated between the Krkonoše mountains and the Jizerské mountains at the altitude of 680 m. Climatic characteristics of the site: average annual rainfall 1020 mm, temperature 5.8 °C, average rainfall in vegetation season 505 mm, average temperature in vegetation season 11.9 °C. Total rainfall in vegetation season in 2003 was 350.2 mm, average 15.9 °C. In 2004 the average monthly temperature in vegetation season was 14.5 °C (average of 50 years 11.9 °C), total rainfall 507.7 mm (average of 50 years 505.0 mm).
Fertiliser treatments and quantities of farmyard manure of average composition are presented in Table 1. Manure was applied in spring of the year of trial establishment, and in autumn in the following years. Dung-water was applied after the first cut. The following mineral fertiliser was applied: nitrogen (N) – treatment no. 1 – 54 kg ha^{-1} (spring 30 kg ha^{-1}, after the 1st cut 24 kg ha^{-1}), treatment no. 2 (spring 30 kg ha^{-1}, after the 1st harvest 30 kg ha^{-1}, after the 2nd cut 24 kg ha^{-1}), treatment no. 3 (spring 40 kg ha^{-1}, after the 1st cut 30 kg ha^{-1}, after the 2nd cut 30 kg ha^{-1}, after the 3rd cut 20 kg ha^{-1}), potassium (K) and phosphorus (P) in the spring (30 and 60 kg ha^{-1}, resp.).

Table 1. Set up of the experiment

Treat-ment	Stocking rate	Fertilisation	Utilisation	Total annual amount of fertilisers					
	LU ha^{-1}		(number of cuts)	N	P	K	Manure	Dung-water	Slurry
				kg ha^{-1}			t ha^{-1}		
1	0.9	Mineral	2	54	30	60	–	–	–
2	1.4	Mineral	3	84	30	60	–	–	–
3	2.0	Mineral	4	120	30	60	–	–	–
4	0.9	Manure+ dung-water	2	–	–	–	9.86	3.67 (after 1st cut)	–
5	1.4	Manure+ dung-water	3	–	–	–	15.33	5.71 (after 1st cut)	–
6	2.0	Manure+ dung-water	4	50	–	–	21.90	8.15 (after 1st cut)	–
7	0.9	Slurry	2	–	–	–	–	–	6.51 (spring) + 6.51(after 1st cut)
8	1.4	Slurry	3	–	–	–	–	–	10.12 (spring) + 10.12(after 1st cut)
9	2.0	Slurry	4	50	–	–	–	–	14.46 (spring) + 14.46(after 1st cut)

The paper evaluates total annual dry matter production and forage quality by NIRS method in terms of crude protein (CP), crude fibre (CF), NEL (net energy of lactation), NEV (net energy of fattening).

Results and Discussion

Dry matter production of grassland (Tables 2 and 3) reached 6.43 t ha^{-1} in the below-average rainfall year at Jevíčko (site A), 4.07 t ha^{-1} in the rainfall normal year at Vysoké nad Jizerou (site B). The highest dry matter production was recorded at both sites on plots with mineral fertilisers; when manure plus dung-water were used dry matter production decreased at site A from 6.85 to 6.52 t ha^{-1}, and to 5.91 t ha^{-1} after beef cattle slurry was applied. A similar decrease was observed at site B, i.e. 5.00 to 3.64 t ha^{-1} when manure plus dung-water were applied, and to 3.57 t ha^{-1} when beef cattle slurry was applied. A higher cattle load increased the production of manure, and this in combination with increasing levels of fertilising increased DM production from 6.00 t ha^{-1} in a two-cut system to 6.52 t ha^{-1} in a three-cut system, and to 6.77 t ha^{-1} in a four-cut system at site A; at site B from 4.11 t ha^{-1} in a two-cut system to 4.14 t ha^{-1} in a four-cut system. Forage production in sustainable agriculture to meet a dry matter demand of 4.50 t LU^{-1} (Kohoutek, 2002) has been modelled according to a following calculation [(the calculation: (DM at site A; Table 2)/(load by LU.ha^{-1} with a different cutting regime)]. The dry matter demand under the stocking rate (SR) of 0.9 LU ha^{-1} is covered with a surplus (the calculation: 6.00/0.9 = 6.66 t LU^{-1}). The SR of 1.4 LU ha^{-1} is balanced with forage requirements (6.52/1.4 = 4.65 t LU^{-1}). A SR of 2.0 LU ha^{-1} would not allow for sufficient forage production (6.77/2.0 = 3.39 t LU^{-1}) and would require further intensification of pasture management or external sources of feedstuff.

Table 2. DM production (t ha^{-1}) and parameters of quality of grassland for different fertilising treatments and intensity of utilisation at Jevíčko (site A) in 2004

Fertiliser treatments, and intensity of utilisation	Parameters DM (t ha^{-1})	CP (g kg^{-1})	CF (g kg^{-1})	NEL (MJ kg^{-1})	NEV (MJ kg^{-1})
Mineral fert. (NPK)	6.85	122.9	232.0	5.45	5.29
Manure+Dung-water	6.52	114.9	234.3	5.42	5.26
Slurry	5.91	112.8	232.4	5.42	5.26
Average	6.43	116.9	232.9	5.43	5.27
$LSD_{0,05}$	0.89	11.1	13.2	0.18	0.21
$LSD_{0,01}$	1.19	14.8	17.6	0.23	0.28
Two cuts N_{54}	6.00	106.6	255.0	5.23	5.01
Three cuts N_{84}	6.52	111.4	227.0	5.49	5.35
Four cuts N_{120}	6.77	132.6	216.3	5.57	5.44
Average	6.43	116.9	232.9	5.43	5.27
$LSD_{0,05}$	0.89	11.1	13.2	0.18	0.21
$LSD_{0,01}$	1.19	14.8	17.6	0.23	0.28

The forage from both sites (Tables 2 and 3) did not show significant differences ($P < 0.05$) in concentration of CP, fibre and concentration of energy (NEL, NEV) between mineral fertiliser and manure treatments. Higher SR in combination with higher intensity of utilisation at both sites increased CP concentration from 106.6 or 125.4 g kg^{-1} DM, (with SR by 0.9 LU ha^{-1} and quantity of N_{54}) to 111.4 or 145.2 g kg^{-1} DM. A SR of 1.4 LU ha^{-1} and N_{84}-treatment increased CP to 132.6 or 169.2 g kg^{-1} DM. A SR of 2.0 LU ha^{-1} and N_{120}-treatment resulted in a concurrent decrease of fibre concentration in forage and moderate increase of energy concentration in forage. These results are in agreement with the findings of GRUBER (2002) who reported that increasing the cutting frequency increases CP content and decreases fibre content. He also reported that lower cutting frequency led to lower digestibility and energy concentration. This corresponds to morphological changes in plants, i.e. a higher proportion of stalks and higher lignin contents (Minson, 1990). From the ecological viewpoint higher cutting frequency is more favourable as it requires fewer cattle per ha and lower consumption of grain feedstuff.

Table 3. DM production (t ha^{-1}) and parameters of grassland quality in relation to fertilisation and intensity of utilisation at Vysoké nad Jizerou (site B) in 2004

Fertiliser treatments and intensity of utilisation	Parameters				
	DM (t ha^{-1})	CP (g kg^{-1})	CF (g kg^{-1})	NEL (MJ kg^{-1})	NEV (MJ kg^{-1})
Mineral fert. (NPK)	5.00	144.9	246.5	5.05	4.79
Manure+Dung-water	3.64	149.8	238.6	5.12	4.89
Slurry	3.57	145.1	234.5	5.29	5.09
Average	4.07	146.6	239.9	5.15	4.92
$LSD_{0,05}$	0.41	10.5	9.7	0.11	0.13
$LSD_{0,01}$	0.55	14.0	12.7	0.15	0.17
Two cuts N_{54}	4.11	125.4	260.3	5.23	4.99
Three cuts N_{84}	3.96	145.5	235.7	5.18	4.95
Four cuts N_{120}	4.14	169.2	223.7	5.05	4.82
Average	4.07	146.6	239.9	5.15	4.92
$LSD_{0.05}$	0.41	10.5	9.7	0.11	0.13
$LSD_{0.01}$	0.55	14.0	12.9	0.15	0.17

Conclusions

Sustainable grassland systems require research to ensure a well-balanced rate of production and utilisation of manure. This has been calculated at a nitrogen input of ca. 60 kg N per ha per LU. Manure and a reasonable level of grassland fertilisation covers the forage needs for 1 to 1.5 LU per ha in the Czech Republic. Higher stocking rates would require intensification of the system or provision of other feedstuff sources. Higher cutting frequencies improve forage quality.

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Production potential and persistence of red clover varieties

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Abstract

Red clover (*Trifolium pratense* L) is botanically a perennial, although it often behaves as a biennial. The crop generally survives for 2 to 3 seasons in most clover-growing regions of the world, and is considered to lack persistence.

The objective of this investigation was to analyse the production potential, persistence and quality characteristics of domestic and imported red clover varieties, with a view to subsequent inclusion in breeding programs.

Experiments were conducted at the Rimski Sancevi Experiment Field Station during 2001–2002. Six clover varieties (Merviot, Mercury, Lemmon, Junior GKT, Diana, Kolubara) and two populations (BS-1 and BL-3) were evaluated.

Keywords: *Trifolium pratense* L., productivity, quality, persistence

Introduction

Red clover (*Trifolium pratense* L.) is a perennial legume with a large distribution in the world. It is grown on about 20 million hectares. The red clover acreage in Serbia and Montenegro is about 123.000 ha (2002 Statistical Yearbook of Yugoslavia). As a forage crop, red clover is characterized by high yield of green forage (40–60 t ha^{-1}), rapid regrowth post cutting and excellent forage quality. Compared with lucerne, red clover prefers less fertile, and more acid and humid soils. A major problem that limits is its poor persistence.

The objectives of this study were to assess red clover genotypes of different geographic origins for production potential, persistence and nutritional value.

Materials and Methods

Six red clover varieties (Merviot, Mercury, Lemmon, Junior GKT, Diana and Kolubara) and two populations (BS-1 and BL-3) were assessed for production and quality characteristics in a two-year study (2001–2002).

The experiments were established in 2001, in a randomised block design, with five replications, at Rimski Sancevi Experiment Field station (in the vicinity of Novi Sad), on a chernozem soil. Experimental plots were 5 m^2. Red clover was sown in rows 20 cm apart, at the seeding rate of 20 kg ha^{-1}.

Two cuts (CI and CII) were obtained in year one of the study. CI was taken on August 4 (at the stage of full flower), and CII on October 12. Three cuts were obtained in year two, on May 14, June 24 and August 28.

Production and quality characteristics (yield of green forage, yield of dry matter (DM), contents of crude proteins and crude cellulose) were analysed per individual cuts in both years. Samples for chemical analyses were taken at the beginning of flowering of primary inflorescences. An exception was made for CI in year one when sampling was done at the stage of full flower. Two-year results were processed by the analysis of variance.

Meteorological conditions

Novi Sad has a moderate continental climate; long-term (1948–1993) average rainfall during the growing season is 338 mm and mean temperature for the same period = 17.8 °C.
Red clover has a specific requirement with regard to climatic conditions. Yield varies from year to year depending on rainfall. The optimum annual rainfall for successful growth of red clover is about 800 mm (Miskovic, 1986). As the long-term average annual rainfall in the locality of Novi Sad is about 590 mm, supplementary irrigation has to be performed in dry years.
With regard to its thermal requirements, red clover is a cool-climate plant.

Results and Discussion

The yields of green forage and dry matter in the study period (2001–2002) were determined per individual cut and per year (Tables 1 and 2).

Table. 1. Yield of green forage (t ha^{-1}) of red clover genotypes

Genotype	Yield of green forage (t ha^{-1})							Average
	2001			2002				
	Cut I	Cut II	Total	Cut I	Cut II	Cut III	Total	
Merviot	21.0	7.0	28.0	17.8	17.8	2.7	38.3	33.2
Mercury	22.9	7.8	30.7	18.2	15.1	2.7	36.0	33.4
Lemmon	22.8	11.5	34.3	22.2	18.6	4.0	44.8	39.5
BS-1	25.4	10.6	36.0	22.0	23.4	3.4	48.8	42.4
Junior GKT	22.4	12.8	35.2	24.2	21.3	4.4	49.9	42.5
Diana	25.2	13.7	38.9	25.2	22.4	4.8	52.4	45.7
BL-3	22.4	12.6	35.0	21.6	21.2	3.0	45.8	40.4
Kolubara	26.8	19.7	46.5	28.0	24.8	5.2	58.0	52.3
LSD 0.05	7.1	2.2	7.6	2.9	2.5	1.1	4.2	4.2
0.01	9.5	2.9	10.3	3.9	3.3	1.5	5.7	5.7

The two-year results show that the red clover genotypes differed significantly in the yield of green forage (Table 1). Average yields of green forage ranged from 33.2 (Merviot) to 52.3 t ha^{-1} (Kolubara). Kolubara was developed in Novi Sad, and had outstanding yields of green forage in both years. Comparing the yields obtained in the year of establishment, it can be seen that the yield from the CII was considerably lower than that from CI. In the second year, CI and CII produced similar yields of green forage. The yields in the CIII were lowest, ranging from 2.7 (Merviot, Mercury) to 5.2 t ha^{-1} (Kolubara). In all three cuts in year two, significant differences existed among the genotypes with respect to yield of green forage.
In the two years of study, the yield of dry matter ranged from 8.1 (Mercury) to 12.2 t ha^{-1} (Kolubara – Table 2). Regarding the total yield of dry matter, significant differences existed among the genotypes in 2001 (Table 2). The highest yield of dry matter was produced by the variety Kolubara (10.4 t ha^{-1}), the lowest by the Belgian variety Merviot (6.8 t ha^{-1}). It was interesting to note that there were no significant differences regarding the yield of dry matter among the red clover genotypes in the first cut in 2001. In 2002, the total yields of dry matter differed significantly, from 8.9 (Mercury) to 14 t ha^{-1} (Kolubara).

Table 2. Dry matter yield (t ha^{-1}) and stand density assessment of red clover genotypes

Genotype	Yield of dry matter (t ha^{-1})							Average	Stand density (1–9)
	2001			2002					
	Cut I	Cut II	Total	Cut I	Cut II	Cut III	Total		
Merviot	5.1	1.7	6.8	3.7	5.7	0.7	10.2	8.5	2
Mercury	5.4	1.9	7.4	3.6	4.6	0.7	8.9	8.1	2
Lemmon	4.9	2.8	7.8	4.4	5.1	0.9	10.4	9.1	3
BS-1	5.6	2.8	8.3	4.6	6.8	0.8	12.2	10.3	5
Junior GKT	4.7	3.1	7.8	4.8	6.0	1.0	11.8	9.8	3
Diana	5.3	3.4	8.7	5.3	5.6	1.1	12.0	10.3	6
BL-3	4.5	3.1	7.6	6.5	5.8	0.8	13.2	10.4	6
Kolubara	5.9	4.5	10.4	6.2	6.6	1.2	14.0	12.2	7
LSD 0.05	1.6	0.5	1.7	0.6	0.6	0.3	1.0	1.0	
0.01	2.1	0.7	2.3	0.8	0.9	0.4	1.4	1.3	

Persistence was estimated on the basis of stand density measured on the scale from 1 to 9 (1–100% of empty places, 3–75% of empty places, 5–50% of empty places, 7–25% of empty places, 9 – no empty places in the row) at the end of 2002. The highest persistence was exhibited by the variety Kolubara. Lowest persistence was found in the Belgian varieties Mercury and Merviot, which was due to their poor acclimation to the local environmental conditions.

The chemical composition of hay of the studied red clover genotypes was analysed per individual cuts in both years of study (Table 3). Increased contents of crude proteins and reduced of crude cellulose contents were registered in CII, which was in full agreement with the phonological stage of development during which the cutting was performed. It should be noted that the highest contents of crude proteins (18.7% and 18.1%) were registered in the Belgian varieties Merviot and Mercury, respectively, which had lowest yields of both green forage and hay.

Table 3. Chemical composition of red clover hay from first and second cut (2001–2002)

Genotype	Chemical composition of hay							
	CP (%)		CF (%)		Fats (%)		Ash (%)	
	Cut I	Cut II	Cut I	Cut II	Cut I	Cut II	Cut I	Cut II
Merviot	15.6	18.7	24.6	20.8	7.2	9.4	1.4	1.9
Mercury	16.3	18.1	24.0	21.0	7.5	10.3	1.4	1.8
Lemmon	16.0	17.5	23.0	24.4	7.5	8.9	1.5	1.8
BS-1	16.1	16.1	25.0	25.4	7.4	7.3	1.4	1.5
Junior GKT	15.9	17.3	24.7	24.9	7.2	8.8	1.2	1.2
Diana	16.5	16.6	23.9	23.9	6.9	8.4	0.9	1.4
BL-3	16.0	17.9	23.2	22.6	7.1	9.6	1.3	1.1
Kolubara	14.9	16.7	27.3	23.3	6.9	9.7	1.5	1.1
LSD 0.05	1.36	0.70	1.76	1.32	0.63	1.80	0.26	0.42
0.01	1.89	0.97	2.44	1.84	0.88	2.50	0.36	0.58

Numerous authors who studied productivity and persistance in red clover (Miladinovic, 1972; Novoselova, 1986; Taylor and Quesenberry, 1996; Simon, 1997; Boller *et al*., 2004) have pointed out advantages of local red cloves ecotypes over materials introduced from other regions, due to better acclimation and yield performance of the domestic material.

Conclusions

The average two-year yield of forage of the studied red clover genotypes ranged from 33.2 (Merviot) to 52.3 t ha^{-1} (Kolubara). In both years of study, Kolubara, a variety developed in Novi Sad, was distinguished for total yield of green forage. Considering individual cuts, the CI produced highest yields of green forage in the study period (2001–2002). The yield of green forage in the third cut of the second year was considerably reduced, ranging from 2.7 (Merviot, Mercury) to 5.2 t ha^{-1} (Kolubara).

The average two-year yield of dry matter of the studied red clover genotypes ranged from 8.1 (Mercury) to 12.2 t ha^{-1} (Kolubara). The variety Kolubara was distinguished for highest total yields of dry matter in both 2001 and 2002.

The varieties Kolubara and Diana and the population BL-3 demonstrated the best persistence. Conversely, the Belgian red clover varieties Merviot, Mercury and Lemmon exhibited low persistence, evidently due to poor adaptation and acclimation to the local agroecological conditions.

The Belgian varieties Merviot and Mercury had highest contents of crude proteins and lowest contents of crude cellulose. At the same time, these genotypes produced lowest yields of both green forage and hay. In that respect, they are prospective material for future breeding for increased protein content.

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Evaluation of yield and quality of *Trifolium repens* L. cultivars in clover/grass mixtures

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Abstract

In a simulated pasture utilisation (6 cuts a year) in five testing stations of crop plant cultivars, the influence of different cultivars of *Trifolium repens* L. on the yields of mixtures with *Lolium perenne* L. cv. Solen and *Festuca pratensis* L. cv. Skawa was ascertained. The total of seven cultivars of white clover were evaluated, of which four were large-leaved forms (Arta, Aura, Riesling and Romena) and three – medium-leaved forms (Astra, Dara and Rawo). In the mixtures with grasses, in all years of utilization, *Trifolium repens* (35% of the sawn seeds) constituted by weight more than half of the mixture dry matter. The share of clover, irrespective of the cultivar, was always the smallest in the first re-growth. All the large-leaved cultivars of white clover were best suited for the mixture with grasses since they gave the best yield (in the third year of utilisation, the total yield of pure white clover constituted over 62% of the dry matter yield of the mixture in the same third year). These cultivars were also characterized by the best re-growth dynamics after cutting (this refers, in particular, to the Riesling cv.). The highest variations in the crude protein content in dry matter were observed when the pair Romena – Riesling was compared (the latter contained little protein).

Keywords: white clover, cultivars, DM yield, crude protein, crude fibre, re-growth of plants

Introduction

White clover continues to stir interest of both breeders and farmers (Collins *et al*., 2001; Kozłowski *et al*., 1998; Woodfield *et al*., 2004). The species has gained its deserved place in all systems of land agricultural utilisation. White clover constitutes an important element in the rotational system, especially in the sustained and organic systems of farming, among other things, because of its positive influence on the soil environment and biodiversity of agricultural ecosystems (Kryszak, 2004). In the case of dairy farms, white clover or, even more frequently, its mixtures with grasses, especially perennial ryegrass, provide an important source of valuable feed. Pastures with a significant proportion of white clover in the sward are quite common on cattle farms, in particular, dairy cows and sheep (Frame, 1992; Halling *et al*., 2004).

The aim of the investigations conducted was to assess the use value, yields and selected quality parameters of white clover grown in the mixture with perennial ryegrass and meadow fescue.

Material and Methods

Investigations were conducted in years 1999–2002, which comprised the total of 5 experiments located in different parts of Poland. The following cultivars of white clover were compared: Arta, Aura, and Romena (large-leaved forms) and Astra, Dara, Rawo (forms with medium-sized leaves) derived from the Poznań Plant Breeding Centre (PL) as well as the Riesling cultivar (large-leaved form) derived from the Cebeco Seeds B.V. (NL). The white clover cultivars were sown in a mixture with meadow fescue cv. Skawa and perennial ryegrass

cv. Solen at the following weight proportions: white clover – 35%, meadow fescue – 40% and perennial ryegrass – 25% with the planned plant density of 500 plants per 1 m^2. The legume-grass mixture was cut 5–6 times a year. The first cut was performed in spring, when the perennial ryegrass was 15 cm high. The second and third cuts were harvested at 21 days intervals, cuts four and five – after 28–35 days, whereas the last, sixth cut – 6 weeks after the harvest of cut 5. The following doses of fertilization were used in the performed experiments: 90 kg P_2O_5 ha^{-1}, 150 kg K_2O ha^{-1} as well as 30 kg N ha^{-1} after each cut.
During the harvest, a representative sward sample was collected from each plot, which was than analysed for its biological composition and, additionally, the drying coefficients of both the white clover and the mixture were determined. This was the basis for the calculation of the dry matter yield and for the determination of the proportion of individual components in the mixture. From among many observations and results, the author selected and presented in this article the most characteristic results concerning the process of plant overwintering and regrowth as well as the sward density, while the assessment of the yield quality of the examined white clover cultivars, the concentration of crude protein and crude fibre in dry matter were taken into account.
Results of dry matter yields of the examined white clover cultivars in consecutive years and re-growths were subjected to statistical calculations. The calculations were carried out for each year of utilisation separately. The significance of differences of interspecific yields of botanically pure plant matter in cuts were determined by Tukey's confidence half intervals at the confidence level of $\alpha = 0.05$.

Results and Discussion

The yields of grass mixtures with white clover cultivars throughout the period of experiment were stable. The proportions of the examined cultivars in the dry matter yield of the mixture were similar in the first and second years of utilisation. It should be emphasised that the relatively smallest proportion of the clover in the mixture dry matter yield was recorded in the first and sixth re-growths (Table 1). However, in all years of utilisation, the highest dry matter yields of the examined mixtures were obtained from the first cut and it was influenced strongest by the proportion of grasses. In the course of the consecutive three years of utilisation, the highest dry matter yields of white clover were obtained from the large-leaved cultivars – Romena and Riesling (in the cuts uniform to group a) and Aura (classified mostly to group b) and their share in the yields of the mixture was greater than that of the remaining white clover cultivars. Rawo and Dara cultivars were characterised by both low yields and small proportions in the dry matter yields of the mixture (in some cuts classified to groups c, d). On the other hand, the Dara cultivar gave exceptionally poor yields in the first year of utilisation.
The yields of clover cultivars in grass-white clover mixtures were higher than those recorded in pure sowing. Mixtures containing Aura, Rawo and Riesling cultivars were characterised by high sward densities throughout the entire period of experiments. The proportion of the examined cultivars depended on the re-growth and duration of utilisation. Statistically significant differences in favour of Arta, Aura, Romena and Riesling cultivars became apparent primarily during the second and third years of experiments. Large-leaved cultivars had a significant influence on higher yields of the pasture sward because, by producing longer petioles, they were capable of competing with grasses more effectively than small-leaved cultivars.
The examined cultivars were characterised by a high concentration of crude protein – the

mean value for the experimental cultivars for the entire period of investigations and re-growths was 251 g kg^{-1} of DM. In comparison with other cultivars, the Aura and Romena cultivars, especially in the third re-growth, showed higher concentrations of crude protein (over 260 g kg^{-1} in DM). In the successive three cuts relatively little crude protein in dry matter characterised cv. Riesling (4–8% less than cv. Romena).
The maximum dynamics of re-growth the plants showed cv. Riesling (Table 2).

Conclusion

Summing up, on the basis of the performed evaluation of the yield, fodder value and re-growth of plant, it can be said that from among the examined white clover cultivars, large-leaved ones deserve special attention Aura, Romena and Riesling (regardless of the yielding). It appears that these cultivars can be most useful for mixtures with grasses, especially in sustained farming.

Table 1. Yields of white clover cultivars in mixtures with meadow fescue and perennial ryegrass in a simulated pasture utilisation (mean for years 2000–2002)

Treatment	Year of utilisation	Cut	Cultivar of white clover: Romena standard (t DM ha^{-1})	Astra	Rawo	Dara	Riesling	Arta	Aura
				In comparison with the cultivar Romena (%)					
DM yield of mixture meadow fescue + perennial ryegrass/ white clover	I	1	2.97	92	92	72	97	85	87
		2	2.79	96	84	91	98	91	94
		3	2.44	94	93	96	106	94	100
		4	1.91	91	96	92	105	95	96
		5+6	4.33	98	105	100	108	98	106
	II	1	2.62	97	96	95	95	100	101
		2	2.61	96	97	102	100	97	102
		3	2.46	91	97	98	97	98	99
		4	2.92	95	97	99	105	101	100
		5+6	3.75	101	104	103	109	100	107
	III	1	2.06	103	99	100	93	106	99
		2	2.62	102	101	105	101	103	106
		3	1.88	92	93	96	115	98	96
		4	2.19	91	92	98	95	98	96
		5+6	2.51	106	112	115	127	111	105
DM yield of white clover	I	1	1.30a	90b	77c	63d	78c	70d	84b
		2	1.52a	88b	70d	70d	89b	80c	86c
		3	1.61a	86b	79c	77c	103a	86b	84b
		4	1.22a	92b	93b	86c	103a	91b	89b
		5+6	3.13b	88c	99b	88c	108a	94c	101b
	II	1	1.40a	91b	93b	86c	99a	94b	99a
		2	1.47a	89b	91b	92b	101a	97a	92b
		3	1.42a	89b	93b	96a	99a	98a	100a
		4	1.91b	89c	97b	93c	116a	104b	100b
		5+6	2.68b	93c	94c	102b	118a	97b	102b
	III	1	1.19a	87c	93b	93b	101a	105a	104a
		2	1.49b	100b	97b	103b	109a	101b	103b
		3	1.22b	81d	93c	94c	128a	102b	96b
		4	1.29b	85c	95b	97b	109a	105b	95b
		5+6	1.75b	102b	114a	118a	133a	109b	105b

a, b, c, d… values within the same year and cut with the same letters are not significantly different ($P < 0.05$)

Table 2. Evaluation of white clover cultivars in mixtures with meadow fescue and perennial ryegrass (mean for years 2000–2002)

Treat-ment	Year of utili-sation	Cut	Cultivar of white clover						
			Romena standard	Astra	Rawo	Dara	Riesling	Arta	Aura
Content of crude protein* ($g\ kg^{-1}$)	I–III	1	252	242	241	242	237	240	244
		2	239	240	242	241	229	236	246
		3	264	261	262	262	244	258	269
Content of crude fibre*, ($g\ kg^{-1}$)	I–III	1	156	158	158	152	154	156	156
		2	179	178	173	175	174	177	175
		3	154	153	152	150	146	155	148
Over wintering (in 9^o scale)**	I	1	8.2	8.4	7.9	7.8	8.3	7.9	8.3
	II	2	6.9	7.0	7.0	7.0	6.9	6.8	7.0
	III	3	6.8	6.5	6.0	7.1	6.6	8.8	6.7
Re-growth (in 9^o scale)**	I–III	spring	8.4	7.9	7.7	7.4	8.3	7.9	8.0
		after 1	8.2	7.5	7.4	7.7	8.6	7.9	7.5
		after 2	8.3	7.7	7.6	7.6	8.7	8.0	7.9
		after 3	8.3	7.9	8.0	8.0	8.7	8.3	7.9
		after 4	8.1	7.8	8.0	7.8	8.7	8.1	7.8
		after 5	6.1	5.8	6.1	6.1	7.0	5.8	6.0
Density of sward (in 9^o scale)**	Sowing year	autumn	7.5	7.2	7.6	6.5	7.9	7.4	6.9
	I	spring	7.4	7.5	7.3	6.8	7.8	7.1	7.3
		autumn	8.2	8.2	8.4	8.2	8.2	8.1	8.3
	II	spring	8.4	8.3	8.2	8.4	8.3	8.2	8.5
		autumn	8.5	8.7	8.5	8.5	8.7	8.5	8.6
	III	spring	7.6	7.8	7.7	7.8	7.8	7.8	7.9
		autumn	7.5	7.7	7.6	7.6	7.7	7.2	7.8

* Standard deviation: crude protein for cuts – 1st 4.6, 2nd 5.3, 3rd 4; crude fibre for cuts – 1st 2.1, 2nd 2.2, 3rd 3.3
** 1 (the worst cultivar); 9 (the best cultivar)

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Additional agronomics of seed production of hybrid lucerne and fodder galega

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Abstract

Different sowing rates, row spacings and optimal and practical mixtures of herbicides were investigated for seed production of Estonian hybrid lucerne varieties 'Karlu', 'Jõgeva 118' (*Medicago varia Mart.*) and fodder galega variety 'Gale' (*Galega orientalis Lam.*).

The control of dicotyledonous weeds with herbicides is well justified in the sowing year because the control remains insufficient in the subsequent years of seed production. However, the control of weeds in the years of seed production reduces the expenditures for seed harvest, drying and cleaning. The control of couch grass is necessary and gives good results on the years of seed harvesting. The most important factors for good seed production are still meteorological, whereas air temperature, amount of precipitation and intensity of sunshine play the most decisive role. The better seed yields from lucerne 'Karlu' were obtained in 1999 at Saku (North Estonia) with a sowing rate of 2.0 kg ha^{-1}. The average seed yield of fodder galega was 350 kg ha^{-1} with the same rate of fertilization.

Desiccant Basta 150 SL (glufosinate-ammonium) with an application rate of 1.0 l ha^{-1} was used before seed harvest of fodder galega in order to dry down the plants, to favor uniform ripening and to diminish the losses in seed harvesting. This produced an extra seed yield of 35%.

Keywords: lucerne, fodder galega, sowing rate, herbicides, seed production, desiccant

Introduction

The seed production of hybrid lucerne varieties has been very unstable in Estonia because the yield varies by year, depending on weather conditions at the time of flowering and harvesting. The potential seed capability of lucerne varieties bred in Estonia is high, reaching in the years of favorable weather, up to 500–600 kg per hectare (Bender, 2000). Hybrid lucerne 'Karlu' had good winterhardiness up to 60°49' northern latitude in Finland (Mela *et al*., 1996). Fodder galega was very persistent with a high yield capability. The herbage of fodder galega had a high nutritive value when the first cut was made at stem elongation, budding or at the beginning of flowering. Fodder galega gave stable seed yield during five harvest years and the average seed yield was 253 to 357 kg ha^{-1} (Nõmmsalu *et al*., 1996; Virkajärvi *et al*., 1991).

In our conditions the most important factor for legumes forming seed is weather and weed control plays an important part here. The objective of the research work was to specify the agronomics necessary for producing of the hybrid lucerne (*Medicago varia Mart*.) varieties 'Jõgeva 118', 'Karlu' and fodder galega variety 'Gale' (*Galega orientalis* Lam.)

Material and Methods

The trials were established to study the impact of different seeding rates, suitable herbicide mixtures and boron fertilizer on seed yield and quality. The trials were established in 1998. The seed fields were established at Saku on a typical soddy-calcareous soil having pH_{KCl} 6.45, humus content 4.7% and P- and K-content were 128 and 125 mg kg^{-1}, respectively. The varieties of the hybrid lucerne 'Karlu' and 'Jõgeva 118' were sown at the beginning of July in a pure stand, with 60 cm row spacing. The seeding rates were 2.0 and 4.0 kg ha^{-1}.

Fodder galega variety Gale was sown in May in a pure stand in a wide row spacing of 60 cm. The sowing rates were 6.0 and 10.0 kg ha^{-1}. The seeds were treated just before seeding with nodule bacteria. The trials were established in 4 replicates and the size of the harvested plot was 50 m^2. In the year of seeding, the weed control was carried out at the second – third true leaf stage of the lucerne and galega. In the year of harvest it was carried out at the beginning of June. The fertilizers P_{35} and K_{90} kg ha^{-1} were applied in autumn.

Table 1. The herbicide variants in the year of sowing were as follows

Species	Variant 1		Variant 2		
	Basagran (bentazone 480 g l^{-1})	Stomp (pendimethalin 330g l^{-1})	MCPA	Basagran (bentazone 480 g l^{-1})	Stomp (pendimethalin 330 g l^{-1})
Lucerne	1,0 l	1,5 l		2,0 l	
Fodder galega		1,5 l	0,6 l	2,0 l	
In the year of harvest the following mixtures of herbicides were applied					
	Variant				
	Basagran (bentazone 480 g l^{-1})	Stomp (pendimethalin 330g l^{-1})	MCPA	Zellek Super (haloxyfop-R methyl ester)	
Lucerne	2,0 l	1,5 l		0,5 l	
Fodder galega	1,5 l	–	0,6 l	1,0 l	

In the year 2000 the galega seed field was treated before harvesting with the desiccant Basta 150 SL (glysinate-ammonium) at a rate of 1.0 l ha^{-1} to dry the green material and to ensure uniform seed ripening and to decrease harvest losses.
The weather conditions during the trial period were very variable. The summer of 1999 was very favorable for grass seed production, with much sunshine and the total effective temperature was 1316º C up to harvest. There was rain (118 mm) only at the time of flowering in June-July. The year 2000 was unfavorable and was especially rainy in June and July (164 mm of precipitation). The seed fields lodged and the second growth grew through. There were few pollinators because of the wet weather and lack of sunshine. The year 2001 was also unfavorable for legume seed production because June was especially rainy (124 mm of precipitation).
The experimental data was processed using Microsoft Excel. The trial data was examined by two-factor dispersion analysis method.

Results and Discussion

In the year of sowing, the following weeds invaded the experimental plotsin great numbers: goose foot (*Chenopodium album*), European field pansy (*Viola arvensis*), drug fumitory (*Fumaria officinalis*), cruciferous weeds (*Thlaspi arvense, Capsella bursa-pastoris),* wild mustard (*Sinapis arvensis*). Corn spurry (*Spergula arvensis*), common chickweed (*Stellaria media*), cleavers (*Galium aparine*), field forget-me-not (*Myosotis arvensis*), hempnettle (*Galeopsis spp*.), wild camomile (*Chamomilla)*, scentless mayweed (*Matricaria indora)*, and garden yellowrocket (*Barbarea arcuata*). The efficacy of both mixtures (Table 1) was good in controlling annual weeds, whereas the Basagran mixture removed scentless mayweed and wild camomile better and Stomp was better for European field pansy. The effect of MCPA was better at controlling crucifers in the field of fodder galega. MCPA and Stomp and their mixtures gave a satisfactory result in the control of chickweed and Basagran mixtures were very good. These mixtures gave 70–80% control of the above-mentioned weeds. The effect of herbicides on perennial weeds (milkwood, etc, *Cirsium arvense, Sonchus arvensis* jt.) remained low, at about 30% control. Different species of crucifers have different sensitivity towards different herbicides. MCPA causes great damage on lucerne.

In the year of harvest graminaceous weeds occurred in both seed fields. To control grasses, Zellek Super (applied at half of the recommended rate) was added to Stomp and Basagran, and Basagran and MCPA. The efficacy of spraying was satisfactory. Zellek Super destroyed couch grass (*Elytrigia repens)* and other weeds 100% when applied together with other preparations. Zellek Super increased the effect of other herbicides on dicot weeds due to good stickiness but at the same time it had the damaging effect on the crop (Meripõld *et al*., 2001). The control of coach grass avoids the seed contamination with sclerociums of ergots.

The weather had an essential effect on seed yield of lucerne. In the years of high precipitation, the vegetative growth of lucerne continued at the time of flowering, pod formation and seed ripening, which decreased the seed yields. In 1999, the lucerne seed yield was between 118–190 kg ha^{-1}, in the following unfavorable year only 22–30 kg ha^{-1} of seed was produced. Throughout the three years, the seed yield of the lucerne 'Jõgeva 118' and 'Karlu' were on average higher with low seeding rate (2.0 kg ha^{-1}). The seed yields were respectively 90 and 80.3 kg ha^{-1} (Table 2). When the seeding rate was doubled up to 4.0 kg ha^{-1}, the lucerne lodged and seed pods appeared only in the upper part of stems.

Table 2. The dependence of lucerne and fodder galega seed yield on sowing rate

Species Variety	Sowing rate, kg ha^{-1}	Seed yield, kg ha^{-1}			
		1999	2000	2001	Average
Medicago varia Mart.	2,0	190	30	50	90,0
\`Jõgeva 118\`	4,0	158	26	48	77,3
PD95 /LSD95%					1,23
Medicago varia Mart .	2,0	122	25	94	80,3
\`Karlu\`	4,0	118	22	84	75,0
PD95 /LSD95%					1,37
Galega orientalis Lam.	6,0	350	220	270	283,3
\`Gale\`	10,0	300	200	250	250,0
PD95 /LSD95%					3,19

In Estonia, fodder galega's seeds ripen at the beginning of August, at a suitable time for combine harvesting. In 2000, the desiccant was used in this experiment before harvesting to remove fodder grass from the fodder galega 'Gale' seed field and to ensure uniform ripening of seeds to avoid a decrease in the yield. The extra yield was 40–50 kg ha^{-1} or 35%. The seed yields of the fodder galega 'Gale' were on the average of 3 years, higher at the lower seeding rate (6.0 kg ha^{-1}). The three year average seed yield was 283.3 kg ha^{-1} (Table 2).

The climatic conditions in Estonia are quite favorable for producing herbage but are unfavorable for obtaining good seed yields of legumes. It is very important that fodder galega give a stable seed yield in regions where it is not possible to obtain good seed yield from lucerne (Raig, 1993; Raig *et al*., 2001).

Conclusions

Chemical control of dicot weeds in the year of seeding was effective. Although the control carried out in the year of legume seed harvest remains usually less effective, spraying does help to decrease the expenses of seed harvest, drying and cleaning. The control of couch grass gave good results in the years of harvest.

The best results are received with the seed rate of 2 kg ha^{-1} of lucerne and 6 kg ha^{-1} of fodder galega.

The most important factor for seed production is weather, especially air temperature, sunshine duration and amount of precipitation (see the methods).

The highest seed yields were obtained by wide row spacing (60 cm) and a seeding rate of 6 to 10 kg ha^{-1}.

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Tetraploid red clover has potential for pasture and grazing by cows

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Abstract

The purpose of the experiment was to investigate tetraploid red clover cv. Ilte in mixture with grasses under grazing. The fertilisations levels were: farmyard manure (10 t ha^{-1}), mineral fertilisers (30 kg P and 90 kg K ha^{-1}) and no fertilisation. The pasture (0.7 ha) was grazed during 2 days (6.5 hours per day) by 54 cows 3–4 times per season from 2002 to 2004. Samples were collected before and after grazing to estimate the DM yield, the DM intake as well as the botanical composition.

Red clover covered 58 to 81% of the botanical composition. Over the 3 harvest years the red clover/grass pasture yielded 6.4–8.8 t DM ha^{-1}. 56 to 97% of the offered grass was grazed by the cows. The results show that tetraploid red clover has a high productivity over 3 years but then, as often occurs, falls out. The red clover can be maintained as a larger component of a grass/legume stand by providing long rests between grazing. The results also indicate that it should be possible to improve the longevity and productivity of red clover for pasture.

Keywords: red clover, mixture, edibility, fertilisation, grazing, DM yield, intake

Introduction

Generally, high yielding, intensively managed and rotationally grazed temporary pastures have been used in Estonia. About 15 years ago pure-grass swards dominated in practice and high rates of nitrogen fertilisation were used. In low-input grassland farming the forage legumes play an essential role, because the majority of farmers cannot afford to apply sufficient amount of mineral fertilisers (Viiralt and Parol, 2001). In the past 30 years red clover (*Trifolium pratense* L.) was included in ley seed mixtures. Red clover is a perennial legume with a good nutritive value and productivity. It is palatable and the animal intake is high. Red clover plays an important role in organic farming systems as leguminous plants can fix atmospheric nitrogen in association with *Rhizobium* bacteria. In previous experiments the most persistent and productive legume species for grazing was tetraploid late red clover cv. Ilte (Viiralt *et al*., 2001). Grass edibility and intake greatly depend on the botanical composition of pasture and on the rate of fertilization with mineral or farm-yard manure. But it is difficult to get additional information about these issues in the actual grazing condition. The objective of our research was to study the productivity of red clover/grass mixtures suitable for grazing utilisation. The swards were fertilised with mineral or organic fertilisers or non-fertilised.

Materials and Methods

The experiment was established at Eerika Experimental Station of EAU in spring 2001. Red clover cv. Ilte (8 kg ha^{-1}) was added to a basic mixture with 3 grasses: timothy cv. Tika (5 kg ha^{-1}) perennial ryegrass cv. Raidi (10 kg ha^{-1}) and bluegrass cv. Esto (3 kg ha^{-1}). The three fertilisations treatments were: farmyard manure (FYM: 10 t ha^{-1}), mineral fertilisers (PK: 30 kg P and 90 kg K ha^{-1}) and no fertilisation (NON). Fertilisers were applied at the end of April in each year. The area of the experimental plot was 200 m^2 (12.5 m × 16 m) and each

treatment was replicated four times. The whole experimental area (0.7 ha) was grazed during 2 days (6.5 hours per day) by 54 cows 3 (2002) or 4 times per season (2003 and 2004).
The botanical composition of the sward was determined by hand separation in each treatment before grazing. The grass on subplots of 10 m^2 was cut and weighed and the remaining area was grazed after that. The remaining herbage after grazing was cut and weighed (from areas of 20 m^2) to determine the grass intake by cows:

intake (kg cow^{-1} day^{-1}) = (DM yield before grazing – DM yield after grazing)/108.

DM and N content was determined. The yield data have been processed statistically by analysis of variance.

Results

During the 3 years the proportion of red clover was high (Fig 1). The annual DM yields reached 6.9-8.8 t ha^{-1} with mineral fertilisation and 6.4-7.3 t ha^{-1} in the non-fertilised treatment (Fig 2). Without fertilisation the yield was to some extent lower than with organic or PK-fertilisers ($P < 0.001$). The highest DM yield (8.8 t ha^{-1}) was gathered during the third year of utilisation on the pasture fertilised with P and K ($P < 0.05$).
The best degree of herbage utilization by cows was obtained in sward fertilised with mineral PK-fertilisers or non-fertilised (Table 1). In the first grazing cycle the edibility was the lowest by using farmyard manure (39.3%).

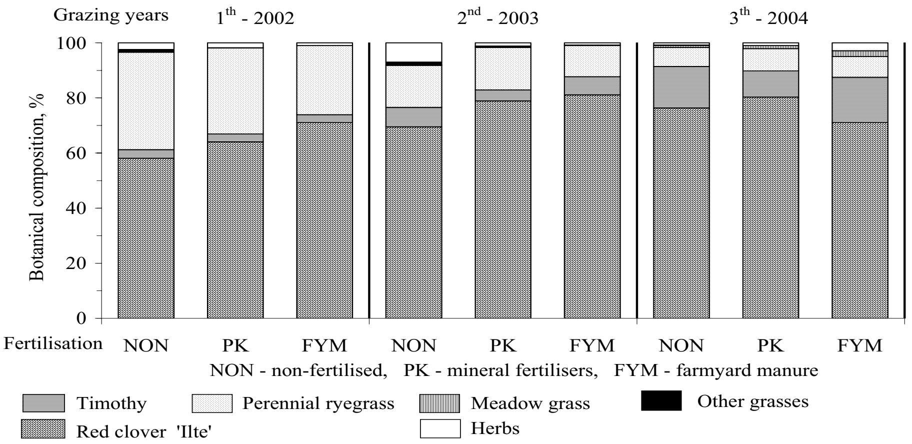

Figure 1. Effect of fertilisation and grazing year on the botanical composition of the red clover-grass mixture

The highest intake (16.3 kg DM cow^{-1} day^{-1}) has been obtained on PK-fertilised pasture and the smallest one (3.1 kg DM cow^{-1} day^{-1}) in case of manure fertilisation. For all treatments the intake during the first year of utilization was higher on the average than during the 2nd year. The greatest differences in intake between grazing cycles were observed when organic fertilisers have been used. At the first grazing cycle the intake of grass fertilised with farmyard manure was nearly twice smaller than that on the pasture fertilised with PK-fertilisers. In the second year of utilisation (2003), the average intake of grass per cow in a day was approximately 2 kg less in the swards treated with organic fertilizers than in the plots where mineral fertilisers have been used. In the 3rd year of utilisation the amount of grass eaten by a cow in a day, either treated with manure or not fertilised at all, was considerably smaller as compared to the 1st year.

Discussion

Clovers are valuable forage plants often having a higher nutritive value than grasses. Red clover is mostly grown on short-time leys and used for cutting but also cultivated on pastures. Tetraploid red clover plants are higher in their growth: stems are thicker, leaves and blossoms are bigger and that is why their yield exceeds that of the diploid varieties.

In organic grasslands the sward N supply depends on biological processes, primary through biological N fixation, and also on mineralization of soil organic matter, plant residues and manure (Younie, 2000).

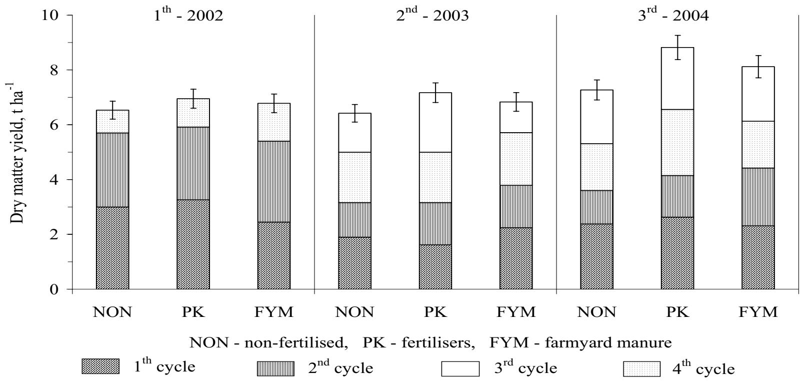

Figure 2. DM-yield of the red clover-grass mixture during 3 grazing years

The botanical composition and edibility of herbage are of high priority, because they affect the intake of grazing animals. The optimum proportion of legumes in the sward has been suggested to be in the range 20–50% (Older *et al.*, 2000). In our trial the proportion of red clover varied from 58 up to 81%.

The yield differences between the grazing cycles were not high – ensuring a constant quantity of forage for animals during the grazing season. It is remarkable that the productivity of the sward increased with time.

The edibility and intake of grass greatly depended on the fertilization. During the droughty year 2002 organic fertilizers did not decompose causing uneven gathering of the yield by cows and its low edibility. When the fertilising with farm-yard manure was used, then the edibility was considerably lower than that of plots fertilised with PK fertilisers or had not been fertilised at all. Within next years of utilisation (2003, 2004) the edibility on pasture where organic fertilisers had been used improved and exceeded the edibility of unfertilised grass. Thus, fertilisation improves the palatability of grass and therefore the amount of grass eaten by cows increased.

The results of the experiment showed that cows ate plots selectively. The intake per cow depends on the grass supply and its edibility. Cows were free to choose between herbages grown with different fertilisations. Intake also depends on the time spent by cows on the pasture and the stocking rate. But it was equal in all treatments.

The final productivity of pastures (milk production and live-weight gain of cows) depends on the content of clovers in the sward. Experiments, carried out earlier, have shown that red clover mixed with grass species was very edible (Parol, 1986). It is widely documented that the productivity of pastures and dairy cows directly depends on the amount of grass eaten in a day (Kuusela and Khalili, 2002).

Table 1. Use of grass by cows and DM intake per cow and day

Year	Grazing cycle	Use of grass by cows, %			DM intake, kg cow^{-1} day^{-1}		
		NON	NPK	FYM	NON	NPK	FYM
2002	I	57.1	65.0	39.0	8.8	13.3	6.5
	II	69.1	69.1	60.7	12.2	11.0	11.0
	III	84.1	81.5	80.1	7.8	9.2	12.1
2003	I	78.1	83.2	59.9	10.0	8.6	9.2
	II	66.1	74.7	78.6	4.7	6.6	7.5
	III	61.6	67.0	73.7	7.5	8.2	6.4
	IV	77.6	84.2	81.7	5.5	9.6	3.5
2004	I	97.0	96.9	56.0	14.8	16.3	8.4
	II	92.1	79.3	70.7	7.1	7.3	8.7
	III	81.1	78.0	77.5	8.3	10.7	7.0
	IV	73.4	72.5	59.0	7.6	12.1	3.1

Conclusions

Red clover covered 58 to 81% of the botanical composition. Over the 3 grazing years red clover-grass pasture yielded 6.4–8.8 t DM ha^{-1}. 56 to 97% of the offered grass was grazed by the cows. In the first droughty year (2002) the sward growth was uneven and the grass edibility was low irrespective of the fertilisation treatment. The grass of the pasture fertilised with farmyard manure stood out for especially low edibility and intake.

During the 2nd and 3rd year the yield of tetraploid red clover was more stable and guaranteed a constant supply of forage for the cows. For all experimental years the use of farmyard manure decreased the edibility and intake of herbage. Therefore, when fertilising pastures with manure, characteristic for organic agriculture, one should take into account that supplying animals with pasture grass calls for longer grazing time per animal.

Acknowledgements

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The influence of alternative management on root production of grass species used for biomass production

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Abstract

A comparison of root production and distribution was evaluated after two years of alternative management of Mountain brome (*Bromus marginatus* Nees ex Steud.) cv. Tacit, smooth brome (*Bromus inermis* Leyss.) cv. Tabrom and tall fescue (*Festuca arundinacea* Schr.) cv. Kora stands. The stands were harvested as biomass for direct combustion in alternative harvesting regimes. The experiment was established in Prague in 2002. The studied variants are: harvested twice per year without fertilisation, harvested twice per year with fertilisation, harvested only once per year at the end of growing season without fertilisation and a single delayed harvest in spring without fertilisation. Fertiliser N in ammonium nitrate was applied in to the soil (100 kg N ha^{-1}) in the spring. Each variant was established in four replicates. The yield of dry root biomass was highest in plots with *B. inermis* (880.3 g m^{-2}) and on the plots with one cut at autumn (818.1 g m^{-2}). *B. marginatus* provided the lowest amount of root biomass of all species in each layer ($P < 0.000$). The highest proportion of root biomass was in the layer of 0–50 mm (in average 71.1%).

Keywords: root production, root distribution, alternative management

Introduction

Root biomass represents 60–90% of net primary production of grass ecosystems (Stanton, 1988). Production of a greater amount of active roots (including a higher amount of reserve substances) means greater longevity because stands have higher resistance to changes in environmental conditions and to stress factors (Straka and Hrabě, 2000). Taking environmental conditions into account, defoliation is one of the major factors affecting root biomass (Meneses Florián *et al*., 2003). Root growth ceases or is markedly reduced in almost all plants following defoliation. Fiala (1997) evaluated the response of underground plant biomass to different intensities of mowing, and concluded that mowing or grazing usually resulted in the decrease of root biomass. This work studied the response of underground biomass of grass swards used for production of energy biomass to fertilizer N input and different harvesting regimes.

Materials and Methods

Mountain brome (*Bromus marginatus* Nees ex Steud.) cv. Tacit, smooth brome (*Bromus inermis* Leyss.) cv. Tabrom and tall fescue (*Festuca arundinacea* Schr.) cv. Kora, were studied in a plot experiment. The experiment was carried out in a field (latitude: 50°08´N, altitude: 14°24´E) at the Czech University of Agriculture in Prague (286 m above sea level). The soil in the experimental area was a deep loamy degraded chernozem with permeable under layer. The soil was neutral or slightly alkaline. The content of available phosphorus and potassium in the layer 100–200 mm was very high and the available magnesium content was high. The area is classified as having a moderate to warm and mostly dry climatic. The average growing

period is 172 days and the mean annual temperature is 7.9 °C (30 year mean). The long-term annual average precipitation was 526 mm.
Pure stands of *B. marginatus, B. inermis* and *F. arundinacea* were sown at a rate of 85 kg ha^{-1}, 45 kg ha^{-1} and 40 kg ha^{-1} respectively. Seeds were drilled with a drill seeder with rows 125 mm apart. The sowing date was April 19. The experiment comprised of four treatments: A – two cuts per year (one at seed ripening – July and a second at the end of growing season – October) with fertilisation (ammonium nitrate was applied in to the soil 100 kg N ha^{-1} in the spring), B – two cuts per year without fertilisation (July and October), C – one cut per year at the end of growing season (October) and D – one cut per year – the delayed harvest in spring (March). Individual plot size was 10 m^2 and the experimental treatments were established in a randomized block design with four replicates.
Two soil core samples (diameter 70 mm) were taken from each plot in July 2004. Soil with roots was taken to 150 mm depth and divided into three layers 1^{st} 0–50 mm, 2^{nd} 50–100 mm and 3^{rd} 100–150 mm. Samples were washed off and the obtained roots were dried at 50 °C for 48 hours.
An analysis of variance was carried out on the variables for yield of underground DM ha^{-1}.

Results and Discussion

Stratification of root biomass in different grasses and treatments are presented in Table 1.
In the layer 0–50 mm, the average weight of root biomass in observed species ranged from 442.37 to 607.42 g m^{-2} (in *B. marginatus* and *F. arundinacea*, respectively). In the layer of 50–100 mm, the corresponding range was 113.29–184.10 g m^{-2} and in 100–150 mm 52.19–88.85 g m^{-2} (in *B. marginatus* and *B. inermis*, respectively).

Table 1. Underground distribution of dry root biomass in observed grass species in the treatments (A–D), year 2004

Species and cultivar sown	Treatment	1^{st} layer g m^{-2}	%	2^{nd} layer g m^{-2}	%	3^{rd} layer g m^{-2}	%	Sum g m^{-2}	%
F. arundinacea cv. Kora	A	742.68	74.5	170.54	17.1	84.31	8.4	997.54	100
	B	648.73	71.2	168.77	18.5	93.59	10.3	911.09	100
	C	564.35	75.9	133.84	18.0	45.07	6.1	743.26	100
	D	473.91	65.3	159.64	22.0	92.31	12.7	725.86	100
B. marginatus cv. Tacit	A	314.86	64.9	121.52	25.1	48.44	10.0	484.82	100
	B	461.16	76.6	106.56	17.7	34.09	5.7	601.81	100
	C	573.30	75.1	115.44	15.1	75.04	9.8	763.77	100
	D	420.18	74.0	109.64	19.3	47.17	6.7	567.99	100
B. inermis cv. Tabrom	A	569.09	70.6	154.20	19.1	82.32	10.2	805.62	100
	B	596.49	68.3	223.15	25.5	54.20	6.2	873.84	100
	C	696.52	73.5	150.22	15.9	100.54	10.6	947.28	100
	D	567.39	63.4	208.84	23.3	118.33	13.2	894.57	100

A – two cuts per year with fertilisation, B – two cuts per year without fertilisation, C – one cut per year – harvest in autumn, D – one cut per year – harvest in spring.

B. marginatus provided the lowest amount of root biomass of all species in each layer ($P < 0.000$). The highest proportion of root biomass was found in the 1^{st} layer in all species ($P < 0.000$). It corresponds with Rieder´s data (1983), which show that there are up to 90% of grassland roots in the soil layer of 0–50 mm.

Although many authors (Davidson and Milthorpe, 1966; Chapin and Slack, 1979) mention that defoliating plants reduces root growth we found that there were no differences in total root biomass in layer 0–150 mm among treatments. It can be ascribed to low intensity of all treatments and to the date of sampling for turnover of roots. For example significant differences were found in root amount between spring and autumn sampling in *Poa pratensis*, *D. caespitosa*, *Agrostis tenuis* and *F. arundinacea* (Straková and Hrabě, 2001).
In spite of this, there were differences among treatments in the third layer. Treatment B (two cuts per year without fertilisation) provided lower total root biomass amount ($P < 0.000$) than treatment D (one cut per year – the delayed harvest in spring) in the layer of 100–150 mm. Two cuts per year without fertilisation had negative effect on production of roots in the third layer in *B. inermis* while this treatment was comparable with treatment A and D in *F. arundinacea* and *B. marginatus*. The interaction of species and treatment on yield of root biomass in the third layer was significant ($P < 0.000$; Fig. 1).

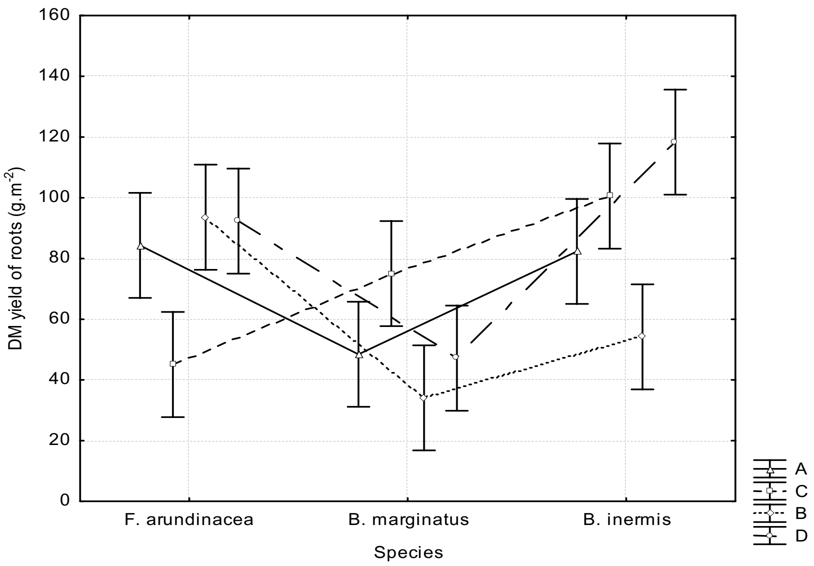

Figure 1. The influence of species and treatments in interaction on yield of root biomass in the third layer (vertical bars denoted 0.95 confidence intervals)

B. marginatus provided the lowest yield of total root biomass in the layer of 0–150 mm (Fig. 2). The fact that in *B. inermis* roots survive for several years (Míka and Řehořek, 2003) can explain why the average weight of total root biomass was in contrast to other species higher.

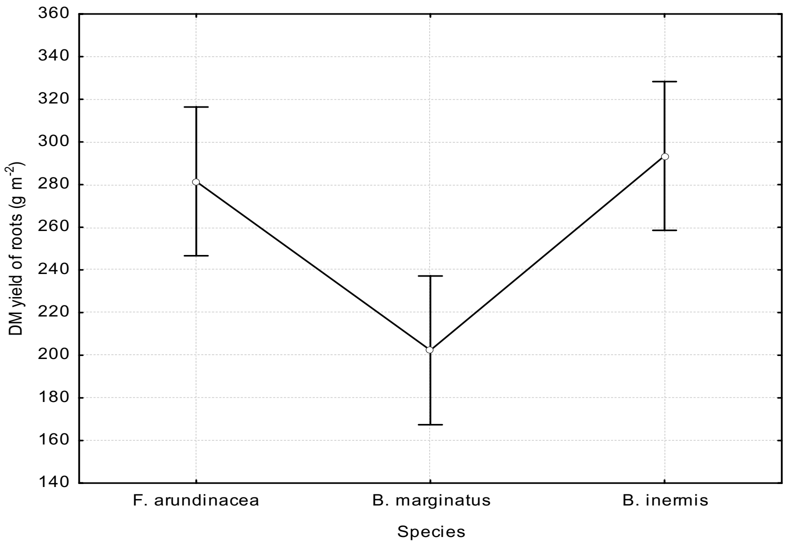

Figure 2. The effect of species on yield of root biomass, average of layers (vertical bars denoted 0.95 confidence intervals)

Conclusion

In conclusion, this study shows that alternative management of grass stands after two years did not affect the total root yield in the layer of 0–150 mm. The higher amount of roots in *F. arundinacea* and *B. inermis* promote the survival these species in following years due to potential higher amount of root reserves. The greatest differences between treatments were found in the third layer 100–150 mm.

Acknowledgements

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The influence of fertilizing on the variation of potassium concentrations in grass pastures

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Abstract

The variation of potassium concentrations in a pasture sward from different grazing regimes depends on different N, P and K rates and the botanical composition of the sward is presented in the paper. Different phosphorus and potassium fertilizer rates had an influence on potassium concentrations in a pasture sward. Lower concentrations of potassium were determined when fertilizing with $P_{30}K_{30}$. While potassium fertilizer rates increased, the concentrations of mobile potassium in the pasture sward also increased. Potassium accumulation in the pasture sward was different and depended on grazing time. Potassium accumulated less in the grass yield of the second grazing. Potassium concentrations of 3.11–3.32% was determined in the yield of third and fourth grazing when fertilizing at $P_{60}K_{60}$. The concentration of potassium in the third grazing reached 3.69% when fertilizing at $P_{60}K_{120}$. The concentrations of potassium in the pasture sward depended on the sward's botanical composition. Legumes accumulated less potassium and these concentrations were stable, independently of mineral fertilizer rates. Higher concentrations of potassium were determined in dandelions (*Taraxacum officinale* L.). They made up about 25% of sward. The concentrations of potassium in the pasture sward did not reach the harmful limit (3%) when fertilizing at the $N_{120}P_{90}K_{120}$ rate, applying K_{120} in 3 times (in spring, after the second and third grazing). The concentration of potassium in dandelions exceeded, and in grasses approached the permissible limit when fertilized at the $N_{120}P_{90}K_{180}$ and $N_{240}P_{90}K_{180}$ rates.

Keywords: potassium, fertilization, permanent grassland

Introduction

One of the main plant nutrients is potassium, which is more prevalent in Lithuanian soils than phosphorus compounds (Mazvila *et al.*, 2000). Acid soil liming (to pH 5.5–6.5) guarantees good quality pastures. However, liming has less influence on yield than mineral fertilizers (Kralovec and Lipavsky, 2000). The efficiency of potassium fertilizers depends on climatic conditions, soil properties and fertilizing with nitrogen and phosphorus fertilizers. The efficiency decreases when the amount of potassium in the soil increases (Daugeliene, 2002). Long-term fertilizing with P and K fertilizers creates excess accumulation of these compounds in the soil (Gutauskas and Slepetiene, 2000; Laegreid *et al.*, 1999). Organic matter and cattle excrement accumulates in the upper soil layers in pasture ecosystems. Therefore, the concentrations of P and K in pasture grass increases (Gutauskas and Slepetiene, 2002; Daugeliene, 2004). Large amounts of P and K are returned to the nutrient cycle from the cattle excrement in the pastures under intensive management. Different references cite a wide range of nutrients returned (40–80%) (Frame, 1992; Thomas and Bax, 1995; Huntley *et al.*, 1997). The variation of potassium concentrations in a pasture sward from different grazing depends on different N, P and K rates and the botanical composition is presented in this paper.

Materials and Methods

The experiments were conducted in Western Lithuania. The soil was a sod podzolic Endocalcaric Gleysol (GLk-n) light loam to medium loam with topsoil pH_{KCl} 6.05, available P_2O_5 132 mg kg^{-1} and K_2O 104 mg kg^{-1}. The swards were annually fertilized by phosphorus in the spring in all trials. Potassium fertilizer in the first trial (data showed in Table 1) was applied in the spring after the first grazing at a rate 30 kg of N ha^{-1}. Table 2 indicates the potassium fertilizer applied in the second trial and nitrogen fertilizers was applied 4 times: in the spring after grass growth was initiated and after the first, second and third grazings. Soil pH_{KCl} was estimated by electrometer with a glass electrode. The amount of potassium in the dry matter yield was determined by flame photometry. The botanical composition (grasses, clovers, forbs) of the samples was measured after separation and is presented as dry matter weight. Potassium level data and its analysis was statistically processed using analysis of variance.

Results and Discussion

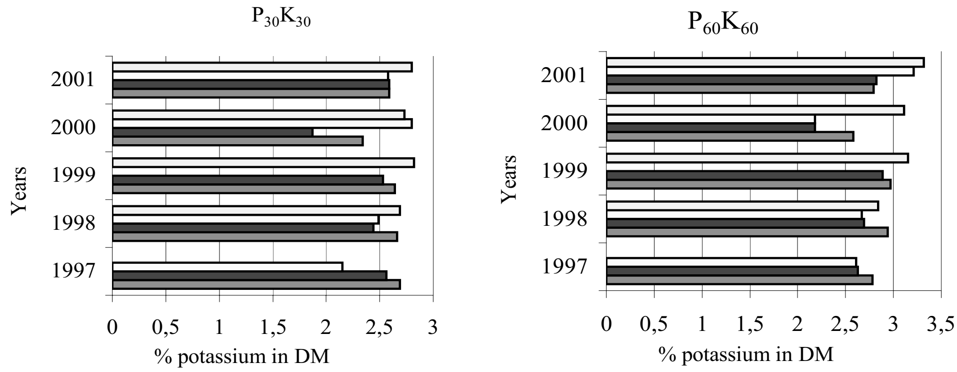
The concentration of potassium in the grass varied depending on mineral fertilizing by P and K fertilizers (Table 1). The lowest potassium concentrations were determined when pasture was fertilized with $P_{30}K_{30}$. The variation of the potassium concentration in the dry matter yield under $P_{30}K_{30}$ fertilization was characterized as the most stable and the regularity of change was the lowest (r = 0.08). Increasing the potassium fertilizer rate from 0 to 120 t ha^{-1} had a tendency to increase the concentration of potassium. The concentration of potassium in the grass DM yield became stable when the fertilization rate was increased to $P_{60}K_{60}$. The largest variation (V = 9.12%) of potassium was determined under $P_{60}K_{120}$ fertilization.

Table 1. Content and regularity of changes of potassium in the annual yield of biomass

Fertilization	Mean %	Error of mean	Coefficient of variation V %	Regularity of change (r)*
P_0K_0	2,58	0,05	4,15	0,11
$P_{30}K_{30}$	2,56	0,03	2,94	0,08
$P_{30}K_{60}$	2,72	0,08	6,93	0,19
$P_{60}K_{60}$	2,87	0,07	5,25	0,15
$P_{60}K_{90}$	2,96	0,09	6,53	0,19
$P_{60}K_{120}$	2,98	0,12	9,12	0,27
LSD_{05}	0,16			

* 05 a level of probability, linear connection

The concentration of potassium in the grass under different grazing regimes varied depending on pasture fertilization (Figure 1). The concentrations of potassium in grass DM yield did not exceed the allowable limit (3%) in all grazing treatments and fertilizing at the $P_{30}K_{30}$ rate did not increase the concentration of potassium in the soil. Therefore potassium accumulation was not determined in the grass DM yield. Increasing potassium fertilizer rates caused the concentration of potassium in the grass DM yield to also increase. Systematic yearly fertilizing influenced this accumulation. The concentration of potassium was 3.15–3.32% in the fourth grazing in 1999 and third and fourth grazings in 2001 under $P_{60}K_{60}$ fertilization. When the potassium fertilizer rate doubled ($P_{60}K_{120}$), 3.69% potassium was found in the third grazing DM yields in 2001. The lowest concentrations of potassium were determined in the second grazing grass. The research data showed that the $P_{30}K_{30}$ rate is sufficient for cultivated pastures, which are established in soils where the potassium concentration is sufficient. Cattle excrement accumulates in the upper soil layers in the pasture ecosystems and higher amounts of K compounds are determined. Excrement replenishes the soil with nutrients. Almost the same level of potassium (33 mg kg^{-1}) gets into the soil with solid and liquid cattle excrements as with mineral fertilizer at rates of $P_{30}K_{30}$ and $P_{30}K_{60}$. These pasture swards were rich in white clovers and cattle grazed them longer (Daugeliene, 2004).



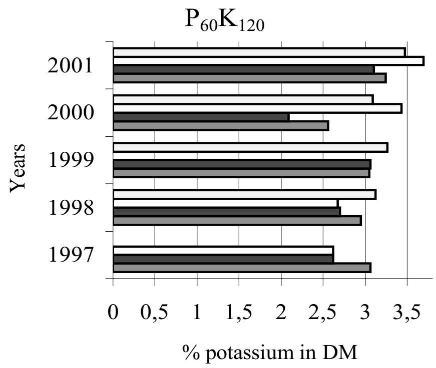


Figure 1. The concentrations of potassium in dry matter yield of differently fertilized pastures.

The efficiency of high potassium fertilizer rates and the time of application are shown in the concentration of potassium in grass DM yield (Table 2). According to the data, the highest concentrations of potassium were determined in the forbs, lesser amounts in the grass and the least in the legumes. The more dandelions in the sward, the more potassium was determined in the DM yield. The concentration of potassium did not exceed the allowable limit (3%) in those pastures where dandelions make up to 25% of the composition in the sward when fertilized at the $N_{120}P_{90}K_{120}$ rate, applying potassium in the spring and after the second and third grazing. The concentration of dandelions in the sward decreased by 10% when fertilized at the $N_{240}P_{90}K_{120}$ rate and when K was applied in parts or once in the spring when compared with pasture fertilized at $N_{120}P_{90}K_{120}$. The concentration of potassium increased not only in the dandelions but also in the grass when pasture is fertilized at $N_{120}P_{90}K_{180}$ and $N_{240}P_{90}K_{180}$ rates. The least and most stable concentrations of potassium were determined in legumes.

Table 2. The concentrations of potassium in different botanical groups DM yield depending on mineral fertilizer rates and time of application

Treatments	Potassium concentration % in dry matter		
	grasses	legumes	dandelions
$N_0P_0K_0$	2,37	1,56	2,76
$N_{120}P_{90}K_{120}$ (in spring)	2,63	2,11	3,04
$N_{120}P_{90}K_{120}$ (in spring, after 2nd and 3rd grazing)	2,64	2,02	2,99
$N_{120}P_{90}K_{180}$ (in spring)	2,90	2,28	3,37
$N_{120}P_{90}K_{180}$ (in spring, after 2nd and 3rd grazing)	2,78	2,38	3,22
$N_{240}P_{90}K_{120}$ (in spring)	2,54	2,17	2,80
$N_{240}P_{90}K_{120}$ (in spring, after 2nd and 3rd grazing)	2,43	2,20	2,71
$N_{240}P_{90}K_{180}$ (in spring)	2,81	2,36	3,18
$N_{240}P_{90}K_{180}$ (in spring, after 2nd and 3rd grazing)	2,76	2,07	2,93
LSD_{05}	0,11	0,14	0,66

Conclusion

Botanical composition of the sward depended on mineral fertilizer rates and the time of application. The highest concentrations of potassium accumulated in dandelions (*Taraxacum officinale* L.) and the lowest concentrations in legumes. Those pastures where dandelions make up to 25% in the sward composition can be fertilized with a $N_{120}P_{90}K_{120}$ rate, applied 3 times: in spring, after the second and the third grazing. The lowest concentrations of potassium accumulated in the DM yield of the second grazing when fertilized at the $N_{120}P_{90}K_{120}$ rate.

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The effect of verticutting on biomass production in several turf cultivars of *Festuca rubra* L.

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Abstract

This work investigated biomass production and tillering of red fescue (*Festuca rubra* L.) cultivars with three types of habitus in response to verticutting in the second year of vegetation. Six different cultivars were evaluated: bunch – type, and slender and strong creeping – types. Lawn samples of all cultivars were collected pre verticutting, and 3–4 weeks post verticutting (which occurred three times during the growing season). All plots were intensively fertilized (four times per growing season) and cut once a week at a sward height of 30 mm.

Biomass production was similar for all cultivars. Mean annual turf biomass was 1.2 g DM m^{-2}. Root and residual shoot biomass comprised 62.4 and 37.6% respectively. In almost all instances verticutting significantly decreased of residual shoot biomass. Verticutting significantly increased root biomass in the 0–20 mm horizon, but had no significant effect in the 21–200 mm horizon. In general verticutting has a positive effect on lawns and can be recommended.

Keywords: biomass, verticutting, Red fescue

Introduction

Red fescue (*Festuca rubra L.*) is one of the most important grass species used in amenity grass mixtures. The species is found mainly in ornamental lawns because of its especially fine leaf texture, high shoot density and tolerance to very close mowing. The fine-leaved fescues are also effective as temporary grasses for establishing greens because of their quick establishment rateand minimal aggressiveness which allows creeping bent grasses to eventually become dominant (Beard, 1982).

In intensively managed turf grasses, the accumulation of dead turfgrass material is greater than natural bacterial decomposition and a thatch horizon builds up in the soil profile (Vodehnal, 2002). This layer can restrict the access of not only air, but also limits the infiltration of water and nutrients into the upper layer of soil profile (Turgeon, 2002). Gandert and Bureš (1991) recognised that lawn thatch contains 30% lignin. A layer of lawn thatch 20 mm thick can retain up to 20 mm of water (Büring, 2002; Straka, 2003). Verticutting (i.e. dethatching, vertical mowing) is necessary for the removal of lawn thatch in order to maintain turf grass healthy. The general effect of verticutting on biomass production of grasses is known. In our study we investigated if the the effect of verticutation is different on the chosen cultivars of Red Fescue with three types of habitus in the first year after establishment.

Materials and Methods

The trial was carried out at the Grassland Research Station Vatín of the Faculty of Agronomy at Mendel University of Agriculture and Forestry in the Czech Highlands – Českomoravská vrchovina (7 km from Žďár nad Sázavou 530 m above the sea level) in 2002, 2003. Individul plot size was 2 m^2 and the experimental plots were established in a randomized block design with three replications. Plots were sown by hand in July 2002. The prevailing soil type was a sandy loam cambisol developing on biotic gneiss. The soil reaction is acidic. Mean annual temperature for the past 50 years has been 6.13 °C and during the vegetation period it has been 13.8°C. The long-term annual precipitations are 736 mm of which 440 mm falls during the growing season. Six cultivars of *Festuca rubra L*. comprising: 'Táborská' and 'Bargena' – types of strong creeping red fescue; (*Festuca rubra* ssp. *rubra*; 'Ferota' and 'Bargreen' – types of chewing fescue (*Festuca rubra* ssp. *commutata*); and 'Barcrown' and 'Fantasie' – types of slender creeping fescue (*Festuca trichophylla*) were used in the experiment. The following spring, the grass stand was mowed every week to a residual sward surface height of 30 mm using a rotary grassland mower BRILL equipped with an aerating cylinder. After June 15 the mowing interval was prolonged to 9–12 days. The experiment was fertilised intensively with fertilizers Floranid Permanent, Floranid Master extra, Floranid Eagle NK, Floranid NK. Details of fertilising is presented in Table 1. The verticutting was not carried out in the year of the establihment In the sekond year of vegetation verticutting was done three times during the growing season, immediately post cutting. Three sampling (soil core samples-diameter 50 mm, depth 250 mm) were taken prior to verticutting, and 3 or 4 weeks post verticutting. Total dry residual shoot and root biomass and its stratification were estimated using the methods of soil monoliths (Fiala, 1987). Each sample was divided into two parts (i.e. residual shoot and root biomass). Tiller number was counted and residual shoot biomass then separated into live and dead part. Root biomass was also separated into two parts (0–20 and 21–200 mm) horizons. Root samples were washed using nets with mesh sieve of 0.5 mm. Both residual shoot and root material were dried in a laboratory condition. The results were evaluated by multiple regression and paired-sample comparison.

Results and Discussion

Mean total annual turf biomass of *F. rubra L.* was 1,219 g DM m^{-2}. Proportion of DM root DM wt and residual shoot DM wt was 62.4 and 37.6% respectively. These values correspond with values of *F. rubra* published by Straková *et al*. (1999) and Straková & Hrabě (2001). Mean total DM weight of root biomass (average of all samplings) ranged from 570.2 to 982.9 g DM m^{-2} (cv. Táborská and cv. Bargreen, respectively). Stratification of total DM root biomass was 68.8 and 31.2% (0–20 and 21–200 mm, respectively). The higher proportion of root DM was at 0–20 mm depth corresponds with the results of Reider (1983), Bäurle & Schultz (1993), and Straková & Hrabě (2001). Mean weight of total residual shoot DM weigh biomass ranged from 395 and 547 g DM m^{-2} (cv. Bargena and Bargreen, respectively). Straková *et al*. (1999) published similar results of residual shoot biomass weight. The total residual shoot biomass was comprised of 50% live and 50% dead components.

Cultivar differences in total weight of residual shoot and root dry matter (DM) before and after verticutting are presented in Table 1. The effect of verticutting on root DM weigh was significant in the 0–20 mm horizon ($P<0.005$), but not significant in the 21–200 mm horizon. An increase in root DM weigh after verticutting was recorded in most cases. Differences in root weight before and after verticutting were significant in the strong creeping type ($P<0.005$) in the 0–20 mm horizon and in the chewing type of red fescue ($P<0.005$) in the 21–200 mm horizon. Significant differences in total root DM quantities were only in the August sampling.

Table 1. Weight of parts of total DM biomass in first harvest year (2003) (i.e. grass sward) in observed cultivars of *Festuca rubra L.* in relation to verticutting (b.v. – before verticutting, a.v. – after verticutting)

Cultivar sown	Residual shoot biomass ($g\ m^{-2}$)						Root biomass ($g\ m^{-2}$)					
	Live part		Dead part		Total biomass		0–20 mm		21–200 mm		0–200 mm	
	b.v.	a.v.	b.v.	a.v.	b.v.	a.v.	b.v.	a.v.	b.v.	a.v.	b.v.	a.v.
Táborská	166.4	189.0	246.2	257.9	412.5	446.9	385.4	566.5	185.0	209.4	570.4	775.8
Bargena	160.7	185.0	234.3	169.2	395.0	354.2	445.9	567.6	260.9	216.7	706.8	784.3
Ferota	224.7	175.4	270.5	136.9	495.2	312.4	550.6	663.8	210.5	280.1	761.1	943.9
Bargreen	271.6	239.9	275.6	145.4	547.2	385.4	705.7	756.0	277.3	317.5	982.9	1073.5
Barcrown	304.5	228.6	159.0	136.4	463.5	365.0	478.7	610.6	216.7	246.7	695.5	857.3
Fantasie	234.8	191.3	202.0	148.8	436.9	340.1	618.5	701.1	228.6	248.4	847.1	949.6
Average	227.1	201.6	231.3	165.8	458.4	367.3	530.8	644.3	229.8	253.1	760.6	897.4

Verticutting had a significant negative effect on the residual shoot DM weight recorded in both live and dead parts. This can be ascribed to early terms of sampling after verticutting and to weather condition especially in summer and autumn. In these seasons there are significant differences in the total shoot DM weight biomass between samples taken before and after verticutting. Significant differences in live residual shoot DM of slender and chewing types were found between sampling before and after verticutting and in the dead part of the chewing type.

There was a significant decrease in number of tillers after verticutting ($P<0.005$) between spring and autumn samplings. Only in summer did verticutting increase tiller numbers, but differences were not significant (Figure 1). This corresponds with the work of many authors (Turgeon, 2002; Svobodová, 1998; Míka, 2002) who report that there are two intensive tillering periods – spring and the end of summer, but these periods are short in turfgrasses. Both residual shoot DM and tiller number decrease after verticutting. Significant differences in tillering due to sampling season were recognized only in chewing type of red fescue (Figure 2).

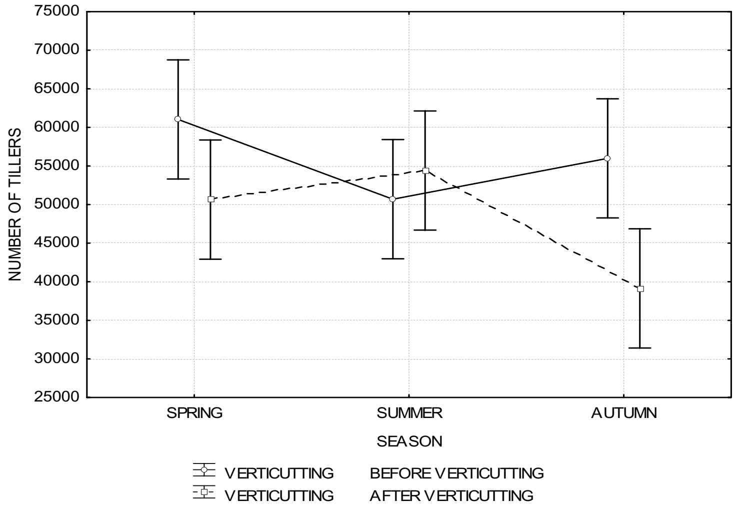

Figure 1. The influence of season and verticutting in interaction on number of tillers (vertical bars denoted 0,95 confidence intervals)

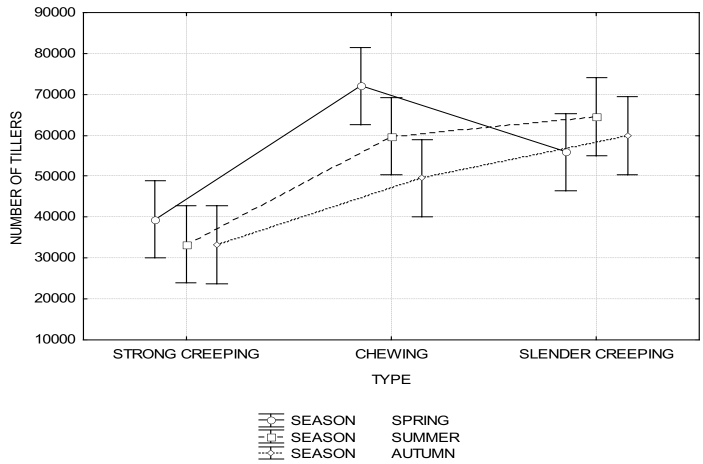

Figure 2. The influence of season and growth type in interaction on number of tillers (vertical bars denoted 0,95 confidence intervals)

Conclusion

The best cultivars for intensive turf grass are the Dutch cultivars Barcrown, and Bargreen, and the Czech cultivars Fantasie and Ferota. These cultivars provided fast production of both root and shoot biomass and fast insertion of grass stand. The effect of verticutting on the decrease of number of tiller and above ground DM weight was higher in chewing and slender creeping red fescue, in comparison with strong creeping fescue.

Acknowledgement

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The relationship between the weather conditions and botanical composition and dry matter yield of a long-term pasture

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Abstract

An experiment lasting 10 years was performed on a long-term pasture in Western Lithuania. The objective of the experiment was to estimate herbage yield of the pasture and botanical composition in relation to the weather conditions. The yields reflected meteorological conditions. The dry matter (DM) yield in dry years ranged between 3.15–4.61 t ha^{-1} and in wet years between 6.19–9.13 t ha^{-1}. Generally there is a lack of warmth and precipitation to achieve the optimal herbage yield of pasture. A medium correlation ($\eta = 0.69$) between the amount of precipitation and herbage DM yield was determined. The correlation between the sum of positive temperatures and DM yield was strong ($\eta = 0.77$). Precipitation and warmth had the greatest impact on the yield of the 2nd and 3rd grazing. White clover in cultured pasture accounted for up to 35–43%, when the amount of precipitation was 454–467 mm over the growing season or 2.90–3.62 mm in twenty-four hours. White clover spread well when the long-term pasture was fertilized by $P_{30-60}K_{30-60}$ rates. Legume/grass sward changed to a grass sward during several dry years in succession. Forbs spread best in unfertilized sward. Within the 10 years' period the share of forbs increased by 28% in unfertilized pasture and by 20% in the pasture applied by $P_{60}K_{60}$ rate. *Taraxacum officinale* L. was the dominant forbs species.

Keywords: permanent grassland, botanical composition, yield, meteorological conditions

Introduction

Lithuania is situated in a transitional zone between West European maritime climate and Asian continental climate. The total annual precipitation in Lithuania is about 700 mm. In general, there is a shortage of soil moisture during April and May and surplus of moisture during July and August. Extremely dry periods occur occasionally, particularly in spring. The growing season lasts from 169 days and the accumulated effective temperatures during the period of plant growth is from 2000 °C to 2200 °C. Lithuania's climate is favourable for herbage production. The development and yield of grasses depend a great deal on the climate, edaphic and biotic factors. Water deficit influences the basic processes connected with grass productivity (Jones, 1988; Assuero *et al*., 2002). An optimal botanical composition of permanent grassland recommended by Buchgraber *et al.* (1994) contains 50–60% of grasses, 10–30% of clovers and 10–30% of other herbage plants. The portion of white clover and grasses in dry matter yield is in the relationship of cyclic fluctuation. The duration of cyclic fluctuation in white clover spread ranged varied between 5–7 years (Gutauskas, 2003). The objectives of our research were to study the variation in sward botanical composition and yield dry matter in a permanent pasture in relation to meteorological conditions.

Materials and Methods

The experiments were conducted in Lithuania. The soil type of the experimental area was a sod podzolic *Endocalcaric Gleysol* (GLk2) light loam on medium loam with top soil's pH_{KCl} 6.05, available P_2O_5 132 mg kg^{-1} and K_2O 104 mg kg^{-1}. A grass mixture consisted of: 25% *Trifolium repens*, 40% *Phleum pratense*, 10% *Festuca pratensis*, 25% *Poa pratensis.* The swards were fertilized annually in spring with phosphorus and potassium. 30 kg N ha^{-1} was applied in the second grazing. The treatments were replicated 4 times and were grazed 4 times with a herd of dairy cows. The botanical composition (grasses, clovers, forbs) of the samples was measured after separation as dry matter weight. Analysis of the weather conditions was based on the data obtained from the weather station. Botanical composition data were statistically processed using analysis of variance. The data of meteorological conditions were statistically analyzed by the ANOVA according to Tarakanovas, 1999.

Results and Discussion

Long-term experiments suggest that botanical composition of the sward was more dependent on the weather conditions rather than on fertilisation (Fig. 1). The share of legumes was subject to the greatest change. In unfavourable years when the rate of precipitation during the growing season amounted to 322 mm, white clover accounted for as little as 8% in the annual yield. $P_{60}K_{60}$ fertilisation did not alleviate the negative effect of the weather conditions on white clover. When the amount of precipitation during the growing season ranged from 454 to 467 mm, white clover accounted for 43–48% in the sward. 25–35% of white clover in pasture swards supply grasses with nitrogen (Breazu, *et al.,* 2002). The share of grasses in unfertilised sward declined by 9% in the last year, and in the treatment fertilised by $P_{60}K_{60}$ the share of grasses increased by 7%, compared with the first year of sward utilisation. Forbs spread most abundantly in drought years and in the swards unfertilised with mineral fertilisers. The content of forbs in unfertilised sward increased by 28% within 10 years, and having fertilised with $P_{60}K_{60}$ the content of forbs was 8% lower. *Taraxacum officinale* L. was the dominant forbs species. The cattle readily grazed herbage in which dandelion accounted for 25%.

During the 10 year period of pasture utilisation there were affected by droughts and excessive moisture (Table 1). This had a decisive effect on pasture productivity. In drought years the yield amounted to 3.15–4.61 t ha^{-1} DM. It was determined by a low precipitation rate, high daily temperature, and a great number of sunny days during the growing season. In droughty years the distribution of yield was very uneven within the growing season. The larger part (45%) of the annual yield was obtained during the first grazing, since there was enough moisture in the soil for the herbs to grow. The yield distribution of the rest of the grazings was more even. In wet years the dry matter yield amounted to on average 6.19–9.13 t ha^{-1}, this resulted from a large percent of cloudy days and abundant rain in the summer. The distribution of DM yield within the growing season during the rainy period was as follows: the first and third grazings accounted for 29–26%, the second for 32%, and the fourth grazing for 13% of the annual yield. In normally wet years the yield of pasture herbs was determined by the weather conditions during the first and third grazings. An especially high (37%) share of the annual yield was obtained during the third grazing, when the mean daily temperature reached 16.5 °C, and the mean daily precipitation rate amounted to 3.1 mm.

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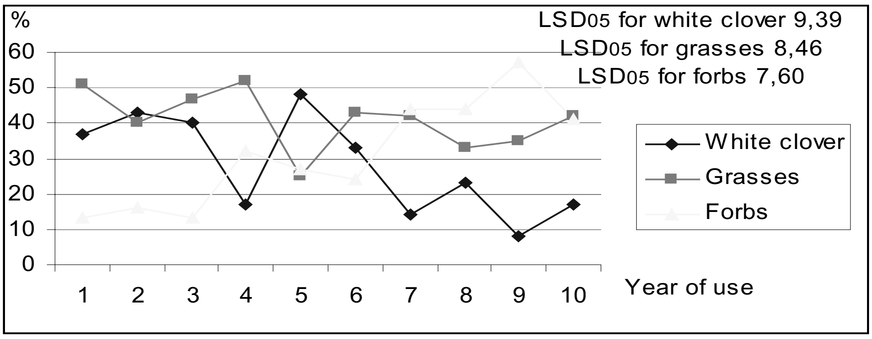

$P_{60}K_{60}$

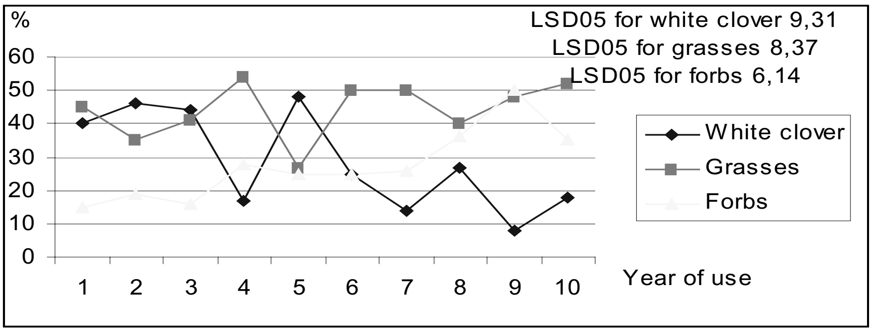

Figure 1. Variation in the botanical composition of the white clover/grass long term pasture (% of the DM)

Table 1. The weather conditions and herbage dry matter yield in separate grazing periods

Grazings	Herbage growth duration (days)	Sunny days %	Cloudy days %	Mean daily air temperature °C	Precipitation mm day^{-1}	Yield t ha^{-1}
Droughty growing season (229–377 mm)						
1	36	39	27	11.5	1.4	1.62
2	33	31	41	12.3	1.5	0.62
3	36	32	16	19.7	1.1	0.63
4	49	25	31	13.7	1.8	0.73
Normally wet growing season (408–532 mm)						
1	38	31	32	10.5	0.6	2.14
2	36	30	42	13.3	3.3	1.59
3	40	36	32	16.5	3.1	2.74
4	44	20	36	12.8	4.5	0.99
Rainy growing season (600–801 mm)						
1	36	30	38	9.6	1.6	2.22
2	35	34	38	14.0	3.1	2.49
3	40	28	28	14.2	6.1	2.05
4	52	30	24	12.0	3.7	1.05

The correlation between the meteorological factors and dry matter yield during separate grazings suggests that the dry matter yield of the first grazing was most dependent on the duration of herbage re-growth and was least dependent on the amount of precipitation (Table 2). The yield of the second grazing was most significantly affected by the amount of precipitation and the sum of positive temperatures, the yield of the third grazing was mostly influenced by the amount of precipitation and percent of sunny and cloudy days, and the yield of the fourth grazing was most significantly influenced by the sum of positive temperatures. The effect of the meteorological conditions on the annual yield of the pasture revealed a strong (r = 0.77) correlation between the dry matter yield and the sum of positive temperatures. This suggests that to obtain a high yield from long-term pastures there is a shortage not only of moisture but also of heat.

Table 2. The correlation between meteorological factors and dry matter yield

Meteorological factors	Correlation coefficient r				
	grazings				annual yield
	1	2	3	4	
Herbage growth duration (days)	0.88	0.77	0.69	0.41	0.65
Sunny days %	0.57	0.63	0.83	0.12	0.62
Cloudy days %	0.46	0.65	0.76	0.34	0.56
Sum of positive temperatures °C	0.53	0.70	0.44	0.37	0.77
Precipitation mm	0.29	0.83	0.80	0.54	0.69

Conclusion

The highest pasture yield and the best proportion of white clover in the sward is achieved when herbage has a regrowth interval of between 35–40 days, and the percent of sunny and cloudy days during this period is almost identical and the mean daily precipitation rate is 3.1 mm.

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The influence of different management systems on the productivity of timothy/clover swards

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Abstract

Mixtures of timothy with red and white clover were sown in a grass rotation and tested under 3 different management systems: cutting, grazing and cutting + grazing.
The soil of the experimental site was a sod podzolic *Orthieutric Albeluvisol* (Jib2) light loam on medium loam with top soil's pH_{KCl} 5.8, available P_2O_5 222 mg kg^{-1} and K_2O 275 mg kg^{-1}.
Proportions of legumes varied from 35.7–50.5% for red clover, highest in the cutting system, and 32.2–38.5% for white clover, highest in the cut + grazed system. DM yields were highest in the cutting system for red clover and cut + grazed system for white clover. A strong correlation (r = 0.96) between dry matter yield and metabolisable energy was established. Grazed grass had the highest crude protein content (180–183 g kg^{-1} DM) but the lowest crude fibre content (208–229 g kg^{-1} DM).

Keywords: timothy, clover, management systems, productivity, herbage quality

Introduction

Lithuania‘s climatic conditions are well-suited for the development of grassland systems. Western regions of the country are strongly affected by the maritime climate (in winter it is warmer, in summer it is cooler than in eastern regions). The soil is more podzolized and acid than in the other regions, it receives the highest rate of precipitation, which has amounted to on average 862 mm annually during the last 10 years. Timothy is a plant well-adapted to Lithuania's natural conditions. It is noted for good winter survival and can well withstand longer periods of flooding. It can grow on acid soils and is well-suited in mixtures with clover as well as for establishment of cultivated grasslands and pastures. Comparison of timothy's chemical composition with that of other grasses (perennial ryegrass, cocksfoot) has caused great controversy of opinions among the authors (Brenciene, 1995; Paplauskiene and Sliesaraviciene, 1998; Scurtu and Blaj, 2003; Skuodiene, 2003; Todorova and Kirilov, 2002). The objectives of this study were to examine the effect of different management systems on the productivity of timothy/clover swards.

Materials and Methods

A field experiment was established with a bi-factorial block design with four replicates. The soil of the experimental site was Orthieutric Albeluvisol (JIb2), pH 5.8, available P_2O_5 222 and K_2O 275 mg kg^{-1}.
Factor A was the management systems: cutting (3 cuts), grazing (4 grazings), cut + grazed (1 cut + 2 grazings). Factor B was the mixture sown: pure Phleum pratense cv. Gintaras II and mixtures with Trifolium pratense cv. Vyliai or Trifolium repens cv. Atoliai (60% clover + 40% timothy). The swards in the first, second and third year of use were applied with 60 kg ha^{-1} of P_2O_5 and 90 kg ha^{-1} of K_2O. No nitrogen fertiliser was applied in the first year, 90 kg N ha^{-1} in the second year and 60 kg ha^{-1} in the third year. The pure grass sward received 120 kg N ha^{-1} in the first and second year, and 60 kg ha^{-1} in the third year.
In the swards under the cutting management 3 cuts were taken in the first and second year of use and 2 cuts in the third year. The cuts were taken at the beginning of ear emergence of grasses.

The swards subjected to grazing management, the start of the grazing season was determined according to the vegetative stage of grasses, i.e. shooting stage. During the vegetative growth period the sward was grazed 4 times in all 3 years of the experiment. The sward was grazed with dairy cows.

In the swards under mixed (cut + grazed) management, 1 cut was taken and 2 grazings during the vegetative growth period. Cuts and grazings were performed at the same stages as in the swards under cutting and grazing management.

The weather conditions of the 1995–1999 period were diverse. The years 1995, 1996, 1997 were especially unfavourable (droughty) for legume-grass and grass swards, however, the conditions were very conducive to grass growing in 1998, when rainfall during the vegetative growth period was 1.3 times higher than perennial mean. In 1999 the weather conditions were favourable for grass growth.

Soil agrochemical properties (in the 0–20 cm soil layer) were estimated using the following methods: pH_{KCl} by electrometric method, hydrolytic acidity by Kappen method, available phosphorus and potassium by A-L method.

Plant chemical composition was determined by the following methods: nitrogen by Kjeldhal method, crude protein according to the amount of nitrogen, multiplying it by 6.25, phosphorus by colorimetric method, potassium by flame photometer.

Statistical data analysis was completed using ANOVA.

Results and Discussion

The swards in the cutting and cut + grazed regimes gave the highest DM yield (Table 1). The yield of grazed swards was lower. The yield difference was significant.

The highest DM yield of mixture Trifolium pratense + Phleum pratense was achieved in cutting regimes while the mixture of Trifolium repens + Phleum pratense produced the highest yield in cut + grazed regimes.

Although pure timothy was abundantly fertilised with nitrogen, the yield was the lowest under all management systems. The yield difference was significant.

The highest amount of Trifolium pratense was in the cutting regime or Trifolium repens was in cut + grazed regimes. The highest content of clover was found in mixtures Phleum pratense with Trifolium pratense, whatever the management regime. The differences were significant.

The content of metabolizable energy varied subject to dry matter yield. A strong linear correlation ($r = 0.98–0.99$) between dry matter yield and metabolizable energy content was obtained in all experimental treatments sown with mixtures (Table 2). Dry matter yield 96–98% determined the content of metabolizable energy. According to the equations of regression the highest metabolizable energy yield increase was obtained for grazed swards. A 1 ton increase in dry matter yield resulted in a 10.1 GJ increase in metabolizable energy content. Under grazing and combined management pure timothy accumulated a similar metabolizable energy content to that of their mixtures with clover. However, this correlation was found to be weaker for the herbage of pure timothy under cutting management. Nutritive value of grasses is to a great extent dependent on the growth stage (Brenciene, 1995; Todorova and Kirilov, 2002; Jatkauskas and Vrotniakiene, 2003).

Table 1. Quality of swards under different management regimes, 1995–1999

Swards (factor B)	Management regimes (factor A) cutting	grazing	cut + grazed	Mean of factor B
	DM yield t ha^{-1}			($LSD_{0.05}$=0.46)
Trifolium pratense + Phleum pratense	7.21	3.87	6.21	5.76
Trifolium repens + Phleum pratense	5.51	4.56	5.76	5.28
Phleum pratense	5.55	3.64	5.08	4.75
Mean of factor A ($LSD_{0.05}$=0.46)	6.09	4.02	5.68	
	Clover % DM			($LSD_{0.05}$=3.14)
Trifolium pratense + Phleum pratense	50.5	35.7	44.1	43.4
Trifolium repens + Phleum pratense	32.2	38.3	38.5	36.4
Mean of factor A ($LSD_{0.05}$=3.14)	41.3	37.0	41.3	
	Metabolizable energy GJ ha^{-1}			($LSD_{0.05}$=4.2)
Trifolium pratense + Phleum pratense	69.8	40.9	56.8	55.8
Trifolium repens + Phleum pratense	54.4	48.2	55.4	52.7
Phleum pratense	48.6	38.3	47.6	44.8
Mean of factor A ($LSD_{0.05}$=4.2)	57.6	42.4	53.3	
	Crude protein g kg^{-1} DM			($LSD_{0.05}$=8.39)
Trifolium pratense + Phleum pratense	128	181	130	146
Trifolium repens + Phleum pratense	139	183	146	156
Phleum pratense	112	180	127	140
Mean of factor A ($LSD_{0.05}$=8.39)	126	181	134	
	Crude fibre g kg^{-1} DM			($LSD_{0.05}$=8.14)
Trifolium pratense + Phleum pratense	260	214	261	245
Trifolium repens + Phleum pratense	257	208	250	238
Phleum pratense	286	229	292	269
Mean of factor A ($LSD_{0.05}$=8.14)	268	217	268	

$LSD_{0.05}$ – least significant difference at $P \leq 0.05$

The content of crude protein and crude fibre was highly dependent on the sward management system.

The yield of the swards used under grazing management had a significantly higher content of crude protein (by 30% and 24%) compared to the swards used under cutting and cut + grazed management systems. Crude protein content (112 g kg^{-1} DM) identified in the swards of pure *Phleum pratense* under cutting management did not meet the nutritional needs of livestock. Crude fibre content in cut swards in mixtures of both clover species and *Phleum pratense* was practically the same (257–260 g kg^{-1}), and in pure *Phleum pratense* its content was higher (286 g kg^{-1}). Crude fibre content was similar in cut + grazed swards, too. In grazed swards the content of crude fibre was considerably lower than in cutting and cut + grazed swards. Clover and grass swards had almost the same content of crude fibre, and for pure *Phleum pratense* its content was slightly higher.

Table 2. The correlation between metabolizable energy and dry matter yield

Swards	Equation	Correlation coefficient r
	Cutting	
Trifolium pratense + Phleum pratense	y = 0.8288 + 9.3628x	0.99**
Trifolium repens + Phleum pratense	y = 0.8812 + 9,2241x	0.99**
Phleum pratense	y = 19.6023 + 3.3462x	0.38
	Grazing	
Trifolium pratense + Phleum pratense	y = 0.3445 + 10.1312x	0.98**
Trifolium repens + Phleum pratense	y = 0.4780 + 10.0906x	0.99**
Phleum pratense	y = 0.3170 + 10.1846x	0.97**
	Cut + grazed	
Trifolium pratense + Phleum pratense	y = 0.3218 + 9.4010x	0.99**
Trifolium repens + Phleum pratense	y = 0.3587 + 9.6116x	0.98**
Phleum pratense	y = 0.4937 + 9.1009x	0.99**

** data significant at 99% probability level

Conclusions

When cut, the most productive swards were *Trifolium pratense* cv. Vyliai + *Phleum pratense*. One hectare yielded 7.21 t of dry matter or 69.8 GJ of metabolizable energy.

Under grazing management the swards of *Trifolium repens* cv. Atoliai + *Phleum pratense* were the most productive. One hectare yielded 4.56 t of dry mater or 48.2 GJ of metabolizable energy.

Under cut + grazed *Trifolium pratense* 'Vyliai'/ *Phleum pratense* and *Trifolium repens* cv. Aoliai + *Phleum pratense* swards gave a similarly high yield. *Trifolium pratense* + *Phleum pratense* gave 6.21 t ha^{-1}, and white clover/timothy swards 5.76 t ha^{-1} of dry matter yield, or 56.8 and 55.4 GJ of metabolizable energy, respectively.

Pure *Phleum pratense* swards produced high yields (5.55 and 5.08 t ha^{-1} of dry matter or 48.6 and 47.6 GJ ha^{-1}) when cut and cut + grazed. Under grazing management dry matter yield was 1.91–1.44 t ha^{-1} lower.

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The effects of long-term manure application on DM yield of perennial grasses and soil chemical properties

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Abstract

The efficiency of systematic fertilisation with different rates of manure in a seven-field rotation was studied in a long-term trial set up at the Vezaiciai Branch of Lithuanian Agriculture Institute in 1959. Perennial grasses were grown in the 6th rotation. The impact of manure on dry matter (DM) yield of perennial grasses and soil agrochemical properties is discussed in the paper. The prevailing soils are loamy *Albeluvisols* (***Ab***, FAO-Unesco, 1998). The research was carried out in two field trials: 1) established in acid and 2) in limed soil. Trial treatments were as follows: 1) without manure, 2) 20, 3) 40, 4) 80 and 5) 120 t ha^{-1} of manure. Manure was incorporated in two times at equal portions per rotation. Perennial grasses were grown in the third and fourth year after manure incorporation. All manure rates significantly increased DM yield of grasses (1st year of use) on acid soil and higher manure rates (80 and 120 t ha^{-1}) on limed soil. The highest DM yield (5.33 and 5.89 t ha^{-1}) of perennial grasses was obtained on the soil that was limed and was applied with the heaviest rates (80 and 120 t ha^{-1}) of farmyard manure. Timothy was the dominant species (27–71%) on acid and red clover (89.7–92.7%) on limed soil. The content of mobile aluminium in acid soil declined from 117.8 to 26.8 mg kg^{-1}, and in limed soil it did not have any effect. Manure fertilisation increased the content of mobile potassium, phosphorus, and humus both in acid and limed soil.

Keywords: perennial grasses, manure, liming, rotation

Introduction

The prevalent soils in west Lithuania's littoral lowland are loamy *Albeluvisols.* They are acid and contain large amounts of mobile aluminium which is toxic to plants. As a result, neutralisation of soil acidity is still a very relevant issue to be solved. Under the effect of lime fertilisers the following changes occur in the main soil chemical properties: acidity and exchangeable aluminium content decline, soil base saturation increases (Nebolsin and Nebolsina, 1997; Shilnikov *et al*., 1997; Chriznikova, 1998). Application of organic fertilisers can prevent the harmful effects of soil acidity on agricultural crops. Farmyard manure is not only the main and most valuable organic fertiliser but also it has a soil neutralising effect. Experimental evidence obtained by researchers from various countries suggests that manure application results in a reduction in mobile aluminium content in the soil, an increase in pH_{KCl} as well as an increase in organic matter content (Jankowska-Huflejt *et al*., 2002; Burgt and Baars, 2001; Pleseviciene *et al*., 1997). Experiments conducted in Romania indicate that fertilisation with only manure resulted in a slightly lower DM yield of grasses compared with mineral fertilisation (Scurtu, 2001). In order to obtain a stable yield of agricultural crops it is necessary to combine organic and mineral fertilisation. Experimental findings obtained in Bulgaria and the Netherlands show that the combination of organic and mineral nitrogen fertilisation was more effective for lucerne and white clover yield compared with only organic fertilisation (Vasileva and Kostov, 2002; Baars, 2001). The data of other researchers suggest that the use of manure by alternating it with mineral fertilisers can secure the best botanical composition of swards and the highest DM yield (Jankowska-Huflejt *et al*., 2002; Burgt and Baars, 2001).

The objective of the present study was to estimate the effects of a long-term systematic manure fertilisation on the yield of perennial grasses and soil chemical characteristics.

Materials and Methods

The efficiency of the systematic manure fertilisation for the crops of the seven-course rotation was tested in the long-term trials (since 1959) conducted at the Lithuanian Agriculture Institute Vezaiciai branch. The article describes the effects of different manure rates on perennial grasses and soil chemical characteristics in the sixth rotation. The soil of the experimental site is *Albeluvisol.* Research was done in two field experiments. One of the experiments was set up on acid soil and the other experiment was set up on limed soil. At the end of each rotation extra liming was applied using 1 rate of powdery limestone according to the soil hydrolytic acidity. Experimental design: 1) without manure, 2) 20 t ha^{-1}, 3) 40 t ha^{-1}, 4) 80 t ha^{-1}, 5) 120 t ha^{-1} of manure. Manure was applied two times per rotation at equal portions (10, 20, 40 and 60 t ha^{-1}) to winter wheat and fodder beet. Solid cattle manure was used. Its chemical composition was as follows: dry matter 21.3–36.4%, total N 0.20–0.41%, P_2O_5 0.18–0.23%, K_2O 1.10–1.22%. Perennial grasses were the third (1st yr. of use) and fourth (2nd yr. of use) crop after manure incorporation. The mixture with *Trifolium pratense* L. (Tp) cv. Liepsna or *Phleum Pratense* L. (Pp) cv. Gintaras II (60 % red clover + 40 % timothy) was sown. Perennial grasses in the 1st year of use were applied with P_2O_5 60 kg ha^{-1}, K_2O 90 kg ha^{-1}, in the 2nd year of use with N 60 kg ha^{-1}, P_2O_5 60 kg ha^{-1}, K_2O 90 kg ha^{-1} mineral fertiliser rates.
Conditions for the cultivation of perennial grasses in the littoral lowland are favourable since this region receives an annual precipitation rate of 750–800 mm. The second half of the year in this region is characterised as extremely wet having two peaks of precipitation in September (89 mm) and November (90 mm). All this creates favourable conditions for soil leaching.
Soil agrochemical properties (in the 0–20 cm soil layer) were established using the following methods: pH_{KCl} – by electrometric method, mobile aluminium – by Sokolov method, mobile phosphorus and potassium by AL method, humus – by Tyurin method. Experimental data were processed by the mathematical statistical methods using ANOVA (Tarakanovas, 2002).
Symbols used in the paper: * correlation link reliable to 95% of possibility level, ** correlation link reliable to 99% of possibility level.

Result and Discussion

Perennial grasses DM yield. When perennial grasses were grown on an acid soil all manure rates had a significant effect on DM yield increase, except for the effect of the lowest (20 t ha^{-1}) rate on DM yield of perennial grasses of the 2nd year of use (Table 1). Only the largest (80 and 120 t ha^{-1}) manure rates had a statistically significant effect on DM yield of perennial grasses of the 1st and 2nd year of use grown on limed soil. In terms of the yield of perennial grasses manure was more effective on acid soil compared with limed soil. Nevertheless, the highest DM yield of perennial grasses was produced on limed soil, compared with acid soil. In terms of DM yield of perennial grasses, long-term systematic manure fertilisation at moderate (40 t ha^{-1}) and higher rates was superior to liming. When growing perennial grasses on acid soil and fertilising with 40 t ha^{-1} of manure per rotation the dry matter yield of perennial grasses of the 1st year of use was 4.49t ha^{-1}, and on acid soil without manure the dry matter yield was 4.30 t ha^{-1}. On acid soil fertilised with the highest (80 and 120 t ha^{-1}) manure rates the dry matter yield of grasses was similar to that obtained on limed soil applied with 40 t ha^{-1} of manure per rotation.

Table 1. The effect of long-term manure fertilisation for DM yield t ha^{-1} of perennial grasses in 2001–2002

Manure rate t ha^{-1} per rotation	*Acid soil*		Limed soil	
	First year of use	Second year of use	First year of use	Second year of use
1. 0	2.49	1.58	4.30	2.08
2. 20	3.68	2.09	4.84	2.45
3. 40	4.49	2.32	5.05	2.35
4. 80	5.08	2.32	5.33	2.62
5. 120	5.13	2.30	5.89	2.63
$LSD_{0.05}$	1.15	0.59	0.99	0.39

$LSD_{0.05}$ – least significant difference at $P \leq 0.05$.

Chemical properties of soil. Systematic and long-term manure fertilisation had a positive effect on the variation of soil agrochemical indicators (Table 2). When fertilising with increasing manure rates an increase in pH_{KCl} from 4.1 to 4.2–4.4 was identified in acid soil and from 5.8 to 5.9–6.1 in limed soil.

Table 2. The effect of manure on topsoil agrochemical properties in 2002

Manure rate t ha^{-1} per rotation	Agrochemical indicators									
	pH_{KCl}		Mobile Al mg kg^{-1}		Mobile P_2O_5 mg kg^{-1}		Mobile K_2O mg kg^{-1}		Humus %	
	Acid soil	Limed soil	Acid soil	Limed soil	Acid soil	Limed soil	Acid soil	Limed soil	Acid soil	Limed soil
1. 0	4.1	5.8	117.8	1.5	163	150	245	196	1.79	1.87
2. 20	4.2	5.9	91.2	1.7	169	160	249	216	1.86	1.87
3. 40	4.2	5.9	69.2	1.8	166	193	252	251	1.96	2.10
4. 80	4.3	6.0	48.3	1.3	188	227	276	294	2.12	2.28
5. 120	4.4	6.1	26.8	1.0	211	239	299	319	2.26	2.33
$LSD_{0.05}$	0.09	0.13	16.58	0.98	10.4	11.3	18.2	17.4	0.289	0.14

Manure fertilisation in acid soil significantly improves growth conditions for plants, since Ca and Mg present in manure bind exchangeable aluminium (Mineev *et al*., 1990). Long-term fertilisation with increasing manure rates had an especially great effect on the reduction of mobile Al in acid soil. The content of mobile Al in acid soil was – 117.8 mg kg^{-1}, under the effect of manure fertilisation 120 t ha^{-1} per rotation, this content declined to 26.8 mg kg^{-1} or it was 4.4 times lower. The content of mobile Al in limed soil was very low 1.5 mg kg^{-1} and manure did not have any appreciable effect.

Having conducted a correlation regression analysis, a linear direct correlation was established between the amount of manure incorporated (t ha^{-1}) per rotation and pH_{KCl} $r = 0.45^{**}$, $R^2 = 0.20$ in acid soil. A parabolic correlation $\eta = 0.89^{**}$, $R^2 = 0.79$ was identified between the amount of manure incorporated (t ha^{-1}) and mobile Al. The correlation regression analysis revealed a strong correlation $\eta = 0.84^{**}$, $R^2 = 0.71$ between the amount of farmyard manure and mobile P_2O_5 in limed soil and a linear direct moderate strong correlation $r = 0.47^{**}$, $R^2 = 0.22$ in acid soil. A significant increase in mobile potassium as well as phosphorus in acid soil occurred through the application of the highest (80 and 120 t ha^{-1}) manure rates, while in limed soil through the application of all rates. Consequently, the correlation between manure rates and mobile potassium was found to be strong $\eta = 0.88^{**}$, $R^2 = 0.77$ in limed soil, in acid soil the correlation was found to be moderate strong $\eta = 0.65^{**}$, $R^2 = 0.42$. In acid soil humus content significantly increased only through the application of the high rates of manure (80 and 120 t ha^{-1}) and in limed soil through the application of all rates, except for the lowest rate 20 t ha^{-1}.

Conclusions

Long-term systematic manure fertilisation had a positive impact on the yield of perennial grasses grown in the crop rotation and on soil chemical properties:

1. The highest DM yield (5.33 and 5.89 t ha^{-1}) of perennial grasses was obtained on the soil that was limed and was applied with the heaviest rates (80 and 120 t ha^{-1}) of farmyard manure.
2. In terms of DM yield of perennial grasses (1st yr. of use), long-term systematic manure fertilisation at 40, 80 and 120 t ha^{-1} rates was more effective compared with only periodically limed soil (1 rate according to hydrolytic acidity).
3. Under the effect of long-term systematic manure fertilisation pH_{KCl} increased from 4.1 to 4.2–4.4 on acid soil, on limed soil from 5.8 to 5.9–6.1. The content of mobile aluminium in acid soil declined from 117.8 to 26.8 mg kg^{-1}, and in limed soil it did not have any effect.
4. Manure fertilisation increased the content of mobile potassium, phosphorus, and humus both in acid and limed soil.

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Fertilization – the effective measure of pastures improvement

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Abstract

Insufficient fertiliser application and intensive use of pastures decrease their productivity and feeding value. Therefore, the renovation of degrade pastures is necessary. Researches underpinning pasture renovation has been carried out in Vezaiciai Branch of Lithuanian Institute of Agriculture for more than two decades.

It was established that all measures used for sward improvement significantly increased pasture yield and improved its botanical and chemical composition. The results show that fertilizing with 120 and 240 kg N ha^{-1} is the most effective mean to improve pastures. With this N application, DM yield increased by 1.72–1.91 t ha^{-1}.

Results from long-term experiments indicate that the efficiency of resown pastures depended on soil acidity. Resowing pastures after liming provided extra dry matter yield of between 1.24–1.66 t ha^{-1} and improved feeding value of the sward. After resowing the amount of legumes increased and amount of forbs decreased. Pasture DM yield also increased by 0.64–0.78 t ha^{-1} when lime material was applied on old pasture surface. Mineral N fertilizing and additional oversowing significantly increased the amount of crude protein and slightly decreased the amount of crude fibre.

Key words: pasture liming, mineral fertilizers, additional oversowing, resowing

Introduction

Researches in many countries determined, that pasture productivity usually needs to be maintained through mineral fertiliser application, especially application of nitrogen. Nitrogen fertilizers in limed pasture, independently from phosphorus and potassium fertilizers rates, increased pasture's productivity and improved forage quality. Extra DM yield (2.19–3.38 t ha^{-1}) was obtained when pasture was fertilized with N_{120} – N_{240} (Daugeliene, 2002). N application at 120 kg N ha^{-1} rate increased DM yield by 1.82–1.85 t ha^{-1} and decreased the amount of forbs by 6.0–7.9%. Additional oversowing increased sward's DM yield by 0.61–0.68 t ha^{-1} and amount of legumes by 5.5%. N fertilizer and additional oversowing has also been shown to increase the accumulation of crude proteins in the pasture's sward (Butkuviene and Butkute, 2004). Increasing N fertilizer rate from 60–180 kg N ha^{-1} increased grass DM yield by 37–97%. Oversowing and resowing increased pasture DM yields from 25 to 40% and to75% respectively. The highest amount of legumes was determined in oversown and resown pastures. Increasing N fertilizer rates, the amount of crude protein in grass yield gradually increased (Zimkus, 1995). The renovation of degraded pastures in south-west Poland with two methods of sward renovation, namely herbicide use in combination with direct drilling and full tillage, proved suitable. Direct drilling was a more successful method of sward renovation in terms of dry matter yield compared with full tillage (Wolski and Stypinski, 2001). Mineral fertilizers influenced pasture yield more than liming (Kralovec and Lipavsky, 2000). Liming and fertilization, especially when applied simultaneously, tend to improve soil fertility, increase pasture yield, improvement in soil structure, and increased plant nutrient concentrations, leading to an improvement in pasture quality (Albizu *et al.*, 2004). In Romanian natural pastures, the highest forage yield was obtained with 100/22/83 kg N/P/K ha^{-1} y^{-1} and 5.5 t $CaCO_3$ ha^{-1}, but the best combination of both soil chemical features

and forage yield was observed with 0/22/83 kg N/P/K ha^{-1} y^{-1} + oversowing with T. repens (3 kg ha^{-1}) + 5.5 t $CaCO_3$ ha^{-1} (Sima *et al.,* 2004).
The researches presented in the paper were conducted with the aim to evaluate the influence of pastures improvement measures on DM yield, botanical and chemical composition.

Materials and Methods

Investigations were carried out in Western Lithuania in a pasture of 6–18 years of use where grasses were dominant. Legumes (white clover *Trifolium repens* L.) accounted for about 10–20% in all trials and forbs – 10–35%, where dandelion (*Taraxacum officinale* L.), yarrow (*Achillea millefolium* L.) and buttercup (*Ranunculus repens* L.) were most prevalent. The soil at the trial site was a *Haplic Luvisols* (*LVh*, FAO-Unesco, 1997). The chemical characteristics of the top-soil were: pH_{KCl} 4.2–6.2, content of mobile P_2O_5 60–184, K_2O – 104–148 mg kg^{-1} and humus 2.9–3.7%.
Limestone was applied on the surface of old pasture and incorporated in the arable soil layer before pasture resowing. Limestone rates differed from 7.5 to 10.8 t ha^{-1} depending on soil pH.
Resowing pasture the legume /grass mixture was sown in all trials. It contained white clover cv. 'Atoliai' 25%, timothy (*Pleum pratense* L.) cv. 'Gintaras II' 40%, smooth-stalked meadow grass (*Poa pratensis* L.) cv. 'Danga' 25% and meadow fescue (*Festuca pratensis* Huds.) cv. 'Dotnuvos I' 10%. The legume/grass mixture was sown with a cover crop – spring barley (*Hordeum vulgare* L.) cv. 'Roland' for grain. White clover and timothy mixture was additionally oversown. The seed rate of white clover cv. 'Atoliai' was 4 kg ha^{-1} and timothy cv. 'Gintaras II' was 2 kg ha^{-1}. The legume-grass mixture was sown with a disk drill straight in the pasture sward.
Each treatment had four replications and was fertilized annually with 60 kg P_2O_5 and 60 kg K_2O ha^{-1} in spring. Fertilizing by nitrogen differed: in liming trials N_{120} rate was applied and in other trials nitrogen fertilizer rates are shown in the research schemes (Tables 2 and 3). Nitrogen fertilizer was applied per two times: after the first and second grazing.

Results and Discussion

Average data of three experiment groups are presented in this paper. The data of three pasture liming experiments are shown in the Table 1. In all soils, surface liming significantly increased pasture yield. Higher DM extra yields were obtained when liming before pasture resowing. Pasture liming and resowing not only increased sward yields, but also improved sward botanical composition (Table 1). The amount of legumes slightly increased and the amount of forbs significantly decreased in soils across the full range of acidity.
Applying N fertilizer at a rate of 240 kg N ha^{-1} significantly increased DM yield from that obtained with an application of 60 kg N ha^{-1} (Table 2). The amount of crude protein in pasture sward also increased. These results confirm results obtained with similar N applications by Daugeliene, 2002 and Zimkus, 1995. The very high N application rate also decreased the forbs and legumes component of old and resown pastures compared with those in pastures which received the least N application. Pasture resowing also significantly increased DM yields by 0.53–0.57 t ha^{-1}. The amount of legumes slightly increased and the amount of forbs significantly decreased in this trial. The amount of crude protein and crude fibre decreased after pasture was resown, but this decrease was insignificant.

Table 1. The influence of liming and resowing on pasture yield and botanical composition of the sward (average of six years)

Treat-ments	Very acidic soil pH 4.2			Average acidity soil pH 4.6			Low acidity soil pH 5.1		
	DM yield t ha^{-1}	legumes %	forbs %	DM yield t ha^{-1}	legumes %	forbs %	DM yield t ha^{-1}	legumes %	forbs %
Old pasture	3.24	2.4	10.4	3.86	10.4	12.3	6.82	3.0	17.6
Old pasture + liming	3.88	2.5	8.2	4.64	11.8	12.0	7.50	3.5	18.0
Resown pasture + liming	4.73	6.2	4.4	5.52	12.5	3.2	8.06	7.2	4.7
LSD_{05}	0.20	4.2	3.1	0.28	5.5	4.8	0.27	5.2	4.3

Table 2. Nitrogen fertilizers influence on pasture's sward yield, botanical and chemical composition (average of five years)

Treatments	Dry matter yield t ha^{-1}	Legumes %	Forbs %	Crude protein g kg^{-1}	Crude fibre g kg^{-1}
Old pasture N_{60}	3.71	13.0	7.0	159	240
Old pasture N_{240}	5.62	2.9	4.9	187	244
Resown pasture N_{60}	4.28	15.1	2.8	152	235
Resown pasture N_{240}	6.15	4.1	1.8	172	239
LSD_{05}	0.25	3.2	1.5	15.0	12.1

Three years average data of four trials where measures of pasture sward improvement were investigated are presented in Table 3. According to the botanical composition data, all pasture improvement measures had positive influence on pasture sward, as the amount of legumes increased and the amount of forbs decreased. Additional oversowing increased the amount of legumes by 6.6% and resowing – by 3.3%.

Table 3. Effect of improvement measures on pasture's yield, botanical and chemical composition (average of three years)

Measure of improvement	DM yield t ha^{-1}	Legumes %	Forbs %	Metabolisable energy GJ ha^{-1}	Crude protein g kg^{-1}	Crude fibre g kg^{-1}
Old pasture	3.52	19.2	27.8	36.5	120	226
Old pasture N_{120}	5.24	3.8	19.7	54.4	128	239
Old pasture + oversowing	4.42	25.8	23.1	44.2	132	223
Resowing	4.73	22.5	18.7	50.6	128	225
LSD_{05}	0.09	3.6	4.5	6.1	7.3	9.5

Fertilizing with nitrogen at 120 kg N ha^{-1} increased pasture DM yield by 1.72 t ha^{-1} or by 49%. Oversowing pastures extra DM yield 1.21 t ha^{-1} was obtained. DM yield increased by 34% in this case. The lowest extra DM yield 0.90 t ha^{-1} was obtained when permanent grasses were additionally oversown into old pasture. DM yield increased by 26% if comparing with the old pasture.

All measures of improvement had significant influence on the accumulation of metabolisable energy. Fertilizing pasture by 120 kg N ha^{-1} gave 17.9 GJ ha^{-1} and resowing – 14.1 GJ ha^{-1}

higher metabolisable energy amounts if comparing with old unfertilized pasture. Additional oversowing increased the amount of metabolisable energy by 7.7 GJ ha^{-1} if comparing with old pasture.
Pasture resowing and oversowing both increased the amount of legumes in the pasture, so that crude protein also increased significantly by 8.0 and 12.0 g kg^{-1} DM, respectively. Fertilizing with 120 kg N ha^{-1} also significantly increased the crude protein by 12.0 g kg^{-1} DM.
Application of nitrogen also significantly increased the crude fibre in pasture by 13.0 g kg^{-1} DM. The amount of crude fibre decreased as the legume component of the pasture increased. in both oversown and resown pastures.

Conclusions

These results show that all renovation options improve pasture composition, yield and quality. Fertilising with 120 and 240 kg N ha^{-1} is the most effective mean to improve pastures. While liming pastures in conjunction with resowing and surface liming of old pastures were less effective measures. Pasture liming, additional grass oversowing and resowing improved the feeding value of sward, as the amount of legumes increased and amount of forbs decreased. Fertilizing with nitrogen and oversowing increased the accumulation of crude protein in the sward.

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Meadow productivity and nitrate leaching under different liming and fertilization

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Abstract

Meadow productivity, nitrate leaching and grass chemical composition in two field trials with different fertilizing ($N_0P_{60}K_{60}$ and $N_{120}P_{60}K_{60}$) were observed. Ecological P and K fertilizers were used. The prevailing soils were loamy *Haplic-Luvisols* (***LVh***, FAO-Unesco, 1997). Soil primary acidity was up to 5.5 pH_{KCl}. Liming formed 4 different pH levels (5.0–5.5, 5.6–6.0, 6.1–6.5 and 6.6–7.0). The sward dry matter yield, its botanical composition and N content, and also nitrate concentrations in leached waters were measured.

Fertilizing by $N_{120}P_{60}K_{60}$ significantly increased dry matter yield. Liming also increased dry matter yield, but a significant increase was obtained only in the pH_{KCl} 5.6–6.0 level in 2003. Legumes almost died out and the amount of forbs decreased by 2.2 times on average when fertilized by N_{120}. In the $N_{120}P_{60}K_{60}$ treatment, nitrogen amounts removed with the DM yield in different pH levels were higher by 4.8, 4.2, 3.5 and 3.3 times, respectively, than in non-fertilized by N meadow. Fertilizing by $N_{120}P_{60}K_{60}$ and liming by higher lime material rates increased NO_3^- concentrations in the leached waters. When meadow was fertilized by N_{120}, NO_3^- concentrations were higher by 1.1–2.4 times if comparing with non-fertilized meadow.

Keywords: permanent meadow, lysimeter, nitrate leaching, liming, fertilizing

Introduction

Soil pH is one of the factors influencing pasture productivity and sustainability (Daugeliene, 1995; Mazvila *et al*., 2000; Marcinkonis *et al*., 2001; Grewal, Williams, 2003).
From an ecological point of view, the adjustment and maintenance of soil pH is especially urgent. Many studies carried out in acid soils have shown that phosphorus and potassium compounds in grassland soils are released when pH is about 6 (Daugeliene, 1995).
The investigations of the last decades in the Baltic region as well as in Lithuania showed that intensive liming and mineral fertilization are the main factors achieving maximum crop yield, but this long-term farming mode had a negative effect on soil quality, and soil leaching became more intensive. Council Directive 91/676/EEC (the Nitrates Directive) adopted on 12 December 1991 provides for the protection of waters against pollution caused by nitrates from agricultural sources. Grassland fertilization with nitrogen helps plants to assimilate P, K, Ca and Na, however it increases leaching of nutrients (Niczyporuk, Jankowska, 1995). Long-term research carried out in Lithuania showed that nitrate leaching was less when clover or un-intensively fertilized permanent grasses were grown (Sleinys, Rimselis, 1998).
Nitrate leaching from grasslands is often low, primarily due to their long period of N uptake compared to arable crops (Korsaeth *et al*., 2003).

Materials and Methods

The investigation was carried out in Western Lithuania, on the eastern part of sea-coast lowland which has a moderately warm agroclimate. The predominant soils were *Haplic-Luvisols* (***LVh***) (FAO-Unesco, 1997), which are loam with primary excess acidity (pH_{KCl}

up to 5.5), low or medium amounts of mobile P_2O_5 (72.5–127.0 mg kg^{-1}) and mobile K_2O (74.0–149.5 mg kg^{-1}). The main liming treatment was done in spring 1991 and established 4 different pH_{KCl} levels (5.0–5.5, 5.6–6.0, 6.1–6.5, 6.6–7.0). Ground limestone was introduced into the top 10 cm depth of the soil before sward sowing. Limestone rate was calculated according to the titration curves (Remezov method), neutralizing the soil with 0.033 N $CaCl_2$ solution. Treatments (liming and fertilizing) had 3 replicates. Two field trials with different fertilization rates ($N_0P_{60}K_{60}$ and $N_{120}P_{60}K_{60}$) were observed. Nitrogen fertilizers (ammonium nitrate) were applied in two equal parts, after the 1st and 2nd cuts. Ecological P (bonemeal) and K (potassium magnesium) fertilizers were applied early in spring before grass growth resumed after winter. Lysimeters (Shilova type) were put into 40 cm depth. Lysimeter water samples were taken in autumn 2003. Sward dry matter (DM) yield, its botanical composition and N content, and also, nitrate concentrations in leached waters were measured.

Results and Discussion

Significantly higher ($P < 0.01$) DM yield of the meadow was obtained when soil pH_{KCl} was 5.6–6.0 in 2003, but there was no effect of soil pH in 2004 (Table 1). Fertilizing (factor B) by $N_{120}P_{60}K_{60}$ significantly increased permanent meadow DM yields both in 2003 and in 2004. If we examine the interaction of factors AxB, significantly ($P < 0.01$) higher DM yields were obtained in all pH_{KCl} levels when fertilized by $N_{120}P_{60}K_{60}$ both in 2003 and in 2004. When the meadow was not fertilized by nitrogen ($N_0P_{60}K_{60}$) significantly higher DM yield (1.33 t ha^{-1}) was obtained only in 5.6–6.0 pH_{KCl} level in 2003. The highest DM yields were obtained in 6.6–7.0 pH_{KCl} level when fertilizing by $N_{120}P_{60}K_{60}$ (2003 – 6.33 t ha^{-1} and 2004 – 5.72 t ha^{-1}).

Table 1. Mean values of meadow DM yields (t ha^{-1})

Fertilizing factor B	Soil pH_{KCl}, factor A				Mean of factor B
	5.0–5.5	5.6–6.0	6.1–6.5	6.6–7.0	
			2003		
$N_0P_{60}K_{60}$	3.10	4.43**	3.48	3.72	3.68
$N_{120}P_{60}K_{60}$	5.94**	5.91**	6.19**	6.33**	6.09**
Mean of factor A	4.52	5.17**	4.83	5.02	
LSD_{05}	A 0.606	B 0.428	A×B 0.857		
LSD_{01}	A 0.841	B 0.594	A×B 1.189		
			2004		
$N_0P_{60}K_{60}$	2.72	3.73	3.69	3.77	3.48
$N_{120}P_{60}K_{60}$	5.38**	5.38**	5.62**	5.72**	5.52**
Mean of factor A	4.05	4.56	4.66	4.75	
LSD_{05}	A 0.769	B 0.544	A×B 1.088		
LSD_{01}	A 1.067	B 0.755	A×B 1.510		

** $P < 0.01$

When soil pH_{KCl} increased, the amount of grasses also increased, but the amount of forbs decreased in 2003 (Table 2). The highest amount of grasses was found when soil pH_{KCl} was 6.6–7.0, of legumes when pH_{KCl} was 6.1–6.5 and of forbs when pH_{KCl} was 5.0–5.5 both in meadows fertilized by $N_0P_{60}K_{60}$ and $N_{120}P_{60}K_{60}$. However, the proportions differed: in nitrogen fertilized meadow the amount of grasses was 1.4 times higher, the amounts of legumes by 5.0 and forbs by 2.2 times lower (respectively 57.5 and 82.5, 11.0 and 2.2, 45.4 and 21.0%). Examining 2004 year data, clear tendencies were not observed. However, the amounts of legumes in meadow fertilized by $N_0P_{60}K_{60}$ in 2004 were 2.5–4.1 times higher than in 2003. Legumes almost died out and the amount of forbs decreased by 2.2 times on average when fertilized by N_{120}.

Table 2. The proportion of botanical groups in the meadow established in different by pH soil under different fertilizing

Soil pH_{KCl}	Fertilizing					
	$N_0P_{60}K_{60}$			$N_{120}P_{60}K_{60}$		
	grasses %	legumes %	forbs %	grasses %	legumes %	forbs %
			2003			
5.0–5.5	43.9	10.7	45.4	77.4	1.6	21.0
5.6–6.0	49.7	7.6*	42.7	78.5	0.9*	20.6
6.1–6.5	50.3*	11.0	38.7*	78.5	2.2*	19.3*
6.6–7.0	57.5*	9.7	32.8*	82.5	1.8*	15.7*
LSD_{05}	6.01	1.16	4.76	5.71	0.12	1.38
			2004			
5.0–5.5	35.9	26.6	37.5	85.1	3.1	11.8
5.6–6.0	45.6*	30.9*	23.5*	84.5	1.8*	13.7*
6.1–6.5	38.9	33.2*	27.9*	86.5	2.2*	11.3
6.6–7.0	43.5*	30.5*	26.0*	81.1	3.4*	15.5*
LSD_{05}	5.75	4.25	4.03	7.45	0.23	1.16

* $P < 0.05$

A partial nitrogen cycle over the period after 2nd cut to the end of permanent grass vegetation is presented in Figure 1. The data shows that nitrate concentrations varied from 4.8 to 18.9 mg l^{-1}. The lowest NO_3^- concentrations in the lysimeter water were when soil pH_{KCl} was 5.0–5.5 either in meadow non-fertilized by N (4.8 mg l^{-1}) or fertilized by N_{120} (6.4 mg l^{-1}). When soil pH_{KCl} approached neutral (5.0→7.0), nitrate concentrations increased by 3.5 times in $N_0P_{60}K_{60}$ and by 3.0 times in $N_{120}P_{60}K_{60}$ fertilized meadow. However, in 3rd pH_{KCl} level (6.0–6.5) nitrate concentrations decreased to 5.0 mg l^{-1} in non-fertilized by N and 9.6 mg l^{-1} in fertilized by N_{120} meadow. We can make assumption that in this pH_{KCl} level N became more available for grasses and lower amounts leached.

N content in grass DM yield differed from 1.14 to 2.53% in meadow non-fertilized by N and from 1.38 to 2.66% when fertilized by N_{120}. Nitrogen amounts removed with the DM yield (kg ha^{-1}) were calculated. Evaluating nitrogen outputs with the DM yield, we see that N amounts varied from 28.3 to 186.7 kg ha^{-1}. The lowest amounts were removed when soil pH_{KCl} was 5.0–5.5 in meadow either non-fertilized by N (28.3 kg ha^{-1}) or fertilized by N_{120} (134.7 kg ha^{-1}). When soil pH_{KCl} approached neutral (5.0→7.0), nitrogen amounts removed with the DM yield increased in meadow fertilized by $N_0P_{60}K_{60}$. Higher DM yields were obtained in meadow fertilized by $N_{120}P_{60}K_{60}$. Therefore, nitrogen amounts removed with the DM yield in different pH levels were higher by 4.8, 4.2, 3.5 and 3.3 times, respectively, than in meadow non-fertilized by N.

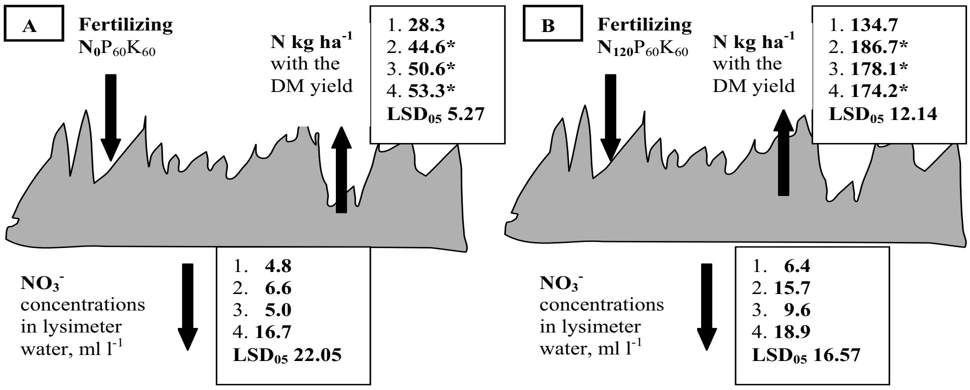

Figure 1. Partial nitrogen cycle in 2003. pH levels: 1 – 5.0–5.5, 2 – 5.6–6.0, 3 – 6.1–6.5 and 4 – 6.6–7.0

Conclusions

Fertilizing by $N_{120}P_{60}K_{60}$ significantly increased permanent meadow DM yields. Significantly ($P<0.01$) higher DM yields were obtained in all pH_{KCl} levels when fertilizing by $N_{120}P_{60}K_{60}$. Liming also increased DM yield, but a significant increase was obtained only in pH_{KCl} 5.6–6.0 level in 2003. Legumes almost died out and the amount of forbs decreased by 2.2 times on average when fertilizing by $N_{120}P_{60}K_{60}$. Fertilizing by N_{120} and liming by higher lime material rates increased NO_3^- concentrations in the leached waters. When meadow was fertilized by N_{120}, NO_3^- concentrations were 1.1–2.4 times higher if comparing with meadow non-fertilized by N. However, NO_3^- concentrations in all treatments met the Nitrates Directive limit. In meadow fertilized by $N_{120}P_{60}K_{60}$ nitrogen amounts removed with the DM yield in different pH levels were 4.8, 4.2, 3.5 and 3.3 times higher, respectively, than in meadow non-fertilized by N.

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Re-growth of original sward following meadow renovation by over drilling – central Poland

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Abstract

Re-growth of original sward plants constitutes significant competition for the development of seedlings and frequently limits the positive results of grassland renovation by using the over-drilling method. The research was aimed at verifying the re-growth capacity of the original sward depending on the renovation period and on how it had been destroyed prior to over-drilling. The following treatments were tested: low cutting of sward without herbicides, selective herbicides (Starane 250 + Aminopielik), Roundup and rototiller. The over-drilling was performed in spring and late summer. The research has proved that Roundup blocks re-growth of original sward for the longest period. Soil rotary tillage creates good conditions for re-growth of plants from their underground vegetative parts and stimulates the seeds in the soil to start germinating. Selective herbicides to a large extent destroy dicotyledonous weeds, but fail to limit the competitiveness of the grasses. Low cutting of the sward is ineffective in limiting original sward competitiveness. Late summer is a better period for grassland renovation by the over-drilling than the spring, which results due to lower regrowth capacity of the original sward.

Keywords: herbicides, over-drilling, re-growth of sward, rototiller, sowing period, weed infestation

Introduction

Currently, over-drilling, with a wide variety of new technical solutions, is superseding tillage cultivation as the most common grassland renovation method in Poland (Goliński, 1998). Original sward re-growth constitutes large competition for the developing seedlings and frequently reduces the positive effects of renovation (Kozłowski, 1998; Janicka, 2004). Measures taken before over-drilling, to limit the competitiveness of the old sward, may delay the re-growth of original plants and facilitate the development and growth of grass seedlings, which in the initial period (in the 1–4 leaf phase) develop relatively slowly and their tillering rate is also low. Such measures include rototiller, application of selective chemicals and total herbicides (Tiley and Frame, 1991; Wolski and Malko, 1998; Baryła, 2001). The aim of the research is to verify the competitiveness of original sward plants depending on the renovation period and on how they had been destroyed.

Materials and Methods

The study was carried out during 2003–2004 at the Experimental Station at Jaktorów (central Poland), in natural, moderately dry meadow site (water table below 150 cm), situated on mineral soil (degraded black earth), poor in potassium and magnesium and with medium phosphorus concentration. The experiment was designed as a randomised complete block with four replicates. Each plot was 15 m^2 in area. The experiment was carried out on a degraded permanent meadow, which had been extensively managed and fertilised. The meadow had a low proportion of valuable high grass species (less than 20%) and had been infested with dicotyledonous herbs and weeds (more than 40%). *Rumex acetosa, Achillea millefolium, Taraxacum officinale, Plantago lanceolata* and *Leontodon autumnalis* had the highest proportion in the sward. Sward cover density was less than 50%. Competitiveness of the original sward was reduced by: 1) cutting low without herbicides (cutting height: 2–3 cm), 2) herbicides: Starane 250 (1l ha^{-1}) + Aminopielik (3l ha^{-1}), active substances: fluroxypyr + 2.4D, 3) Roundup (5l ha^{-1}; active substance: glyphosate) and 4) rototiller (twice). The meadow was renovated three times: spring (6 May 2003 and 21 April 2004) and late summer (27 August 2003). The height of the re-grown sward and the dominating grass species were verified once a week in three points on the diagonal line across the plots. Weed infestation by respective species was specified by means of Weber's frame (50 cm by 50 cm), 8 and 12 weeks after the over-drilling.

Results and Discussion

Dicotyledonous plants represent significant competition for developing grass and clover seedlings. They are characterised by fast growth and development. As early as two weeks after the over-drilling, regardless of the sowing period, some dicotyledonous plants started re-growing from those parts of roots that had been pulled out by rototiller over the soil level, *inter alia*: *Rumex acetosa, Achillea millefolium* and *Taraxacum officinale*, a little later also *Plantago lanceolata*. The roots of *Rumex acetosa* protruded over the soil level even as high as 9 cm and a rosette of leaves were developing on their top. Dicotyledonous plants developed also from seeds that remained in the soil 'waiting' for advantageous conditions for growth and development. Previous research proved that dicotyledonous plants seeds account for over 90% of the soil seed bank (Kozłowski, 1998). Application of rototiller stimulated the seeds to germinate, whilst the majority of species stared to sprout, depending on humidity conditions, around 3 (in spring) – 4 (in late summer) weeks after over-drilling. The seeds included mainly: *Rumex acetosa, Taraxacum officinale* and *Plantago lanceolata* as well as annual species, such as: *Stellaria media, Capsella bursa-pastoris, Cerastium vulgatum, Chenopodium album, Lamium purpureum, Viola arvensis* and *Veronica sp.* A particularly large number of the annual species developed in the spring period. Rotary tillage does not completely cover sods, due to which their regeneration is not significantly impeded (Olszewska and Wielicka, 1981). Runners pulled out over the soil level developed mainly into *Poa pratensis* and *Festuca rubra.* Runners of these species were 2.5–5.5 cm long whilst young tillers developed from third or fourth node over the ground level. *Carex fusca* plants developed similar re-growths. Application of Roundup limited the re-growth of original sward plants for a longer time. Dicotyledonous plants from the seed bank developed first (around four weeks after over-drilling). When compared with plots that had undergone rotary tillage, weed infestation in plots treated with Roundup was much smaller and respective species were in earlier development phases. Dominating species included: *Rumex acetosa, Plantago lanceolata, Taraxacum officinale, Achillea millefolium* and *Stellaria media,* and in smaller quantities: *Lamium purpureum, Capsella bursa-pastoris* and *Cerastium vulgatum.* Original sward plants started to regrow around six weeks after over-drilling; it has to be noted that at that time grass seedlings had already entered the tillering phase (Janicka, 2004). In the initial period the main re-growing species was *Poa pratensis*, followed by *Holcus lanatus* and dicotyledonous plants: *Rumex acetosa, Plantago lanceolata* and *Taraxacum officinale* started to re-grow. In the spring period a large number of *Plantago lanceolata* plants developed. The process of re-growing of *Holcus lanatus* deserves special attention; having been treated with Roundup, similar as after rototiller, this tuft grass developed numerous re-growths that were morphologically and anatomically similar to runners (Olszewska and Wielicka, 1981a). Application of selective herbicides significantly decreased the occurrence of dicotyledonous plants, which supports previous research (*inter alia* Tiley and Frame, 1991; Wolski and Malko, 1998). Four weeks after over-drilling, in empty spaces that remained in the sward, seedlings of dicotyledonous plants developed from the soil seed bank. In the sixth week this group of plants started to re-grow from parts of their vegetative organs. Dicotyledonous plants were more developed in plots treated with selective chemicals than in plots where Roundup had been applied but less developed when compared with plots that had undergone rotary tillage. The most numerous species included: *Rumex acetosa, Achillea millefolium* and *Taraxacum officinale.* Verification of the weed infestation level was performed 8 and 12 weeks after over-drilling and showed that selective herbicides limited the development of *Taraxacum officinale* and *Leontodon autumnalis* the most, whilst of *Achillea millefolium* the least (Table 1). In his research Kostuch (1994) proved that during dry periods this species and *Rumex acetosa* grow and develop in a normal manner or even increase their share in sward cover. It should be noted that growth and development of *Plantago lanceolata* was limited only shortly after selective herbicides had been applied (Table 1).

Table 1. Number of dicotyledonous plants (plant m^{-2}), 8 and 12 weeks after over-drilling, depending on sward treatment and efficiency of herbicides against the dominating species (mean for the renovation periods)

Species	8 weeks after over-drilling		12 weeks after over-drilling			
	Low cutting	Herbicides	Low cutting	Herbicides	Control	Efficiency of herbicides % control
Achillea milefolium	102.5	32.5	114.0	57.0	113.5	49.8
Leontodon autumnalis	19.0	6.5	21.5	6.7	25.5	73.7
Plantago lanceolata	20.5	1.0	31.5	12.5	30.0	58.3
Rumex acetosa	28.3	12.0	30.0	12.3	32.5	62.1
Taraxacum officinale	25.0	6.5	39.5	7.5	34.5	78.3

Low cutting without selective herbicides did not influence the weed infestation level, which remained the same as in control plots and in spring it amounted to around 53%, whilst in late summer it equalled around 40%. On plots treated with herbicides, weed infestation level varied between 5 and 7%. Growth and development conditions were better for over-drilled species on plots treated with selective herbicides than on plots that had undergone low cutting without herbicides. Nonetheless, it should be noted that empty spaces were quickly dominated by grass species from the old sward, mostly by *Poa pratensis* and *Festuca rubra*.

Competitiveness of plants from the original sward constitutes the most significant obstacle for successful over-drilling. Selective chemicals decreased the pace of original sward re-growth to a small extent (Table 2). Delaying the re-growth process by means of limiting meristem volume due to low cutting proved to be ineffective. Re-growing grasses quickly become competitive for developing seedlings. This could be observed especially in the spring period, when the pace of sward re-growth during first two weeks after over-drilling was much faster than in the late summer period, when plant vigour is naturally reduced (Table 2). Moreover, in the spring grasses developed generative tillers and low cutting failed to destroy their stem apexes. Therefore, grasses were around 10 cm higher than in a corresponding period after late summer over-drilling. In order to improve light conditions for the developing seedlings (2.5–

4 cm high) two defoliations were performed (at the height of around 6–7 cm). The pace at which respective grass species were re-growing depended on their natural morphological and physiological characteristics and on habitat conditions (Table 2). High grasses were the fastest to re-grow, especially in spring 2004, as weather conditions at that period were advantageous for grass development. Moreover species developing short underground runners, mainly *Poa pratensis* and *Festuca rubra* also gave significant competition for the developing seedlings. Such species not only started to re-grow very shortly after the cutting but they spread even more intensely, occupying free spots in the sward.

Table 2. The daily re-growth rate of original sward and the dominating grass species (mm day^{-1}) depending on the renovation period

	2003				2004		Average
	Spring		Late-summer		Spring		
	I	II	I	II	I	II	
Sward treatment							
Low cutting	4.4	6.7	2.8	4.8	6.4	8.3	5.57
Herbicides	5.1	6.9	2.5	5.4	6.0	7.7	5.60
$LSD_{0,05}$ for treatments	NS	NS	NS	NS	NS	NS	
Species							
Arrhenatherum elatius	9.1	7.5	3.0	7.2	10.2	8.7	7.62 a
Dactylis glomerata	7.8	7.7	4.1	5.2	8.6	8.3	6.95 b
Poa pratensis	4.2	5.1	2.0	3.7	6.7	10.1	5.30 c
Festuca rubra	4.4	4.2	2.3	2.3	4.2	6.2	3.93 d
Average	6.37 B*	6.09 B	2.81 D	4.56 C	7.39 A	8.29 A	
$LSD_{0,05}$ for species 0.55; $LSD_{0,05}$ for period 1.29							

I – two weeks after over-drilling; II - one week after first defoliation
Low cutting (without herbicides); Herbicides – Starane + Aminopielik, active substances: fluroxypyr + 2.4D;
* figures indicated by the same letters are not significantly different

Conclusions

Roundup blocked the re-growth of plants from original sward for the longest time. Selective herbicides effectively limited the occurrence of dicotyledonous plants, however, they did not reduce the competitiveness of monocotyledonous plants from the original sward and decreased their re-growth pace only to a small extent. Re-growing grasses effectively competed with young plants introduced during over-drilling, whilst species developing short underground runners very quickly colonised spaces in the sward. Low cutting proved to be an inefficient solution for limiting the competitiveness of the original sward. On the other hand, rotary tillage created good conditions for re-growth of dicotyledonous plant from parts of underground vegetative organs and stimulated seeds in the soil to start germinating. The results of the research showed that the late summer period was better for grassland renovation by means of over-drilling than the spring period. This was due to a lower capacity of the plants from the original sward to start re-growing.

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Quantitative and qualitative dynamics of sward production in clover/grass pastures

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Abstract

The trial was carried out in the years 1999–2004 in West Lithuania's undulating region on the north-west-facing slope with a mean inclination of 5°. Perennial clover/grass mixtures (60% clover and 40% grasses *Lolium perenne* and *Poa pratensis* at initial ratio 1:1) were sown with barley as a cover crop. The plot size was 20 m^2. The following treatments replicated four times were: 1. *Trifolium repens*, grasses; 2. *T. pratense*, grasses; 3. *T. repens* 30%, *T. pratense* 30%, grasses; 4. Grasses. The experimental area was grazed 3–5 times per season with cattle. Prior to each grazing one half of the plots were cut for herbage DM yield, its botanical composition, crude protein and crude fibre content measurements. The yield of pasture varied within the grazing season, the treatment and especially year of use. In total, the most productive were the swards of mixtures including red clover. The highest composition of legumes in the DM yield was identified in the second and fifth years of use in the mixtures with red clover. The highest protein content in herbage was recorded in the second year of use in the mixed clover/grass pasture when the swards contained a large amount of legumes and ryegrass, noted for their high feeding value.

Keywords: clover, grasses, grazing, yield, botanical composition, quality

Introduction

Ecological farming is steadily increasing in importance in European farming systems. As the use of mineral nitrogen fertiliser is strictly prohibited on such farms, legumes such as white and red clover are an important source of nitrogen. Legumes grown with grasses offer several advantages over grasses or legumes grown alone, *ie.* increased yield of a higher quality pasture as well as improved seasonal distribution of the forage (Sleugh *et al*., 2000). Legume/grass mixtures reduce weed encroachment and erosion (Droslom and Smith, 1976 in Sleugh *et al*., 2000; Geherman *et al*., 2003). White clover in binary mixtures with grasses contributed to the production of high quality herbage swards with the average yields of crude protein 1.14 to 1.75 t ha^{-1}, on brown-lessive and sod-podzolic gleysolic soils under conditions of Latvia (Adamovich, 2002). The yields of dry matter and protein in the mixtures depended on the associated grass species.
The purpose of this study was to estimate the effects of white and red clover grown in different mixtures with perennial ryegrass and smooth-stalked meadow grass on the DM yield, on botanical composition and on quality in N unfertilised swards under grazing management on the hilly soils of West Lithuania.

Materials and Methods

The trial was carried out in the years 1999–2004 in West Lithuania's undulating region of the southern-central Zemaiciai Upland (55°36′N, 22°28′E) at 160–170 m altitude on the north-west-facing slope with a mean inclination of 5°. Local soils are sandy clay loam Dystric

Albeluvisols. Mean organic matter content in the Ah horizon (0–20 cm depth) was 20.0 g kg^{-1}, available P 136, K 115 mg kg^{-1} and pH_{KCl} 5.5. Perennial clover/grass mixtures (60% clover and 40% perennial ryegrass and smooth stalked meadow-grass at initial ratio 1:1) were sown with barley as a cover crop. The plot size was 20 m^2. The following treatments replicated four times were: 1. White clover (w.clover), grasses; 2. Red clover (r.clover), grasses; 3. W.clover 30%, r.clover 30%, grasses; 4. Grasses (control). During the growing season, the swards were grazed with cattle. In the first production year (2000) the plots were grazed five times, second and fifth years – four times, and for the 2002 and 2003 – only three times. Prior to each grazing, one half of the plots were cut for herbage DM yield, its botanical composition (dead material, *T. repens*, *T. pratense*, *L. perenne*, *P. pratensis* and other not sown herbs), crude protein and crude fibre content measurements.

Results and Discussion

Seasonal changes in botanical composition of a grass/legume pasture were investigated annually under each grazing (Figure 1).

In the mixed legumes/grass pastures, white clover accounted for 17.3–69.4% in the first treatment and for 4.3–14.7% in the third (averaging respectively 43.2 and 10.2% throughout the season). Red clover accounted for a larger part in the DM yield than white clover in respective treatments: from 34.9–86.3% in the triple *T. pratense-L. perenne-P. pratensis* mixture and 8.1–70.1% in the mixed red and white clover/grass pasture, averaging throughout the season 50.8–61.3%, respectively. There were similar trends in the composition change in the mixed clover/grass pasture. In most cases the proportion of legumes was the lowest in the herbage mass of the first grazings and increased in the herbage of subsequent grazings. Seasonal increase in legumes occurred in the first to fourth year of pasture use and in the fifth year in mixtures with white clover. In the dry third and fourth years of use, a marked reduction in both clover species occurred. However, in the fifth year of pasture use white clover already accounted for 34.05–58.1% and red clover for 37.01–56.04% of sward yield. Both white and red clovers lack drought tolerance. Geherman *et al.* (2003) noted that red clover is short lived and sensitive to unfavourable growing and wintering conditions. Perennial ryegrass was the dominant grass species in the herbage in all treatments. With some exceptions this was specific to all grazings, especially at the beginning of the trial. In later years of pasture use the content of ryegrass tended to decline. Poor persistence of perennial ryegrass is often attributed to lack of winter-hardiness but may also be due to drought stress in autumn which is not apparent until spring growth is impaired (Karsten and MacAdam, 2001). In mixed clover/grass pastures during the 2000 and 2001 grazing seasons, the share of grasses in DM yield declined. The share of smooth-stalked meadow grass was very low but increased within the year of use. The advantage of *P. pratensis*, as a pasture component best adapted to adverse wintering conditions was revealed in the fourth year of sward use. Its share in the dry matter of herbage of the first grazing was approximately that of ryegrass. In the first year of use, the share of herbs in the DM yields of swards varied on average within 9.33–23.66%. In the third and fourth years of swards use all treatments, especially the first grazing, were characterized by an increased content of unsown species of herbs. Dandelion accounted for the vast majority in the first year. In the second and later grazings in the fifth year, populations of small-leaved prostrate forms of white clover were dominant. They constituted a high proportion of the sward in the control treatment grass pasture. The content of dead material (mainly stubble) amounting to 6–13% was found only in 2000 in the first grazing.

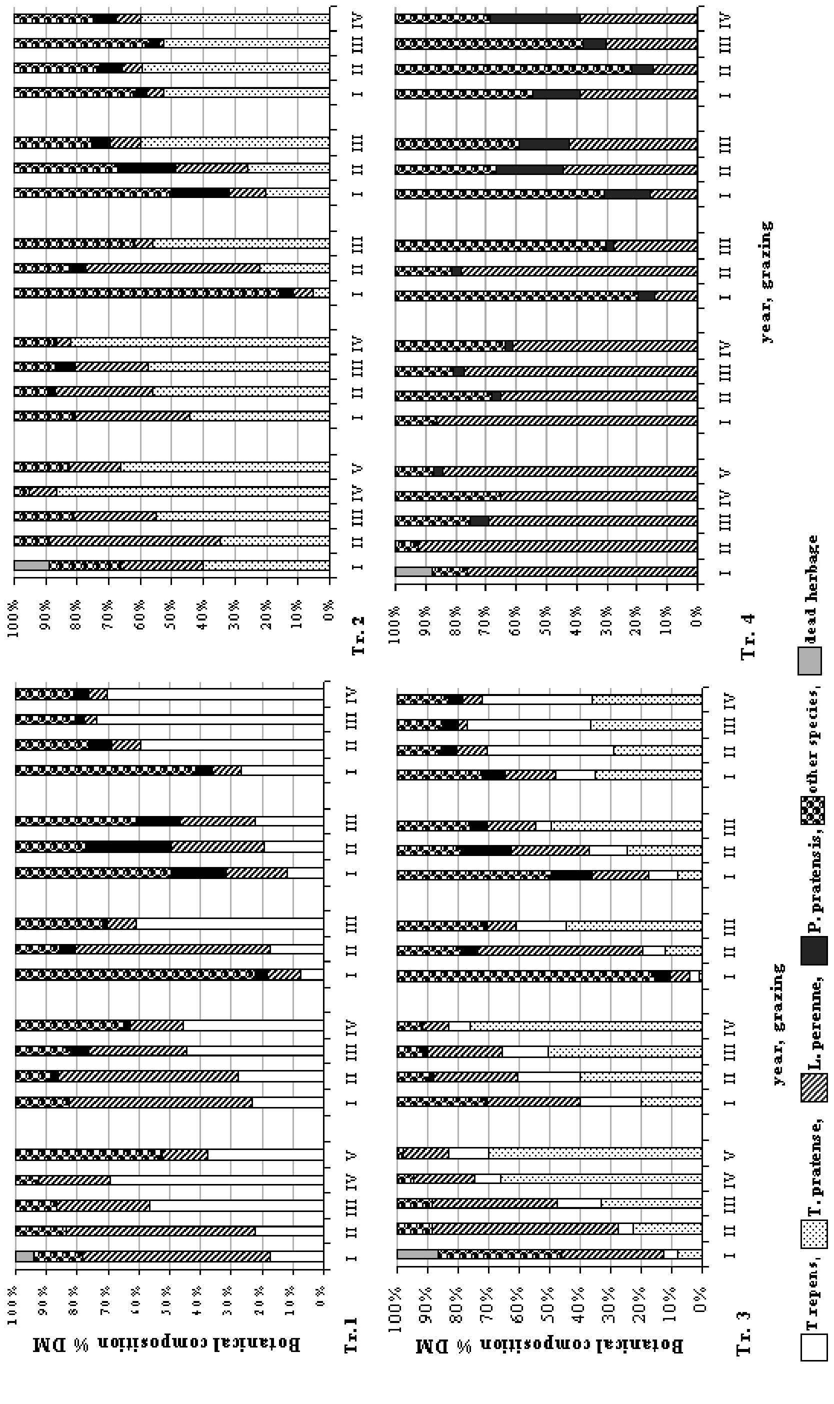

Figure 1. Seasonal changes in botanical composition of swards %, 1999–2004

The yield of the pasture varied within the grazing season, the treatment and especially year of use. The first year dry matter yield reach from 2.56 t ha^{-1} in grass sward to 3.90 t ha^{-1} in red clover/grass sward (Table 1). From the second year of use, white clover/grass mixtures were inappreciably out yielded by the control treatment consisting of grasses. All mixed swards exhibited a more pronounced response to adverse weather conditions in the third to fourth year of swards use compared with grass swards. In 2002 herbage DM yield was the lowest of all the experimental period, while the highest yield was obtained in the fifth year of sward use (8.46 to 9.57 t ha^{-1}).

Table 1. Annual dry mater yield of swards t ha^{-1} in 1999–2004

Treatment	Year				
	2000	2001	2002	2003	2004
1. W.clover 60% + ryegrass, meadow-grass in 20%	3.58	6.50	2.70	4.02	8.46
2. R.clover 60% + ryegrass, meadow-grass in 20%	3.90	7.65	2.46	4.14	8.93
3. W.clover, r.clover in 30% + ryegrass, meadow-grass in 20%	3.73	8.38	2.61	4.46	9.57
4. Ryegrass, meadow-grass in 50%	2.56	6.55	2.98	4.60	8.72
LSD_{05}	0.458	0.234	0.742	0.582	0.239

The most productive was the sward mixtures including both white and red clover. Recent research indicates potential herbage yield benefits from species-rich mixtures for pastures (Sanderson *et al.*, 2004). In our experiment the year had a dramatic effect on herbage yield. This agrees with many researchers' findings. The yield in one year could be less than half in the other year (Bryan *et al.*, 2000). A fluctuation in DM yield most likely depends on the amount and distribution of rainfall. One of the reasons why the yield of mixed swards did not exceed significantly that of grass swards in every year could be the fact clovers are best adapted to fertile soil with a pH ranging from 6.0 to 7.0.

Herbage quality of swards ranged from 135.7 to 211.0 g kg^{-1} of crude protein and 199.5–242.7 g kg^{-1} of crude fibre (Fig. 2). Variation of herbage mass quality depended on treatment, grazing and year. In the dry and hot third and fourth years of use the herbage was noted for the highest fibre and lowest protein content, which was especially obvious in the mixed swards. It is known that forages grown under high temperatures are usually of lower quality than those grown in cool conditions (Buxton *et al.,* 1995).

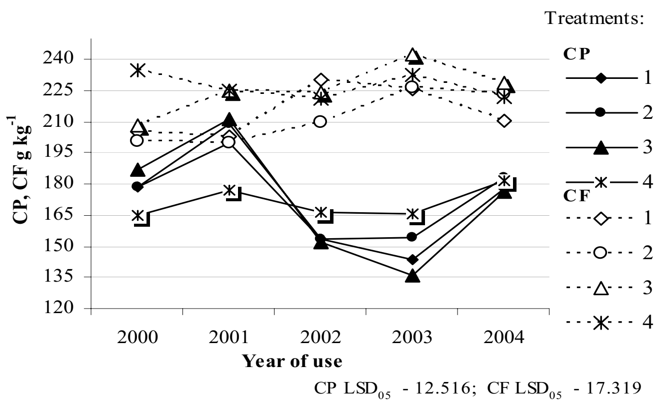

Figure 2. Concentration of crude protein and crude fibre (g kg^{-1} DM). Averaged annual data, 1999–2004

The reduced CP content of the herbage grown under the dry conditions of 2002, compared with normal conditions, can be explained by a reduction in N uptake by plants in response to water deficits. The highest protein content in herbage was recorded in the second year of use in the mixed clover/grass pasture when the swards contained a large amount of legumes and ryegrass, which is noted for its high feeding value. During the whole experimental period the most stable chemical composition was identified for grass swards.

Conclusions

The productivity of white clover/grass mixed swards depended on meteorological conditions. Red clover/grass mixture swards were more productivity in all years of use.

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The improvement of fodder galega silage quality by using galega-grass mixtures and additive

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Abstract

In this ensiling study, direct-cut pure galega and galega-meadow fescue, galega-timothy and galega-bromegrass mixtures were ensiled without additive and with the chemical additive Niben at an application rate of 5 l t^{-1} fresh matter. The results indicated that the nutritive value of silage was dependent on the mixture. Pure galega resulted in the highest crude protein concentration. The silage fermentation quality was dependent on the mixture and the use of additive. The silage made of pure galega had the lowest quality. The fermentation of the galega-timothy mixture was superior to that of the other mixtures. Niben reduced butyric acid and ammonia concentration in silage by 59–80%. Dry matter losses were reduced by 60–76%. Interactions occurred between the use of additive and choice of mixture.

Keywords: fodder galega, galega-grass mixture, additive

Introduction

Fodder galega (*Galega orientalis*) belongs to the group of legumes crops. Legumes have a high nutritive value but they are known to be difficult to ensile and often result in poorly fermented silage. This is mainly due to high buffering capacity (BC) and low available sugar (WSC) concentration (McDonald *et al*., 1991). Compared to other legumes, galega has even higher BC and lower WSC concentrations and ensiling is particularly problematical. However, studies have shown that the use of an efficient additive may considerably reduce clostridial fermentation and losses (Raig *et al*., 2001; Lättemäe *et al*., 2000). It is also possible to use galega-grass mixtures to improve the fermentation properties of the silage material. The aim of this study was to investigate the influence of different galega-grass mixtures and the use of additive on fermentation quality and dry matter losses.

Materials and Methods

The ensiling trial was carried out in 2004. Silage material was collected from first-cut galega, galega-meadow fescue, galega-timothy and galega-bromegrass mixtures. Grass originated from Juuliku grassland trial plots, which were established in 2003. The seed sowing rate of galega was 20 kg ha^{-1}. The same seed rate was used for galega in the mixtures but with meadow fescue 'Arni' at 10 kg seed ha^{-1}, timothy 'Tika' at 6 kg ha^{-1} or bromegrass 'Lincoln' at 15 kg ha^{-1}. The field was fertilized with ammonium nitrate (40 kg N ha^{-1}) in spring 2004. The silage was made of direct-cut crop. The crop was harvested by a mowing machine, chopped 4–6 cm chop-length and ensiled in 3–l glass jars. The following additive treatments were used in two replicates: untreated and Niben-treated at 5 l t^{-1} fresh matter (FM). Niben is a chemical additive based on sodium benzoate. In addition it also contains sodium nitrite. Glass jars were sealed with four layers of plastic film (0.025 mm thickness) and their weights were recorded. Thereafter, the jars were stored at room temperature (18–25 °C) for 100 days, after which samples were taken for chemical analyses. In order to determine dry matter losses, the weights were again recorded prior to opening the jars. The trial data were examined statistically by analysis of variance using the GLM procedure of the computer package SAS.

Results and Discussion

The silage quality, fermentation products and dry matter losses are presented in Tables 1 and 2. The nutritive value of silage was dependent on the mixture. Silage made of pure fodder galega had higher crude protein and lower fibre concentrations compared to mixtures. In the mixtures the nutritive value of silage decreased. However, the results indicate that the crops were harvested too late, in view of the relatively low protein and high fibre concentrations of the silages. The crude protein concentration of mixture silages varied in the range 111–127 g kg^{-1} DM (dry matter) and the crude fibre concentration in the range 312–361 g kg^{-1} DM.

Table 1. The effect of galega-grass mixtures and the use of additive on chemical composition and dry matter losses of silage

Mixture Additive	Dry matter (DM) g kg^{-1}	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	pH	Ammonia % of total N	DM losses %
Galega						
Untreated	127	160	303	5.9	34.5	14.4
Niben	149	181	276	4.5	7.5	3.5
Galega + meadow fescue						
Untreated	167	113	355	5.8	32.9	11.5
Niben	179	122	329	4.4	7.2	4.3
Galega + timothy						
Untreated	185	119	330	5.4	13.5	10.1
Niben	205	127	312	4.2	5.0	3.4
Galega + bromegrass						
Untreated	187	111	361	5.9	19.9	9.0
Niben	196	125	343	4.6	8.1	3.6
$LSD_{0.05}$		22.8	42.2	0.5	8.7	3.5

All silages had relatively low DM concentration, particular pure galega. The average DM concentration of galega silage was 138 g kg^{-1}. Such silage material favours the growth of clostridia and enterobacteria and results in high effluent losses.

The fermentation quality and DM losses were dependent on the mixture but mostly on whether additive was used. The lowest quality silage was produced where pure galega was ensiled without additive. The average butyric acid concentration of galega silage was 36.7 g kg^{-1} DM, butandiole 11.2 g kg^{-1} DM and ammonia-N 34%. Dry matter losses were 14.4%. Such silage is completely spoiled and of no use as an animal feed. Niben reduced clostridial fermentation about five times and resulted in medium quality silage. There was a corresponding reduction in DM losses.

Mixtures also improved fermentation and reduced DM losses. However, the results were variable and the effect was smaller. There were also interactive effects when using additive and mixtures (Figures 1 and 2). The lowest quality of silage was obtained when the galega-meadow fescue mixture was ensiled and followed the galega-bromegrass and galega-timothy mixtures. The best silage quality was obtained when galega-timothy mixture was ensiled together with additive. In this silage, the butyric acid concentration was 4.6 g kg^{-1} DM, butandiole 0.4 g kg^{-1} DM, ammonia-N 5.0% and pH 4.2. On this basis, this was considered to be a good quality silage.

Table 2. The effect of galega-grass mixtures and the use of additive on silage fermentation

Mixture Additive	Acetic acid g kg^{-1} DM	Propionic acid g kg^{-1} DM	Ethanol g kg^{-1} DM	Butandiole g kg^{-1} DM	Butyric acid g kg^{-1} DM
Galega					
Untreated	23	7.0	32	9.2	36.7
Niben	29	1.7	18	0.9	7.5
Galega + meadow fescue					
Untreated	24	4.6	78	11.2	22.3
Niben	22	1.6	35	1.8	6.9
Galega + timothy					
Untreated	7	1.0	49	9.0	17.0
Niben	13	0.3	30	0.4	4.6
Galega + bromegrass					
Untreated	9	2.0	31	11.0	23.0
Niben	18	0.5	17	2.2	4.6
$LSD_{0.05}$		1.5	19.8	4.8	7.6

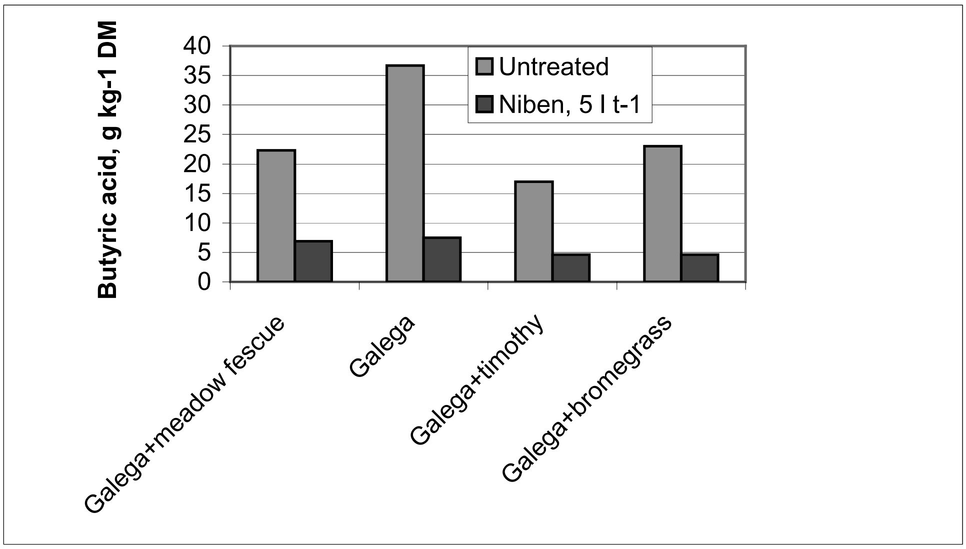

Figure 1. Butyric acid concentration in pure galega and galega + grass silages prepared with and without additive

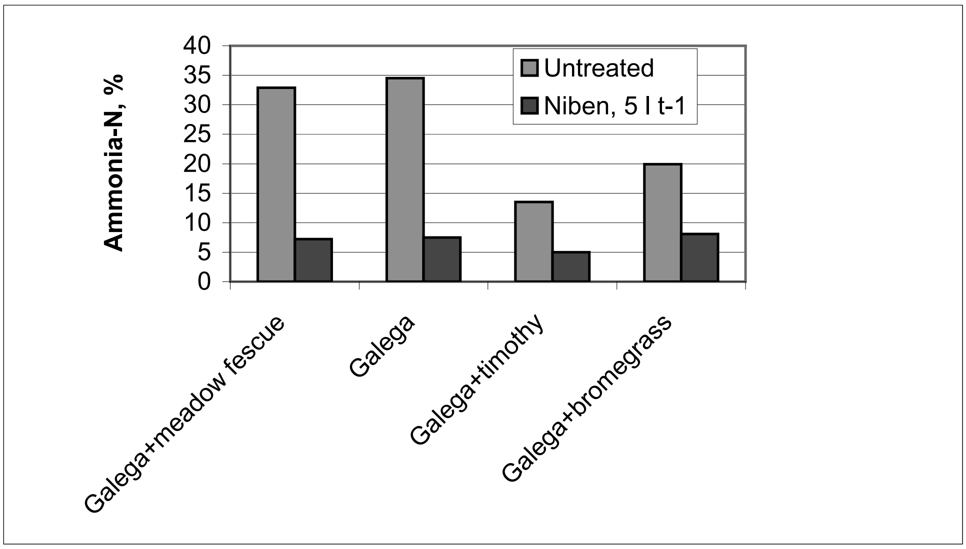

Figure 2. Ammonia-N concentration in pure galega and galega + grass silages prepared with and without additive

Conclusions

The results indicated that the quality of silage, made of fodder galega, can be improved when it is grown in a mixture with grasses and an effective additive is used. The best silage quality with minimal DM losses was obtained when a galega-timothy mixture was ensiled with additive treatment. Of the mixtures, the galega-meadow fescue silage had the lowest quality. There were interactive effects on fermentation between choice of mixture and whether additive was used. The results indicated that the additive had a greater effect than the choice of mixture.

Acknowledgements

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Strip over-sowing of selected species in a mountain region of Slovakia

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Abstract

In 2001, a field trial with over-sown grasses and legumes was established in the Low Tatras (northern Slovakia). The over-drilled legumes and grasses were *Trifolium pratense* cv. Vesna, *Medicago sativa* cv. Zuzana, *Lotus corniculatus* cv. Polom, *Festuca arundinacea* cv. Kora, *Bromus marginatus* cv. Tacit and *Arrhenatherum elatius* cv. Median. The species were introduced into the original sward by the strip over-sowing method. *Bromus marginatus* had the highest germination (46.50%) while *Festuca arundinacea* had the lowest (9.67%). The average content of legumes to yield ranged from 26 to 38% while the content of grasses ranged only from 16.1 to 20.4%. The most productive species were *Trifolium pratense* and *Festuca arundinacea* (DM yield of 5.015 and 5.182t ha^{-1}, respectively).

Key words: over-sowing, germination, herbage production, grass, legume

Introduction

Despite a decreasing number of ruminants, extensive management of grasslands and a preference for forage production on arable soil, there will be a need to use grassland intensively in some regions of Slovakia. Čaboun (1996) observed that the trend in climate change can result in adaptation of existing ecosystems either to advantage or disadvantage. In some cases, it can lead to damage to ecosystems. The aim of this study is to investigate use of some agricultural legume and grass species suitable for dry conditions into mountain environment by using the strip over-sown method.

Materials and Methods

The trial was carried out at a site at Liptovská Teplička (northern Slovakia). The main site characteristics were: average annual rainfall 900 mm (500 mm during the growing season) and average annual temperature 4 °C (9.5 °C during the growing season). Over the growing seasons of 2001–2004 the total rainfall was 592.2 mm, 462.6 mm, 322.0 mm and 510.9 mm, respectively. The soil was a rendzina with pH 6.97, contents of humus 55.00g kg^{-1}, of total nitrogen 0.30g kg^{-1}, of P 2.25mg kg^{-1}, of K 100.59mg kg^{-1} and of Mg 643.67mg kg^{-1}. Over-sown species and seed rates are given in Table 1.

Table 1. Treatment, species, seed rate and field germination of over-sown species

Treat-ment	Oversowing species	Cultivar	Seed rate[1]	Germination[2]	Percentage of germinated plants[3]
1.	*Trifolium pratense* L.	Vesna	800	217	27.13
2.	*Medicago sativa* L.	Zuzana	800	235	29.38
3.	*Lotus corniculatus* L.	Polom	1500	273	18.20
4.	*Festuca arundinacea* Schreb.	Kora	1200	116	9.67
5.	*Bromus marginatus* Ness ex Steud	Tacit	400	186	46.50
6.	*Arrhenatherum elatius* L.	Median	1210	294	24.30

[1] germinate seeds per meter quadratic [2] pieces established plants from strip with length 1 m[3] %

Seeds were over-sown on 31st July 2001 using the seeding machine SPP 6 (made in the Czech Republic). The seeding machine made two strips per treatment (dimensions of a plot: 10m x 1.5m; four randomized replicates) and cultivated a strip of soil 0.10m deep and 0.15m wide 0.5m apart. In 2001, field germination was assessed 21 days after over-sowing by counting established seedlings along a 1m transect for three replicates per plot.

For all treatments P and K were applied at rates of 30 kg ha^{-1}, 50 kg ha^{-1}, respectively. For over-sown grasses nitrogen was applied at the rate of 120 kg ha^{-1} divided into two applications. Before each cut, botanical composition according to Gáborčík and Javorková (1980) and proportion of over-sowing species in total fresh yield from the plots of 1.5 m × 0.15 m were assessed. Total yield dry matter was determined in three cuts over the growing season (dates of cutting: early June, early July and end September).

Results and Discussion

Krajčovič and Knotek (1995) reported that field germination of *Trifolium pratense* in strip over-sowing varied from 20 to 22% of the seed rate. Higher field germination was found with *Trifolium pratense* and *Medicago sativa* and lower with *Lotus corniculatus* (Table 1). But the *Bromus marginatus* had the highest germination (46.50%) and *Festuca arundinacea* the lowest (9.67%).

The average herbage production over 3 years, relative content of over-sown species in yield, absolute content of over-sown species in weight and presence of over-sown species in sward are given in Table 2. The highest proportions were observed for *Trifolium pratense*. The average weight proportion of legumes in the total yield ranged from 23.3 to 38.0% while the proportion of grasses ranged only from 16.1 to 20.4%.

Presence of *Arrhenatherum elatius, Lotus corniculatus* and *Festuca arundinacea* was low. The lowest were recorded in the treatment with *Medicago sativa* and *Bromus marginatus*. Over the 3-years of the investigation, botanical composition of grassland changed according to management. *Trifolium repens* gradually dominated in treatments which received applications of PK fertilisers and native *Dactylis glomerata* dominated the N fertiliser treatments.

Table 2. Mean herbage production, relative content of over-sown species in yield, absolute content of over-sown species in yield, presence of over-sown species in sward (3-year average)

Treatment	herbage yield, t ha^{-1}	weight proportion, %	Proportion in yield, t ha^{-1}	Species presence in sward, D %
1.	27.107	38.0	10.161	38.5
2.	19.658	23.3	4.549	22.7
3.	20.171	26.9	5.293	28.8
4.	23.361	19.8	4.503	28.7
5.	20.680	16.1	3.132	18.5
6.	22.459	20.4	4.428	29.2

DM yield in each year and the average of three years are given in Table 3. The highest DM production (average over three years) was reached on the treatment with over-sown *Festuca arundinacea* and the smallest in the treatment with over-sown *Medicago sativa* (Table 3). DM production of over-sown grasses exceeded that of legumes with the exception of *Trifolium pratense*. However, over-sown grass species responded to nitrogen from mineral fertilisers. *Trifolium pratense* was the control for legumes and produced higher DM yield in comparison with the over-sown *Medicago sativa* and *Lotus corniculatus*, production of which reached only 77.8 per cent and 78.0 per cent respectively. *Festuca arundinacea* was the control for over-sown grasses. Dry matter production of over-sown *Bromus marginatus* and *Arrhenatherum elatius* relative to control was higher than that of over-sown legumes relative to the legume control, but the production of the two grasses did not exceed that of *Festuca arundinacea*.

Table 3. DM production of grassland with over-sown legume and grass species (± standard deviation) (t ha^{-1})

Treatment	2002	2003	2004	mean	proportion, %
Treatments with over-sown legumes					
1.	5.919 ± 0.503	4.222 ± 0.216	4.923 ± 0.700	5.015	100
2.	4.460 ± 0.505	2.695 ± 0.210	4.550 ± 0.432	3.902	77.8
3.	4.260 ± 0.277	2.826 ± 0.292	4.643 ± 0.532	3.910	78.0
$LSD_{0.05}$	1.045	0.466	0.848		
$LSD_{0.01}$	1.502	0.640	1.219		
Treatments with over-sown grasses					
4.	5.738 ± 0.581	3.663 ± 0.311	6.146 ± 0.182	5.182	100
5.	4.912 ± 0.358	3.455 ± 0.361	5.515 ± 0.653	4.627	89.3
6.	5.172 ± 0.686	3.460 ± 0.477	6.167 ± 0.498	4.933	95.2
$LSD_{0.05}$	0.823	0.719	1.031		
$LSD_{0.01}$	1.183	1.034	1.482		

Overall, the highest DM yield was achieved in the treatment with over-sown *Trifolium pratense* in the first harvest year. At $P < 0.01$, DM production of this treatment was significantly higher than the treatment with over-sown *Lotus corniculatus*. A significant difference at the level $P < 0.05$ was recorded between treatments with *Trifolium pratense* and *Medicago sativa* and between *Festuca arundinacea* and *Bromus marginatus*. Significant differences at the level $P < 0.05$ among over-sown legumes were recorded only in the second harvest year. Dry matter production of the treatment with *Trifolium pratense* was significantly higher than those with over-sown *Medicago sativa* and *Lotus corniculatus*. No significant differences were observed between over-sown grasses in the second harvested year and among all over-sown species in the third year.

DM production of *Medicago sativa*, *Lotus corniculatus, Bromus marginatus* and *Arrhenatherum elatius* were expected to be higher, as they are drought-resistant species. Their DM production did not exceed the yield of the control treatments, *Trifolium pratense* and *Festuca arundinacea,* in the second harvested year, when total rainfall in the growing season was the lowest. However, the cause of low production of these species may have been their lower suitability for the climatic conditions experienced. Their role should increase when conditions experienced in the second harvested year are repeated. Low defoliation height could also have been the reason for the low DM yield of *Bromus marginatus*. Míka and Řehořek (2004) reported that low cutting height limits formation of new tillers of *Bromus marginatus* because supply of carbohydrates decreases and/or the apical domes of new tillers are cut. These authors recommended that *Bromus marginatus* be cut at the height 5–8 cm but in our trial the height was 3 cm.

Conclusions

DM yield of over-sown species Medicago sativa, Lotus corniculatus, Bromus marginatus and Arrhenatherum elatius were lower in comparison to Trifolium pratense and Festuca arundinacea in the humid region of Slovakia. However, Medicago sativa, Lotus corniculatus, Bromus marginatus and Arrhenatherum elatius can play an important role in this region of Slovakia, if the shortage of rainfall will be similar to that in 2003.

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The effects of feeding grass and grass/clover silages on dairy cows' metabolism

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Abstract

Holstein-Friesian cows were fed wilted silage from herbage of semi-natural grassland and wilted silage from grass/clover mixture preserved in large round bales. From beginning of lactation and till the end of research trial there were not recorded significant differences in metabolic profile indices of animals. The limiting factor of the production was nitrogen nutrition in both observed forages over the whole lactation. The activation of dairy cow immune system within the haematological background was confirmed by high values of leukocytes. In comparison with referential range dairy cows of both groups had markedly lower haemoglobin values during the lactation. Over the second half of lactation the considerable appearance of chronic ketosis was recorded. In spite of that the mean daily milk yield at dairy cows fed with silage from semi-natural grassland herbage and grass/clover silage was achieved 20.80 kg head^{-1} and 20.78 kg head^{-1}, respectively. The portion of concentrate supplements in feeding rate was low (max 25%). The results confirm the high production potential of investigated silages.

Keywords: silage, ketosis, demineralisation processes

Introduction

Grasslands represent the base of forage production in the upland regions of Slovakia. Silage making is the effective way of herbage preservation to keep nutritive value of herbage and high production efficiency as well. A decrease in the number of ruminant animals in recent years in this region has resulted in a decrease in forage production and thus, more attention has been devoted to production of silage and its quality. The objective of the paper was to evaluate production potential of wilted silage from herbage of semi-natural grassland and from grass/clover sward and the effect on metabolism and health of dairy cows.

Materials and Methods

During the research trial wilted silages made from grass/clover (GCM) mixture (*Trifolium pratense* L. – cv. Kvarta 4n, inter-generic hybrid Odra (*Lolium* x *Hybridum Heausskn*.) and inter-generic hybrid Becva (*Lolium multiflorum* x *Festuca arundinacea*) and from herbage of semi-natural (PG) grassland (*Lolium perenne* L., *Festuca rubra* L., *Festuca pratensis* Huds., *Dactylis glomerata* L., *Phleum pratense* L., *Poa pratensis* L., *Trifolium repens* L., *Trifolium pratense* L. and other herb species), respectively, were fed to dairy cows over the whole lactation. The swards received fertiliser at the rates of 60 kg N ha^{-1} and 50 kg P ha^{-1}. Herbage was harvested at the stage of ear emergence, wilted to reach the recommended dry matter content of 350–400 g kg^{-1} and ensiled in big wrapped round bales. Two groups of eight Holstein x Friesian dairy cows were fed only one type of silage as the sole forage crop of their ration. To achieve homogeneity of the experimental groups, milk yield at previous lactation was taken into account. Cows were individually fed, the rations were weighed daily and faeces were recorded before feeding in the morning. The feeding ration was provided twice a day and consisted of one type of wilted silage and concentrates (a commercial HD-12 mixture containing crushed maize and soybean meal). Composition of feeding ration is given in the Table 1. Average samples of the wilted silage and concentrates were taken at regular two-week intervals to analyse the nutrient content and to determine the nutritive value. Quality rank (class) of wilted silage was assessed subjectively. Production efficiency of silages was calculated as difference between production efficiency of total feeding ratio (True-test) and production milk potential of each concentrate supplements on the base of their nutritive value and nutrient requirement for milk production.

Table 1. Mean forage intake (kg DM) and production (kg milk) of feeding rations (per the whole lactation)

Group	Silage	HD-12	Soybean meal	Crushed maize	Total feeding ration	Milk production	
						silage	total feed. ration
1. (GCM)	13.45	2.72	0.80	0.76	17.73	11.19	20.80
2. (PG)	13.10	2.22	1.02	0.77	17.12	12.03	20.78
P < 0.05	–	+	–	–	–	–	–

Within the whole period of experiment, individual milk production of each dairy cow was recorded every seventh day at the evening and the morning milking using the Tru-test. To assess parameters of metabolism, the milk, urine and blood samples from *Vena jugularis* were taken at each lactation stage (on the 60th, 150th and 240th day of lactation). Only the mean values for the whole of lactation are presented in Tables 3 and 4. The differences between the animal groups were analysed and statistical significance was determined using the Tukey-test at the significance level of $\alpha<0.05$. The referential range for each parameter was taken from long-term data from the State Veterinary Institute of Slovak Republic.

Table 2. Mean nutrient content in DM and nutritive value of feeds (per the whole lactation)

Parameter/ Feeds	Dry matter	Crude protein	Fat	Ash	Fibre	P	Ca	PDI	NEL	NEV	ME
					g kg^{-1} DM					MJ kg^{-1} DM	
GCM silage	346.65	110.94	37.07	101.61	280.73	3.73	6.41	63.10	5.34	5.13	9.12
PG silage	394.08	108.37	39.63	96.96	280.95	2.92	6.85	65.80	5.63	5.48	9.54
Soybean meal	859.81	192.68	25.45	76.32	35.74	11.10	12.87	128.70	6.10	5.97	10.33
Crushed maize	860.91	69.32	42.61	12.03	5.22	2.89	0.29	45.00	9.02	9.80	14.06
Concentrate HD-12	879.62	606.90	16.87	72.68	6.00	7.10	5.22	271.60	8.34	8.59	13.61

Results and Discussion

The mean daily milk yield at dairy cows fed with wilted grass/clover silage (Group 1) was 20.80 kg head^{-1} per day (Table 1), and that only 0.02 kg more than that recorded with wilted herbage from permanent grassland (Group 2). DM intake was higher with wilted silage made from permanent grassland. Considering lower nutrient content of the silages, mainly of grass/clover silage, quality rank for both the silages was specified as Class 1 and Class 2. In terms of total milk yield, production efficiency was 11.19 kg with grass/clover and 12.03 kg with permanent grassland silage, respectively. The differences in milk production between cow groups were not statistically significant. Wilman and Williams (1993) observed intake of 14.6 kg DM head^{-1} day^{-1} with wilted *Lolium perenne* silage. The studies of Valihora (2002) showed that milk efficiency of *Lolium perenne* silage was 9.6 kg milk. Similarly, Sommer *et al*. (1995) recorded production efficiency of the basic feeding ration 8 kg of milk by feeding wilted grass silage with DM content of 380 g kg^{-1} and fibre content of 260 g kg^{-1} DM.

High content of crude protein, correct proportion of fibre in DM indicate that GCM and PG silages were harvested at the optimum harvest date. GCM silage was expected to have higher crude protein content because of higher proportion of legumes in the sward. Nevertheless, crude protein content was similar to PG silage. Feeding value expressed by PDI, NEL, NEV and ME parameters (Table 2) was similar for the both silages. For this reason, differences in the milk production in the both groups were small and non-significant.

At the beginning of lactation during the puerperal period, decrease in live weight gain was recorded. The change became over the second third of lactation, when live weight gains increased in both groups of dairy cows. During the first third of lactation, chronic ketosis and demineralisation processes were observed. The increased level of aspartate aminotransferase, alanile aminotransferase and γ-glutamyltransferase in blood plasma shows the processes of lipolysis and demineralisation (Table 3, Table 4). Consequently, detoxification function of liver was restricted and liver dystrophia was occurring. In contrast with referential range, dairy cows of both groups had markedly lower haemoglobin values during the lactation than would be expected. Over the second half of lactation, chronic ketosis was recorded. The secondary process of ketosis was burning of fat and body stores which is a life-threatening condition and the cows lost weight. Utilisation of fatty substances leads to a gradual imbalance and results in greater than normal production of ketone substances (Jursik, Kvietkova, 1997). Moreover, dairy cows suffering from ketosis produce milk of low nutritional and dietetic quality due to increased content of ketone substances (mainly acetone) and decreased lactose (Foltys *et al*., 1996). Tylecek (1998) reported that ketosis is the most frequently and serious metabolic disease of dairy cows, and is most commonly found in high producing animals during the first lactation period, and most frequently during the first two months after calving. Simplified diets based on a one-component feeding ration are most often associated with these effects. Mariscakova and Vajda (2002) showed that mixed feeding rations maintained energy metabolism parameters at more normal levels recorded in referential data.

Over the last third of lactation, increased release of calcium in urine and decreased values of pure acid-base secretion in urine were observed, indicating the hypercalciurine condition of animals using these feeds (Table 4). Low levels of beta carotene in blood serum was observed over the whole of the lactation, a finding which could be associated with primary and/or secondary vitamin A deficiency. Low levels of beta carotene are known to reduce fertility in dairy cows.

Stastny (2002) reported that economic performance of livestock production is mainly determined by regular and sufficient reproduction. Maintenance of animal health needs optimal digestion processes in rumen and stability of intermediary metabolism (Goof, Horst, 1997; Oetzel, 1998). Disorders of energy and mineral elements metabolism are critical to high-yielding dairy cows, which are susceptible to the diseases.

Table 3. Mean nitrogen, energetic and enzymatic concentration of cow's urine and blood serum in the research groups and the referential range (per the whole lactation)

Group	Serum					Urine				Milk
	haem.[a] i.l^{-1}	erytr.[b] t.l^{-1}	leuc.[c] g.l^{-1}	hmg.[d] g.l^{-1}	urea mmol.l^{-1}	ket.[e]	pH	PABS[f] mmol.l^{-1}	spec. weight g.l^{-1}	urea mmol.l^{-1}
1. (GCM)	0.3	6.3	12.1	82	215	+	7.9	115	1029	4.7
2. (PG)	0.3	6.1	10.5	82	238	+	7.9	108	1030	5.0
r.range[k]	0.3–0.4	5.0–6.5	6.0–10.0	90–130	130–300		7.8–8.4	100–200	1030–1045	3.2–4.3
P < 0.05	–	–	+	–	+		–	–	–	–
	Serum									
Group	tot. lip.[g]	urea	gluc.[h]	chol.[i]	lipids	AST	ALT	ALP	GMT	β-car.[j]
	g.l^{-1}		mmol.l^{-1}		g.l^{-1}		ucat.l^{-1}		umol.l^{-1}	
1. (GCM)	72	4.9	3.2	5.3	4.2	0.5	0.3	1.1	1.1	3.1
2. (PG)	72	5.2	2.9	5.2	4.1	0.5	0.3	1.4	0.8	4.2
r.range[k]	68–84	3.0–5.0	3.0–4.0	2.8–5.2	4.0–8.5	0.2–0.5	0.2–0.4	0.2–0.8	0.2–0.5	7.4–21.0
P < 0.05	–	+	–	–	–	–	–	++	++	++

[a] haematocri, [b] erytrocytes, [c] leucocytes, [d] haemoglobin, [e] ketones, [f] pure acid-base secretion, [g] total lipids, [h] glukose, [i] cholesterol, [j] β-carotene, [k] referential range

Table 4. Mean content of minerals in urine and blood serum of observed animal groups and the referential range (per the whole lactation)

	Group	Ca	P	Mg	Na	K
				mmol.l^{-1}		
Serum	1. (GCM)	2.7	2.1	1.0	139	4.8
	2. (PG)	2.6	2.0	1.1	138	4.8
	referential range	2.3–2.8	1.7–2.0	0.8–1.1	136–152	4.1–5.5
	P < 0.05	–	–	–	–	–
Urine	1. (GCM)	1.7	3.2	5.4	50.0	166
	2. (PG)	1.2	3.2	5.4	33.7	158
	referential range	1.3–1.5	0.3–5.2	5.2–16.5	19.0–80.0	140–320
	P < 0.05	+	–	–	++	–

Conclusions

Daily DM intake was 13.45 kg and production efficiency was 11.19 kg with wilted grass/ clover silage. With grass silage DM intake was 13.10 kg and production efficiency was 12.03 kg of milk. The processes of lipolysis and demineralisation were observed with both animal groups. These effects are connected with restriction of feeding ration to sole forage. (GCM or PG silage), and confirms the potential health disorder in ruminants of feeding over-simplified diets. It is necessary to take into account the effect of each forage and their mixtures on animal health and performance. As most productive diseases have sub-clinical manifestation, farmers are not able to easily detect these disorders or estimate their impact on economic returns. However, ketosis processes can be reversed through the use of forage of high nutritive and dietetic value and a balanced diet.

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Ensiling of red clover and red clover-ryegrass mixture by using additives and herbage wilting

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Abstract

Red clover 'Varte' and red clover-ryegrass 'Molisto' mixture were ensiled without herbage wilting and with wilting for 24 hours in the field. The silage was made of first-cut crop. The clover and clover-grass silages were also prepared using the chemical additive, Niben or the biological additive 'Josilac' (5 l t^{-1} fresh matter). The results indicated that the nutritive value of silage was dependent on the mixture. Pure red clover 'Varte' resulted in the higher crude protein concentration. The silage fermentation quality was dependent on the mixture, herbage wilting and the use of additive. The lowest quality silage was made from fresh pure red clover. Herbage wilting and mixing clover with grass improved fermentation and silage quality. The silage additives improved fermentation, with Niben being the more effective. There were interactive effects when using additive, herbage wilting and red clover or clover-ryegrass mixture.

Keywords: red clover, clover-ryegrass mixture, silage quality, additives, herbage wilting

Introduction

Red clover (*Trifolium pratense*) is one of the most popular legume in grassland cultivation. Red clover has a high nutritive value but poor ensiling properties. This is mainly due to high buffering capacity (BC) and low available sugar concentration (McDonald *et al*., 1991). Furthermore, compared to other legumes, red clover usually has a lower dry matter (DM) concentration, which increases the risk of high effluent losses. This is particularly characteristic of tetraploid cultivars of red clover when they are ensiled (Olt, 2003; Lättemäe and Tamm, 2005). However, herbage wilting may considerably reduce clostridial fermentation and effluent losses. It is also possible to use red clover-grass mixtures and/or efficient silage additives.

Materials and Methods

The ensiling trial was carried out in 2004. Silage material was first-cut red clover cultivar 'Varte' and a red clover-hybrid ryegrass 'Molisto' mixture. The chemical composition of red clover was as follows: dry matter concentration (DM) 120 g kg^{-1}, neutral detergent fibre (NDF) 353 g kg^{-1} DM, acid detergent fibre (ADF) 200 g kg^{-1} DM, water soluble carbohydrates (WSC) 82 g kg^{-1} DM and buffering capacity (BC) 117 g lactic acid kg^{-1} DM. The chemical composition of the red clover-ryegrass mixture was DM 123 g kg^{-1}, NDF 418 g kg^{-1} DM, ADF 259 g kg^{-1} DM, WSC 117 g kg^{-1} DM and BC 101 g lactic acid kg^{-1} DM. The botanical composition the ensiled mixture consisted of approximately of 84% red clover and 16% ryegrass. Silages were made from both fresh-cut crop and wilted crop. When wilting, the crop was wilted for 24 hours in the field. The crop was harvested by a mowing machine, chopped 4–6 cm chop-length and ensiled in 3–l glass jars. The following additive treatments were used in two replicates: untreated, Niben-treated at 5 l t^{-1} fresh matter (FM) and Josilac-treated at 5 l t^{-1} FM. Niben is a chemical additive based on sodium benzoate, which also contains sodium nitrite. Josilac is a biological additive and consists of selected lactic acid bacteria. Glass jars were sealed with 4 layers of plastic film (0.025 mm thickness) and their weights were recorded. Thereafter, the jars were stored at room temperature (18–25 °C) for 100 days, after which samples were taken for chemical analyses. In order to determine dry matter losses, the weights were again recorded prior to opening the jars. The trial data were examined statistically by using GLM procedure of the computer package SAS.

Results and Discussion

The silage quality, fermentation results and dry matter losses for silage prepared from fresh and wilted herbage are presented in Tables 1 and 2, respectively. The nutritive value of silage material was dependent on the botanical composition. Pure red clover resulted in higher crude protein concentration and nutritive value compared to the mixture. On the other hand the mixture improved the fermentation properties of silage material by increasing WSC concentration and decreasing BC. However, both direct-cut red clover and red clover-ryegrass silages were very vet. The average DM concentration of red clover silage was 105 and the mixed silage 117 g kg^{-1}. Such silage material favours the growth of clostridia and enterobacteria and results in high effluent losses.

Table 1. The effect of using additives and red clover or clover-grass mixture on silage fermentation and dry matter losses. The silage was made from fresh cut herbage

Mixture Additive	Dry matter (DM) g kg^{-1}	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	pH	Ammonia % of total N	Butyric acid g kg^{-1} DM	DM losses %
Red clover							
Untreated	104	221	217	4.8	12.9	8.4	8.2
Niben	108	228	187	4.2	3.2	1.0	4.0
Josilac	104	213	213	4.3	5.7	1.1	6.1
Red clover-ryegrass mixture							
Untreated	114	192	213	4.4	6.9	4.1	6.2
Niben, 5l t^{-1} FM	118	195	212	4.1	3.1	0.5	3.9
Josilac, 5l t^{-1} FM	118	188	223	4.3	4.6	0.5	3.2
$LSD_{0.05}$		20.8	38.2	0.4	2.7	3.9	3.5

Table 2. The effect of using additives and red clover or clover-grass mixture on silage fermentation and dry matter losses. The silage was made from wilted herbage

Mixture Additive	Dry matter (DM) g kg^{-1}	Crude protein g kg^{-1} DM	Crude fibre g kg^{-1} DM	pH	Ammonia % of total N	Butyric acid g kg^{-1} DM	DM losses %
Red clover							
Untreated	146	217	203	4.5	6.4	4.2	7.4
Niben	163	220	191	4.2	3.9	1.2	3.3
Josilac	158	227	206	4.6	5.4	1.2	5.5
Red clover-ryegrass mixture							
Untreated	187	197	216	4.5	4.3	1.2	4.4
Niben	201	192	209	4.1	3.2	0.6	2.8
Josilac	212	195	217	4.2	4.3	0.7	3.7
$LSD_{0.05}$		22.5	33.0	0.4	3.0	2.5	3.2

When the crop was wilted, the DM concentration of red clover silage was increased by approximately 33% and for the mixed silage by 42%. These wilted silages still remained too wet, indicating that the harvested material was not easily wilted.
The fermentation quality and dry matter losses were dependent on botanical composition, herbage wilting and mostly on whether additive was used. The silage made of untreated red clover crop had the lowest quality. It contained 8.4 g kg^{-1} DM butyric acid and 12.9% of ammonia nitrogen. Dry matter losses were well correlated with butyric acid concentration in the silage (Figure 1).

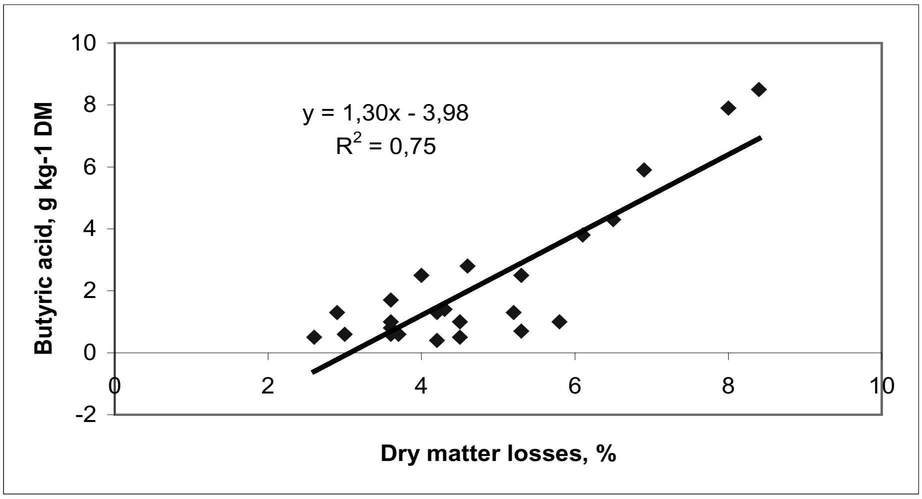

Figure 1. Butyric acid concentration in silage related to the dry matter losses

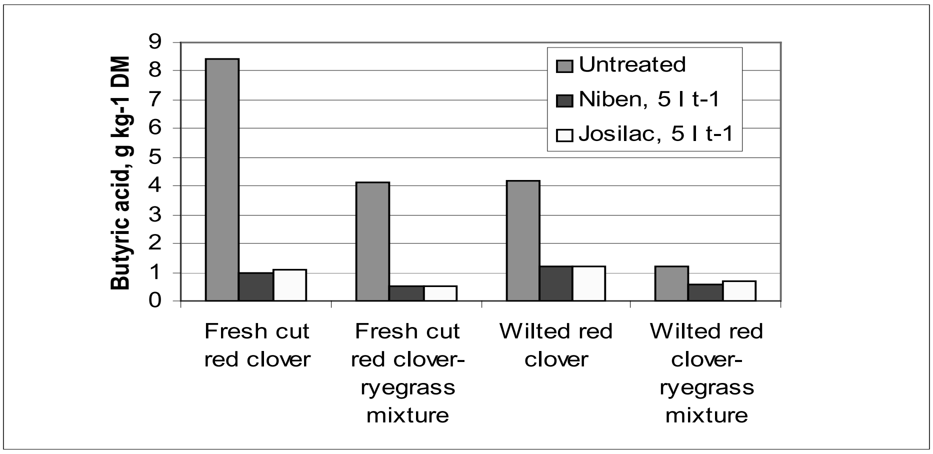

Figure 2. Butyric acid concentration in silage depending on the botanical composition of the ensiled material, herbage wilting and the use of additives

Including ryegrass improved the fermentation properties of the ensiled material, and therefore the silage quality was better. Herbage wilting also improved fermentation. These results were expected. Both additives improved fermentation, as indicated by butyric acid concentrations, and reduced DM losses. However, Niben was slightly more effective. There were interactive effects when using additive, wilting and red clover or clover-grass mixture (Figure 2).

Conclusions

The nutritive value of silage was dependent on the botanical composition. Pure red clover 'Varte' resulted in the higher crude protein concentration of silage. The silage fermentation quality and dry matter losses were dependent on botanical composition, herbage wilting and the use of additive. The silage, made of fresh red clover, had the lowest quality. Herbage wilting and mixture improved fermentation and silage quality. The silage additives improved fermentation, with Niben being slightly more effective. However, the ensiling of tetraploid red clover is still problematical due to the low dry matter concentration of this cultivar.

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Effect of liming and sewage sludge application on the botanical composition of a pasture grown under *Pinus radiata*

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Abstract

The objective of this experiment was to study the influence of sewage sludge and lime application on the botanical composition of a pasture established under a *Pinus radiata* D. Don plantation. Organic matter and nutrient sewage sludge content, principally nitrogen, indicated that it can be used as fertiliser. The experiment was conducted in the north-west of Spain. The soil was very acid (pH = 4.5) and had a very low nutrient level. It was sown as a grass mixture (25 kg ha^{-1} of *Lolium perenne*, 10 kg ha^{-1} of *Dactylis glomerata* and 4 kg ha^{-1} of *Trifolium repens*) in autumn of 1997 under a five year old plantation of *Pinus radiata* at a density of 1,667 trees ha^{-1}. Treatments were no fertilisation (NF), three sewage sludge doses based on nitrogen contents (L1: 160 kg N ha^{-1}; L2: 320 kg N ha^{-1}; L3: 480 kg N ha^{-1}), with or without lime (2.5 t $CaCO_3$ ha^{-1}) and mineral fertilisation usually applied in this area (MIN: 40 kg N ha^{-1}, 120 kg P ha^{-1} and 80 kg K ha^{-1}). Fertiliser treatments were applied over a period of three years. Liming and sewage sludge fertilisation increased sown species contribution, especially *Dactylis glomerata*, due to soil fertility iimprovement. *Trifolium repens* and *Lolium perenne* presence was low because of shade conditions. Organic fertilisation reduced senescent material.

Keywords: *Trifolium repens*, *Dactylis glomerata*, *Lolium perenne*, nitrogen, lime, sewage sludge, silvopastoral system

Introduction

Silvopastoral systems are ecosystems in which wood (long term economic return) and pasture (short term economic return) productions are combined. Both productions result from existing interactions among three components: tree, pasture and animals. In silvopastoral systems, the sowing of quality species, as well as liming and fertilisation, improve pasture quality and production (Silva-Pando *et al*., 1998) and, therefore, allow an increased stocking rate. Sowing can succeed when shade is scarce, i.e. when trees are young or in stands with low density, because shade can limit pasture establishment, persistence and productivity. Otherwise, the species introduction is not profitable.

In pastures growing on acid soils, P and K fertilisation is usually applied before sowing in order to reach target levels for better pasture growth and establishment. These elements are also necessary for the development of legumes (González-Rodríguez, 1992). Later on, mineral nitrogen is applied to pasture, and this usually favours grass sown species. An adequate fertilisation program would improve pasture and tree growth. In silvopastoral systems, trees have a lower need of nutrients, because of their slower growth rate, than pasture. Moreover, fertilisation treatments should be chosen to promote both pasture and tree production (Sinclair *et al*., 2000). In the last few years, sewage sludge production has increased in the EU countries, due to the European Directive 91/271/CEE implementation (DOCE no L 135). Therefore, it is necessary to find suitable uses for these residues in accordance with EU policy. Organic matter and sewage sludge nutrient contents, principally nitrogen, indicate that it can be used as a fertiliser with advantage (Navarro-Pedreño *et al*., 1995). The main problem of sewage sludge is its heavy metal content, especially as metal solubility is normally increased in acid soils (Pomares and Canet, 2001). The objective of the experiment was to evaluate the effect of liming and sewage sludge application on botanical composition.

Materials and Methods

The soil was very acid (pH 4.5) (Guitián and Carballás, 1976) and had a high total nitrogen content (2.5 g kg^{-1}) (Castro *et al*., 1990). The total phosphorus (0.4 g kg^{-1}) and potassium (0.9 g kg^{-1}) contents (Castro *et al*., 1990) were low, which is typical of this area. In autumn 1997, a pasture mixture was sown (25 kg ha^{-1} *Lolium perenne* cv ´Brigantia´, 10 kg ha^{-1} *Dactylis glomerata* cv ´Artabro´, 4 kg ha^{-1} *Trifolium repens* cv ´Huia´) under a five year old *Pinus radiata* plantation (1667 trees ha^{-1}). The experiment was a completely randomised block design with three replicates. Treatments consisted of no fertilisation (NF), three sewage sludge doses (L1: 160 kg N total ha^{-1}; L2: 320 kg N total ha^{-1}; L3: 480 kg N total ha^{-1}), with or without lime (2.5 t CO_3Ca ha^{-1}), which was applied in autumn 1997, and mineral fertilisation (MIN: 40 kg N ha^{-1}, 120 kg P ha^{-1} and 80 kg K ha^{-1}). In total, nine treatments were established. Fertilisation treatments were applied in spring 1998, 1999 and 2000. Eight pasture harvests took place in July and November 1998 and May, July and November 1999 and 2000. Four samples per plot (0.09 m^2) were taken by using a hand clipper. Sown and adventitious species were separated and their proportions estimated after drying in an oven at 80 ºC for 72 hours. The data were analysed using ANOVA and regressions and means were subjected to the Duncan test. For statistical analysis, the SAS program was used (SAS, 1985).

Results and Discussion

Dactylis glomerata (cocksfoot), *Lolium perenne* (ryegrass), *Trifolium repens* (white clover), adventitious species and dead senescent proportions can be seen in Figure 1. *Trifolium repens* and *Lolium perenne* presence was scarce because their proportion is usually inversely proportional to soil acidity (Mosquera-Losada *et al*., 1999). Moreover, they need more fertile soils with low saturated aluminium percentage (Mosquera-Losada *et al*., 2000). Both species almost disappeared in the second year, due to their low shade tolerance (Balocchi and Philips, 1997). *Dactylis glomerata* was the species with the best establishment and persistence. Therefore, it is better suited to silvopastoral systems (Mosquera-Losada *et al*., 2001) than ryegrass or clover.

Most adventitious species were grasses, like *Agrostis* sp., *Anthoxantum odoratum*, *Festuca arundinacea*, *Holcus lanatus*, *Holcus mollis* and *Pseudarrhenatherum longifolium*.

Liming and sewage sludge fertilisation increased the sown species proportions, especially cocksfoot, in agreement with the observations by Wheeler (1998) (for liming) and Mosquera-Losada *et al*. (2001) (for sewage sludge). This could be explained by increased nutrient availability, especially nitrogen, which produced a competitive advantage for sown grass species (López-Díaz *et al*., 1999).

Organic fertilisation reduced senescent material, especially in autumn 1998 and 1999, because it prolonged the vegetative cycle. Compared to no fertilisation treatment, mineral fertilisation improved sown the species proportions in 1998, when it produced similar results to sewage sludge. In the following years, pH reduction and nitrogen leaching, caused by high precipitation, produced a lower availability of nutrients for sown species. That caused better tree growth and favoured the adventitious species. Higher soil phosphorus concentration which resulted from inorganic fertiliser application did not improve P availability, because it was fixed by aluminium.

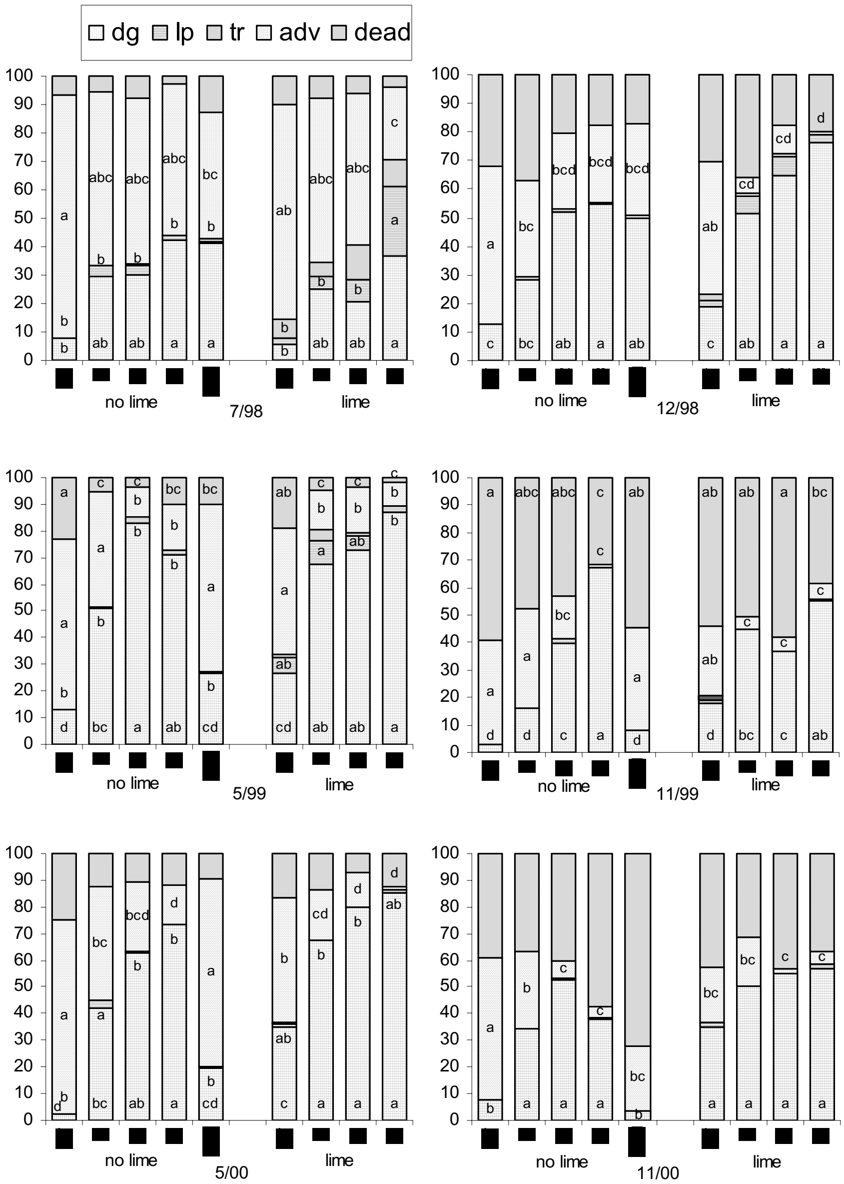

Figure 1. Proportion (% dry matter) of each sown and adventitious species in pasture with different fertilisation treatments in July and December of 1998 and May and November of 1999 and 2000. Lime: 2.5 t CO_3Ca ha^{-1}; NF: no fertilisation; L1: low sewage sludge doses (160 kg total N ha^{-1}); L2: medium sewage sludge doses (320 kg total N ha^{-1}); L3: high sewage sludge doses (480 kg total N ha^{-1}). dg: *Dactylis glomerata*; lp: *Lolium perenne*; tr: *Trifolium repens*; adv: adventitious species; dead: dead matter. The first five bars represent no limed treatments and the last four the limed treatments

Conclusions

Liming and sewage sludge fertilisation improved pasture quality and production, because they increased sown species contribution, especially *Dactylis glomerata*. *Trifolium repens* and *Lolium perenne* presence was low because of shade conditions. Because of its good establishment and persistence *Dactylis glomerata* is more suited for silvopastoral systems than clover and ryegrass. Organic fertilisation reduced senescent material too. Mineral fertiliser application initially increased sown species (1998), but this effect was reduced with time due to increased soil acidity.

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Red clover varieties for conventional and ecological farming systems in Lithuania

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Abstract

Red clover is a major perennial forage legume grown for forage on arable land in Lithuania. In terms of productivity and forage quality it does not lag much behind lucerne. The main problems of red clover cultivation are clover rot, root rot and persistence. To solve these problems we have used various methods of breeding under natural and artificial infection. 6 varieties of red clover with different earliness, ploidy and resistance to diseases were bred in Dotnuva and registered in Lithuania. These varieties have performed well in terms of productivity and forage quality and have been grown successfully in both conventional and ecological farming systems. The old varieties 'Liepsna' and 'Kamaniai' produced lower yields than the latest varieties, however, during the long cultivation period they have adapted very well to the local agroclimatic conditions. Of special importance was the variety 'Arimaičiai' which produced a high yield for 2–3 years of use and appeared well suited to continuous growing. The tetraploid clover varieties 'Vyliai' and 'Kiršinai' were also valuable. However, the low seed yield produced by these varieties prevents their spread in the large-scale production areas. Another two valuable varieties of red clover will soon be transferred to the State Variety Testing Trials. Thus there is a diverse range of varieties of red clover for growing both in conventional and ecological farming. Since 2003 most of the listed varieties have been tested for DUS in Poland.

Keywords: red clover, varieties, yield, resistance, diseases, quality

Introduction

There is little evidence to show when red clover was first grown in Lithuania. In 1815 in the daily paper "Dziennik Vilenski" published in Vilnius Paškevičius wrote that in 1811 red clover was grown in the crop rotation in Vilnius province in Ščorsai, on Chrebtavičius farm. According to Semionov the first red clover was cultivated in Belarus in 1813. Moreover, he notes that the first clover seeds were imported from the Baltic States (Семенов, 1965). Thus one can assume that cultivation of red clover in Lithuania started at least as early as 1811.

Until the late 19th century the area sown with red clover hardly changed. In 1901 the area under perennial grasses (including red clover) in Lithuania was 2.61% of the arable area. From the early 20th century the area of clover started rapidly to increase. In 1938 the area amounted to 445 550 ha, some 16.2% of the total arable land (Vazalinskas, 1937). In 1958 in Lithuania the area of red clover and its mixtures with grasses reached 484 400 ha or 20.1% of the total arable land. Large amounts of clover seeds were exported. Currently due to the prolonged agricultural reform and changes in land use the area of perennial grasses, including clover, is much smaller.

The beginning of clover breeding began with the establishment of the Dotnuva Breeding Station in 1922. No red clover varieties were developed in Lithuania until the Second World War. The first early red clover diploid variety was released in 1957, late diploid variety 'Kamaniai' in 1959, early tetraploid variety 'Vyliai' in 1990, medium-late diploid variety 'Arimaičiai' in 1996, late tetraploid variety 'Kiršinai' in 1996 and early diploid variety 'Vyčiai' in 2001.

The above-listed varieties are well-adapted to Lithuania's agroclimatic conditions and spread successfully in the country. Red clover breeding continues at the Lithuanian Institute of Agriculture. The institute's best red clover varieties are currently being tested for distinctness, uniformity and stability (DUS testing) in Poland.

Experimental conditions and methods

Clover breeding as well as breeding of other perennial legumes is conducted at the Lithuanian Institute of Agriculture's experimental department in the field in a six-course crop rotation of forage grasses. The soil of the experimental site is Endocalcari-Endohypogleyic Cambisol RDg 4-K_2 (pH-7.3, P_2O_5 and K_2O – 140 and 178 mg kg^{-1}, humus – 2.46%). Clover is sown after a black fallow without a cover crop. Breeding nurseries and variety testing trials of perennial legumes are used for two years. NPK fertilisers and pesticides are applied only to the cereals grown in the crop rotation, therefore the developed varieties are also well-suited for ecological farming.

The following methods are used in red clover breeding: mass, individual, and family selection, polyploidy, polycross, topcross, intervarietal crossing, recurrent selection and others (Svirskis, 1995; Кильчевский, Хотылева, 1997; Sprainaitis *et al.,* 2003).

Experimental results and discussion

Red clover is affected by about 100 various diseases (Strukčinskas, 1974). Diseases and adverse agroclimatic conditions determine not only clover yield, quality but also persistence. Quite often clover persists for only one or two years. As a result, in the development of new clover varieties, we use various methods of natural and artificial infection in the infection nursery established in 1973. Here clover selection is conducted against a background of artificial clover rot (*Sclerotinia trifoliorum Erikss.*) and root rot infection and continuous growing. In the crop rotations the red clover variety 'Arimaičiai' is characterised by a high dry matter and seed yield for 2–3 years of use, can well withstand continuous growing and is especially suited for ecological farming, where clover is re-seeded every 2–3 years in the crop rotation (Kadžiulienė, 2004).

Tetraploid clover 'Vyliai' and 'Kiršinai' are high-yielding and possess a rather high disease resistance. The greatest drawback of these varieties is a low seed yield. For example, in the year 2004, which was unfavourable for seed clover, 'Vyliai' and 'Kiršinai' yielded as little as 100 kg seed per 1.5 ha area, whereas 'Arimaičiai' produced 400 kg of seed of the 1st grade on the same area. The old and stable varieties 'Liepsna'' and 'Kamaniai' that have passed a long natural selection and adaptation to local agroclimatic conditions, are also valuable, especially in ecological farming.

The tetraploid breeding line No.31 (Sadūnai) has been passed on to the State Variety Testing (Official Testing) this year. It is a hybrid population of very early plants, selected from various varieties in breeding nurseries and freely cross-pollinated in the infection nursery. The data from two experiments suggest that this breeding line surpasses the standard variety 'Arimaičiai' in dry matter yield by 16.7% and only slightly lags behind in terms of persistence and resistance to continuous growing (Table 1).

A rather promising and homogeneous line is the breeding line No. 32. It is a productive early diploid clover population. The initial breeding material was collected in Noreikiškiai vicinity (Kaunas district), and mass selection was performed in the infection nursery. This line is characterised by a good chemical composition and digestibility (Table 2).

Table 1. Yield data of the three promising breeding lines of red clover of 2001 and 2002 sowing year Dotnuva, 2001–2004

Varieties and promising lines	Height, cm			Herbage yield		DM yield	
	1st crop	2nd crop	3rd crop	Tha^{-1}	%	Tha^{-1}	%
2001 sowing year 1st year of use (2002)							
1. Arimaičiai 2n st.	42	30	22	34,6	100,0	11,3	100,0
32 promising line 2n, LŽI, LŽŪU	44	26	18	39,0	112,7	12,6	111,5
31 Sadūnai 4n, LŽI	50	46	16	44,4	128,3	14,1	124,8
33 promising line 2n, LŽI	50	44	19	41.3	119.4	13.4	118.6
LSD_{05}				3.0		1.3	
2nd year of use (2003)							
1 Arimaičiai 2n	30	30	20	21.4	100.0	6.7	100.0
32 promising line 2n, LŽI, LŽŪU	34	32	21	25.4	118.7	8.2	122.4
31 Sadūnai 4n, LŽI	36	34	24	31.1	145.3	9.8	146.3
33 Promising line 2n, LŽI	30	30	25	19.2	89.7	6.1	91.0
LSD_{05}				8.0		3.0	
2002 sowing year, 1st year of use (2003)							
1 Arimaičiai 2n	50	46	25	48.8	100.0	14.9	100.0
32 promising line 2n, LŽI, LŽŪU	48	54	30	49.3	101.0	15.4	103.4
31 Sadūnai 4n, LŽI	52	54	38	56.2	115.2	16.6	111.4
33 promising line 2n, LŽI	52	54	30	55.2	113.1	16.9	113.4
34 Vyliai 4n	50	56	34	47.8	98.0	14.4	96.6
LSD_{05}				4.6		1.4	
2nd year of use (2004)*							
1. Arimaičiai 2n st.	32	63	–	55.3	100.0	12.7	100.0
32 promising line 2n, LŽI, LŽŪU	30	72	–	42.2	87.2	12.6	99.2
31 Sadūnai 4n, LŽI	36	70	–	51.5	93.1	12.6	99.2
33 promising line 2n, LŽI	36	70	–	52.0	94.0	12.9	101.6
34 Vyliai, 4n	35	74	–	41.7	75.0	10.8	85.0
LSD_{05}				6.5		1.7	
* Data from two cuts							
Averaged data from two trials (2001–2004)							
1 Arimaičiai 2n	38	42	–	40.1	100.0	11.4	100.0
32 promising line 2n, LŽI, LŽŪU	34	45	–	40.5	101.0	12.2	107.0
31 Sadūnai 4n, LŽI	43	51	–	45.8	114.2	13.3	116.7
33 promising line 2n, LŽI	42	49	–	41.9	104.5	12.4	108.8
LSD_{05}				5.0		1.6	

Table 2. Chemical composition (%) of red clover 'Arimaičiai' and 3 promising lines Dotnuva, 2002

Variety and catalogue No.	NIRS				Chemical analysis	
	Crude protein	Digestibility PCDigest	Fibre	Digestibility enzymatic b.	Protein	Fibre
		1st crop (beginning of flowering)				
Arimaičiai, st.	17.96	68.44	19.69	71.8	17.4	23.42
33 promising line 2n, LŽI	19.10	70.20	20.18	79.0	18.6	18.90
31 Sadūnai 4n, LŽI	19.33	67.22	20.56	78.0	17.6	20.71
32 promising line 2n, LŽI, LŽŪU	21.25	66.46	27.09	76.7	21.9	24.66
		2nd crop				
Arimaičiai, st.	19.53	61.87	20.30	72.1	18.5	19.75
33 promising line 2n, LŽI	19.35	70.40	20.51	69.4	18.4	19.44
31 Sadūnai 4n, LŽI	17.34	57.59	26.52	68.2	16.6	24.12
32 promising line 2n, LŽI, LŽŪU	16.69	58.08	27.48	66.2	16.1	26.46

Analyses were done at LIA's analytical laboratory.

Conclusions

Lithuanian-bred red clover varieties are characterised by a high productivity, resistance to diseases and ability to grow in adverse agroclimatic conditions. They can be grown in various mixtures with grasses and fully meet the growing needs of intensive and ecological contemporary animal production.

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Towards the optimum dosage of mineral fertilizers in a mountain pasture: how to balance yield against fodder quality

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Abstract

Fertilization of permanent grassland improves its production and causes changes in plant composition. To find an efficient dosage for a mountain pasture a four-year field experiment was conducted in Poland. This involved four treatments: 1) control: without fertilization; 2) $P_{26}K_{50}$ only; 3) $P_{26}K_{50}N_{100}$; 4) $P_{26}K_{50}N_{200}$. Grass samples were used to estimate total yields and rates of grass intake by grazing sheep. Plant composition was assessed yearly to find out qualitative changes for each treatment. Grazing alone caused a reduction of *Nardus stricta* in favour of *Festuca rubra* and *F. pratensis*. Due to PK fertilization *N. stricta* almost disappeared, *Agrostis capillaris* was reduced, while *F. pratensis* and *Trifolium repens* showed significant expansion. Nitrogen fertilization at the PK background produced reduction of *F. rubra* and *A. capillaris*, in favour of *F. pratensis* and *Poa pratensis*. With higher dosage of N plant composition became simplified mainly to *F. pratensis* and *P. pratensis* formerly seen as traces. Mineral fertilization treatments clearly improved average DM production, respectively by 31%, 64% or 87% over the control. In the case of the PK treatment (as well as with grazing alone) it increased progressively over years, while in both the PKN treatments there was no change. However, this increase in production was not reflected in a higher grass intake by sheep, which did not necessary prefer eating the most productive plant species, especially *P. pratensis*. To guarantee appropriate yield and quality of green fodder for a mountain pasture an efficient strategy appeared to be PK fertilization alone or supplemented with 100 kg N ha^{-1}.

Keywords: permanent grassland, grazing, sheep, fertilization, production, fodder quality

Introduction

Due to poor fertility of the soil and relatively severe climate mountain pastures are often overgrown with plant species of low nutritional value. Most of them are eaten reluctantly or ignored by grazing animals. Yields of such grasslands might be improved by means of efficiently used fertilizers. Mountain grasslands respond to this treatment well and immediately (Filipek, Skrijka, 1973; Smoron, Kopec, 1996; Kasperczyk, 2002) showing changes in their plant composition and higher yields. However, there is a question at what dose fertilizers would guarantee not only better grassland production, but also high quality of the grass. For a pasture an elementary indicator of its fodder value is the rate of grass intake by grazing animals. Therefore, this study aimed to determine the effects of fertilization of a mountain pasture on grass intake in grazing sheep, as well as on pasture production.

Materials and Methods

The research was conducted on permanent mountain pasture (640 m a.s.l.) in the years between 1998 and 2001. This grassland covered a layer of brown soil classified by size grading as medium clay. Its chemical characteristics were as follows: pH_{KCl} 4.3, available P 8.0mg kg^{-1}, and available K 50mg kg^{-1}. Initial percentages of main plant species in the pasture are shown in Table 1. A field experiment was set up in an enclosed portion of the pasture with a surface area 0.3ha. The enclosed area including the experimental field was grazed four times in yearly rotation, using a flock of 30 sheep at the same time for 3–4 days. The experiment consisted of 4 treatments as specified in Tables 1 and 2, and involved 4 replications. For this purpose experimental plots, $24m^2$ each, were allotted. Plots were not separated by fences and sheep could graze freely across the plots. As regards mineral fertilizers, phosphorus and potassium ones were applied once every spring, while nitrogen ones were divided into 4 equal doses over a whole season. Plant species composition was assessed yearly in the sward before first rotation by Klapp's technique. Grass samples covering $8.4m^2$ out of each plot were taken before and after grazing and were used to estimate yield of the pasture and grazing refusals. Dry mass yield results were subjected to analysis of variance and compared by LSD test.

Results and Discussion

At the beginning of the study the predominant grass species in pasture green were: *Nardus stricta*, *Agrostis capillaris* and *Festuca rubra* (Table 1). After a 4-year period, using an efficient grazing system without any fertilization, the pasture vegetation was considerably changed. The percentage of *Nardus stricta* showed at least threefold reduction in favour of *Festuca rubra* and *Festuca pratensis*. The former increased by 50%, whereas the latter expanded from trace amounts up to 6%.

PK-fertilization of the grazed pasture caused even greater changes in percentages of plant species. As a result *Nardus stricta* almost disappeared in the sward, while *Agrostis capillaris* diminished its share twofold. On the other hand, this treatment further induced the growth of *Festuca pratensis* and *Trifolium repens*. The latter expanded from 6 do 26% in the grassland.

Supplemental nitrogen fertilizing with 100kg N ha^{-1} alongside the PK-fertilization background produced further reduction in the amounts of *Festuca rubra* and *Agrostis capillaris*, principally in favour of *Festuca pratensis* and *Poa pratensis*. With more intensive, doubled nitrogen dosage of 200kg N ha^{-1} the formerly dominant species dropped completely out of the sward. In this case the plant composition of the pasture became considerably simplified, such that two thirds of the whole green mass constituted *Festuca pratensis* and *Poa pratensis*, two species that initially were seen only as traces.

Table 1. Percentages of main species in pasture vegetation

Species	Initial	After treatment			
		control	$P_{26}K_{50}$	$P_{26}K_{50}N_{100}$	$P_{26}K_{50}N_{200}$
Nardus stricta	18	5	1	–	–
Agrostis capillaris	17	17	8	4	–
Festuca rubra	13	26	20	7	3
Festuca pratensis	1	6	11	36	36
Poa pratensis	3	7	6	16	29
Trifolium pratense	6	8	26	17	6

Plant responses to fertilizers were strong as early as in the first year after treatment. The experimental grassland increased production by 42% through PK-fertilization alone, by 11% with the lower, and by 152% with the higher N-supplementation at this background. For the control and PK-fertilized treatments dry matter production grew progressively over subsequent years by respectively 62% and 45% at the end of the study. In contrast, both the PKN-fertilized treatments gave similar yearly production over the whole period. At the end of this four-year experiment average yields of the fertilized pasture objects were higher than

the control; in the case of PK-fertilization by 31% and in the case of NPK-fertilization by 64% or 87% respectively for the dosages of 100kg N ha^{-1} or 200kg N ha^{-1}.
Estimated rates of green pasture intake by sheep, were least, for the control and PKN-fertilisation at 200kg N dosage per hectare (Table 2). After 4 years the greatest improvement in intake rate was recorded for the control and PK-fertilization, whereas the 'double' N-dosage resulted in the least value, being unchanged in the experimental period. The highest average grass intake by sheep was achieved with the PK-fertilized treatment, where the animals utilized 15% grass more than in case of the most intensively fertilized one (200 kg N ha^{-1} at the PK background). Such low grass intake rate in the latter means that, even if production per hectare in this treatment was potentially 1 Mg higher than in the former, the animals harvested from both nearly the same amounts of green matter.

Table 2. Dry matter yield and intake rate by sheep

Treatment	Dry matter yield, t ha^{-1}			Intake rate, %		
	1st year	4th year	Average	1st year	4th year	Average
Control	3.15	5.10	4.36	70.2	80.9	81.0
$P_{26}K_{50}$	4.48	6.49	5.70	79.0	88.5	86.9
$P_{26}K_{50}N_{100}$	6.43	7.18	7.15	78.5	80.6	80.4
$P_{26}K_{50}N_{200}$	7.93	8.39	8.17	76.6	70.4	71.9
$LSD_{0.05}$	0.95	0.81	1.01			

From these results the fact that an increase in pasture production due to more intensive fertilization was not associated with a higher green matter intake by sheep deserves special attention. Preference of specific plants by animals seems to be a complex issue. However, judging by the above results we would see that while higher pasture production is commensurate with an expansion of *Trifolium repens*, *Festuca pratensis* and *Poa pratensis*, only the former two species were eaten eagerly, and not the latter one. This observation was reported also by the others (Drozdz, 1983; Warda, 1997; Taube *et al*., 2004).

Conclusions

Phosphorus-and-potassium fertilization alone appeared to be a significant and economical means of intensifying mountain pasture production.
As far as nitrogen fertilization of this pasture was concerned, the maximum yearly dosage of 100kg N ha^{-1} would be considered most efficient to secure appropriate fodder quality.

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