



EGF 2010  
Kiel Germany

# *Grassland in a changing world*

## **Book of Abstract**

*Edited by*

**H. Schnyder  
J. Isselstein  
F. Taube  
K. Auerswald  
J. Schellberg  
M. Wachendorf  
A. Herrmann  
M. Gierus  
N. Wrage  
A. Hopkins**



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23<sup>th</sup> General Meeting  
of the European Grassland Federation  
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Kiel Germany



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## Foreword

Grassland is the major resource to sustain the living of about one billion people worldwide. In industrialized Europe, grassland covers some 30 % of the agricultural area and forms the basis of a strong ruminant livestock sector. Grassland also provides a broad range of services that are beneficial for man. In addition to the production of herbage for livestock, grassland plays a major role in, for example, the maintenance of biodiversity, carbon sequestration into soils, clean surface and ground water, and the provision of an attractive environment for recreation and leisure activities. The way grassland provides these services is increasingly being affected by large scale processes that are commonly summarized as "global change". Grassland farming, the intensity of management and utilization, and the production of goods and environmental services at a given site are strongly affected by global markets for tradable goods, by international societal developments, by worldwide and realtime information exchange, and, most importantly, by climate change. These factors are seriously challenging the functioning of grassland and there is a great uncertainty as to how grassland will maintain its importance. Grassland researchers have realized this challenge and they have responded with in depth research in the various aspects of grassland farming and global change.

This was the background for the organizers of the EGF 2010 General Meeting to select 'Grassland in a Changing World' as the general topic of the conference. It is the first time that this topic has been addressed as the major theme for an EGF conference. Within this theme, five sections have been identified, ranging from 'grassland, climate and socio-economic change', over 'the future of grassland production systems', 'from grass to milk and meat', 'grassland ecosystem services', to 'pastoral systems'. Peer reviewed papers have been included in the present conference proceedings that are published in the EGF book series 'Grassland Science in Europe' as volume 15. Each section is introduced by a pair of review-papers from experienced scientists, followed by a set of voluntary submissions that had been presented at the conference as either oral or paper contributions. The book is an excellent source for up-to-date research in the field of grassland science and global change.

We wish to express our gratitude to the many people who have contributed to the conference. First of all we thank the 400 delegates from more than 40 countries all over the world for their scientific contributions as lectures, papers, posters and in the discussions. We particularly thank the numerous people that actively supported the planning and preparation of the conference: the members of the Organizing and the Scientific Committees, the many external reviewers, Alan Hopkins for the anglicizing of the manuscripts, Karl Auerswald for revising, formatting and proofreading of the whole book, and Melitta Sternkopf for managing the correspondence with the authors. Special thanks go to the members of the organizing group at Kiel University, Antje Herrmann as the Conference Secretary, Sigmone Hoffmann, Karin Rahn and the many 'helping hands' in the conference office, and the technical support team. Many thanks also to Martin Elsässer and his team for organizing the most attractive pre-conference tour. They were all very dedicated to the conference and it was a pleasure to share the experience of organizing a General Meeting with them. The European Grassland Federation Secretary Willy Kessler was very helpful in giving sound advice throughout the four years of conference preparations.

The conference was supported by many sponsors whose contributions are gratefully acknowledged.

Hans Schnyder

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Scientific Committee

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# **Session 1**

## **Grassland and Global Change**





## **Impact of economic and political drivers on the grassland use in the EU**

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The paper provides an insight into structures and recent trends of grazing livestock production (cattle, sheep, goats and equids) and their relation to forage area. Dairy production and grassland use are in the focus of the study. The differing land use and farming conditions throughout the EU are briefly addressed as well as farm structural change. The dairy, beef and sheep sectors highly depend on policy interventions implemented as part of the EU Common Agricultural Policy (CAP). These policies have been subject to fundamental reforms during the last years. Expected short-term impacts of these agricultural policy changes on livestock production and land use are discussed and as far as possible compared to recent empirical data. Also, the influence of environmental policies is considered. Building on this analysis, the future prospects of grazing livestock and grassland use in Europe are examined, and finally challenges for research are discussed.

## **C3/C4 grasslands and climate change**

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Species with the C3 and C4 modes of photosynthesis coexist in grasslands of North and South America, Central Asia, South Africa, Australia and New Zealand. In these ecosystems, the balance between C3 and C4 vegetation affects many functional aspects, including total and seasonal primary productivity and water use, the digestibility of herbage available to grazing animals, and the decomposability of litter and roots. Therefore, changes in the C3/C4 balance strongly influence the biogeochemistry and agronomic performance of these ecosystems, with potential impacts on animal productivity, carbon storage and nitrogen cycling. This review first presents the primary difference between the C3 and C4 photosynthetic pathways, and its consequences for plant carbon, water and nitrogen economies. Then, it explores how these physiological differences would influence the response of the C3/C4 balance to elevated CO<sub>2</sub> and global warming. Finally, expected responses are contrasted to the available evidence (from present-day and past-climate/vegetation studies, from analysis of recent regional changes, and from manipulative experiments) to verify their actual role in observed C3/C4 responses, and to identify gaps in our understanding of the mechanisms controlling the C3/C4 balance of grasslands.

## Session 1.1 Grassland and climate change

### Changes in soil organic matter content of grassland and maize land in the Netherlands between 1970 and 2009

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Soil organic matter (SOM) content is of prime importance for sustained levels of agricultural production. Reports indicate that SOM levels have decreased in, e.g., England, Wales and Belgium. Farmers in the Netherlands are concerned that introduction of more strict legislation on manure application will decrease SOM content in the Netherlands too. Here, we report on changes in SOM contents of grasslands and maize lands using a database with more than 2.5 million records of SOM determinations from farmers' fields. SOM content of grassland on mineral soils remained stable or tended to increase on average by  $0.097 \text{ g kg}^{-1} \text{ yr}^{-1} \text{ C}$  during the period 1984-2000. However, there were considerable differences between soil types and regions. Areas with relatively low SOM contents showed increasing SOM contents, while areas with relatively high SOMC (e.g., peaty clays) showed decreasing SOM contents.

### Changes in abundance and diversity of wild species in grass fields in Denmark

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There has been growing concern about the declining species diversity and abundance in agro-ecosystems caused by the intensification of land use practice during the last 50 years. Danish surveys in grass leys show that the frequency of many common species declined significantly between 1967-70 and 1987-89. From 1987-89 to 2001-04 the decline continued for a few species (*Matricaria discoidea*, *Plantago major*, *Ranunculus repens*, *Tripleurospermum inodorum* and *Viola arvensis*), while the frequency of the grass weeds *Elytrigia repens* and *Poa annua* increased significantly.

# Impacts of climate change on the grazing period, and the conserved feeding costs of grazing systems in the UK

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Grassland is the main driver of ruminant systems and its productivity is sensitive to climate. This study explores the response of ruminant production within the UK to climate change. Using climate predictions and grass productivity and animal nutrition models, the impacts are explored for 2020, 2050 and 2080 in ten regions. The associated costs of the predicted changes are assessed using the changes in the ratio of grass to other forage feed and estimating the financial impact. In pastoral systems, climate change is likely to increase grass production. Increased forage availability could increase the annual grazing period by a maximum of five weeks for cattle systems, and seven weeks for sheep systems. In most regions, this will allow animals to be kept outdoors for longer, and could mean a potential reduction in the proportion of the year that animals require housing and/or access to conserved forages. The changes in length of the grass growth season are generally more substantial in northerly than in southerly regions. The results indicate that a changing climate may actually lead to a saving in forage costs to the dairy, beef and sheep sectors of £42m, £5m and £90m respectively by 2080.

## 1.1.01 Effect of crude protein intake on CH<sub>4</sub> concentration in a dairy stall

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Grasslands have historically constituted the main source of forages for dairy cattle in the Basque Country. However, the intensification of dairy production has minimized the use of grass-based feedstuffs on commercial farms. Rations are currently formulated on crude protein (CP) content basis, with a high use of concentrates. The use of concentrates is related to increasing ammonia (NH<sub>3</sub>) accumulation in stalls, but little is known on how CP content may affect methane (CH<sub>4</sub>) concentration. The aim of this study was to relate the protein nutrition of lactating dairy cows and the CH<sub>4</sub> concentration in dairy stalls. Three total-mixed-ration diets were formulated whose CP contents were 14.1%, 15.9% and 16.9% for low (LP), medium (MP) and high protein (HP) treatments, respectively. Three Holstein cows were confined to metabolic tie-stalls for individual control and CH<sub>4</sub> monitoring. Methane measurements were made either *in situ* in the stall or in the laboratory through slurry incubations at different temperatures. CH<sub>4</sub> concentration in the stall was measured using a photoacoustic gas analyser. Results showed no effect of dietary CP content on the CH<sub>4</sub> concentration in tie stalls whereas CH<sub>4</sub> concentration increased with increasing temperatures in the laboratory. Dietary protein manipulation was not a successful strategy to alter CH<sub>4</sub> accumulation in stalls in our conditions.

### 1.1.02 Quantification of ley yield increase by climate change in mountainous regions of southern Norway

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The COUP – ENGNOR ley crop model for calculating fodder dry matter (DM) production was calibrated on data from field trials in southern Norway. By including a function for herbage net energy contents, in feed units lactation, the net energy production was estimated. Potential ley production at Fokstua (62° N, 970 m a.s.l.) for the period 1961-1990 was compared with that of a Hadley A2 climatic scenario for this site during the period 2071-2100. The scenario projects a temperature increase of 2-3 °C, and a lengthening of the growing season by approximately 1½ months, implying an appreciable increase in DM and fodder net energy production potential. The change would allow a new harvesting regime, with a relatively early first cut and two seasonal cuts. Impacts of the increased production potential in the mountainous districts of southern Norway towards the end of this century are considered. The value of ley plant breeding towards optimal combination of late seasonal growth with maximum winter hardiness will still be imperative.

### 1.1.03 Evaluation of greenhouse gas emissions from fertilized grassland

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Since the Climate Change Convention (UNFCCC, 1994) and the Kyoto Protocol (1997) intergovernmental mitigation of climate change has become an increasing concern for scientists, public opinion and policy makers. We investigated biosphere-atmosphere interactions on a light loam soil (*Calc(ar)i-Endohypogleyic Luvisol*) in different managed grassland ecosystems of the training farm of the Lithuanian University of Agriculture in 2009, within the frame of a European COST Project. The objective of this investigation was to determine the impact of fertilizers, their rates and combinations on GHG emissions and productivity of natural and sown grassland.

GHG emission measurements were run in June-September, when meteorological conditions were optimal for intensive plant and soil biota physiological processes, in the absence of frost stress. In this study we compared fertilized natural and sown grasslands by using GHG emissions as indicator. This revealed stronger positive correlation ( $r = 0.8$ ) between applied monomial  $N_{60-240}$  fertilizers on GHG fluxes than of complex NPK fertilizers ( $r = 0.7$ ) in both natural and sown grasslands. Our results imply that  $N_2O$  emissions ( $0.02 \text{ mg h}^{-1} \text{ m}^{-2}$ ) were the same in natural and sown grasslands. Nonetheless,  $CO_2$  and  $CH_4$  emissions were less by  $3.09 \text{ mg h}^{-1} \text{ m}^{-2}$  and  $0.01 \text{ } \mu\text{g h}^{-1} \text{ m}^{-2}$ , respectively, in sown grassland, when the same fertilizer rate ( $N_{180}P_{41}K_{125}$ ) was applied.

#### 1.1.04 Carbon gain of C3 and C4 grasses in a dense canopy in the field

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Daily carbon gain of a C3 (*Lolium perenne* L.) and a C4 (*Paspalum dilatatum* Poir.) species growing in a mixed dense canopy was assessed at the end of summer, in Argentina. Chambers of transparent acrylic glass received <sup>13</sup>C-enriched CO<sub>2</sub> continuously from 12:00 to 19:00 on a given day. Immediately after labelling, samples were harvested and carbon gain was estimated as plant carbon mass times the proportion of newly assimilated carbon. *P. dilatatum* contributed more than *L. perenne* to both canopy standing biomass (164 vs. 22 g per m<sup>2</sup> ground) and canopy carbon gain (830 vs. 120 mg C per m<sup>2</sup> and per h). Both species showed a similar ability to capture carbon per unit canopy mass (*P. dilatatum* = 5.1; *L. perenne* = 5.5 mg C per g C and h), which suggested that the C3/C4-grasses composition of the canopy was not changing. Tiller-level analysis revealed that in both species big tillers captured more carbon per unit mass than small tillers (asymmetric competition), and that the C3 and C4 grass species achieved a similar relative photosynthesis rate (mg C per g C and h) in different ways: high gross assimilation rate (mg C per m<sup>2</sup> and h) in *P. dilatatum*, and high leaf area ratio (m<sup>2</sup> per g C) in *L. perenne*.

#### 1.1.05 AFLP analysis of genetic differentiation in legume germplasm in contrasting environments

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We used AFLP (amplified fragment length polymorphism) markers to analyse changes in population genetic differentiation ('genetic shift') over time in red and white clover germplasm, and to assess the effect of contrasting sites (Iceland, Sweden and the UK) on the magnitude of these changes. The AFLP technique successfully identified populations in, which genetic shift had occurred. The clearest evidence of this was in Sweden within the short time span of three years. This site showed the greatest annual amplitude in temperature during the experiment and was also the driest, and one or both of these factors may have exerted strong directional selective pressure on the populations grown there.

### **1.1.06 Factors determining changes in the xerothermic grasslands in Skierbieszów Landscape Park (SE Poland)**

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The main goal of this study was to investigate if changes in xerothermic flora of the Skierbieszów Landscape Park (SE Poland) were caused by cessation of use or by the influence of climatic changes. The flora of 15 slopes with dry grasslands was examined. The Ellenberg ecological indicator values were used to detect which habitat factor has changed the most. The greatest changes were noted in the value of substrate fertility N. Changes in the flora also demonstrated statistically important dependences on temperature (T) and continentality (K). The changes in xerothermic flora were mainly caused by succession. However, the increase in T and K indicators may have been caused by either their higher tolerance towards worsening light conditions or more favourable thermal conditions.

### **1.1.07 Greenhouse gas inventory for grasslands in the Basque Country in 1990 and 2008**

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The countries that have ratified the United Nations Framework Convention on Climate Change have the obligation to report their greenhouse gas (GHG) inventories. Grasslands cover about 30% of the area of the Basque Country, so the objective of this study was to calculate, according to IPCC guidelines, emissions and removals in 1990 and 2008 concerning grasslands, that are included in the Agriculture and LULUCF (Land Use, Land-Use Change and Forestry) sectors of GHG inventories, to provide information for developing research strategies and management practices to enhance C sequestration in grasslands of the Basque Country. A total of 513 Gg CO<sub>2</sub>-eq was emitted from the Agriculture sector related to grasslands in 2008 (31% lower than in 1990). Total removals from the LULUCF sector related to grasslands in 2008 were 289 Gg CO<sub>2</sub>-eq (42% lower than in 1990). Thus, considering Agriculture and LULUCF sectors together, grasslands were an emission source of GHG, emitting 224 Gg CO<sub>2</sub>-eq in 2008 (6% lower than in 1990). Although not calculated, uncertainties were high, indicating the need for more research on land-use changes in grassland area (e.g. through remote sensing technology) and on improving emission factors (particularly those related to organic C contents in grasslands and to enteric fermentation).

### **1.1.08 Fertiliser value and environmental impact of digestate application on permanent grassland**

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Fertiliser value and trace gas emissions after application (CH<sub>4</sub>, N<sub>2</sub>O) of digestate are evaluated. Biomass yields and trace gas emissions were measured at four levels of mineral N addition over one growing season. Our results suggest that the mineral N in digestate is less efficient for the support of plant growth than chemical fertiliser. However, digestate may have environmental advantages, as total specific trace gas emissions were found to be lower.

### **1.1.09 Change in carbon balance of a dry calcareous grassland caused by spontaneous afforestation**

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Changes in land use represent one of the most important components of global environmental change. An experimental site has been established in the Slovenian Karst (Submediterranean climate region) with the aim to investigate the effects of land use change on ecosystem carbon cycling. Paired eddy flux measurement design was used to assess net ecosystem exchange (NEE) of two ecosystems: extensively used dry grassland and abandoned grassland invaded by woody plants. The use of two eddy towers allowed us to detect the influence of land use change on C fluxes. In this work we present one year of measurements with the emphasis on distinct responses of NEE of both ecosystems to short term effects such as rain pulses.

### **1.1.10 Using a dynamic system simulation model to assess the effects of climate change on grass-based dairy systems in Ireland**

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Ireland has experienced a rise of 0.7 °C in mean temperature over the last century and this trend is predicted to continue and accelerate. Dairy production is an important mainstream



agricultural enterprise in Ireland and it is important to evaluate if current systems can adapt to climate change. A dairy system simulator, Dairy\_sim, was designed for assessing the interaction of climate and management on grass-based systems. Two scenarios were defined as a basis for evaluation. The first, a maximised production scenario assumed the greatest output on a given land area. It was found that dairy production under this scenario should readily adapt to climate change and production will increase by 2080 when compared with the baseline (1961-1990). The second scenario was based on current environmental legislation with limited stocking rates and N and was known as the minimum input scenario. Dairy\_sim indicated that grass production would exceed animal demand for minimum input systems by 2080, on both well- and poorly-drained soils. It is predicted that this increase in production will require adaptation of the current low-input dairy system to the altered atmosphere and climate.

### **1.1.11 Reduction of N<sub>2</sub>O emissions from grasslands under Atlantic conditions with the use of inhibitors (Basque Country, northern Spain)**

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Intensively managed grasslands are a potentially large source of N<sub>2</sub>O emissions because of the total input of nitrogen fertilizers. Addition of nitrification inhibitors (NI) or urease activity inhibitors to fertilizers could reduce these losses to the atmosphere. In our studies N<sub>2</sub>O losses were evaluated as well as the effect of the nitrification inhibitors dicyandiamide (DCD) and 3,4-dimethylpyrazol phosphate (DMPP) and the urease activity inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) on N<sub>2</sub>O emissions. The study was carried out after the application of ammonium sulphate nitrate, urea or cattle slurry to a mixed clover-ryegrass sward in the edafoclimatic conditions of the Basque Country (northern Spain). Results showed that efficiency of inhibitors in reducing N<sub>2</sub>O emissions varied according to environmental conditions. DMPP reduced losses up to 42% in ammonium sulphate nitrate fertiliser and 69% in slurry. NBPT showed reduction efficiencies of 8% with urea fertiliser and 13% with slurry.

### **1.1.12 Evapotranspiration from grassland with contact to groundwater**

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The paper presents the results of lysimetric analysis of actual evapotranspiration and water use efficiency from grass communities. The study was carried out in the Małe Pieniny mountain area on brown soils (about 600 m above sea-level). The actual evapotranspiration of grasslands correlated with their yield. The highest evapotranspiration (over 550 mm) was found on a 3-cut meadow, which was also characterized by the highest yield. Pasture yield was 20-30% less than meadow yield, which also reduced the amount of water lost through evapotranspiration by 15-20%. For lawns (cut every 10 days) the amount of water lost

through evapotranspiration did not exceed 350 mm. The lowest water use efficiency ( $1.4 \text{ g dm}^{-3}$ ) was found for low-yielding unfertilized meadow. The fertilization increased DM yield and improved water use efficiency, which under the high fertilization level exceeded  $3.3 \text{ g dm}^{-3}$ . It was found that evapotranspiration was significantly correlated with dry matter yield and in the case of 3-cut meadow also with contact to groundwater.

### **1.1.13 Climate change mitigation in European grasslands**

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Grasslands are both a source and a sink of greenhouse gases (GHG). Techniques and production systems can be developed for reducing GHG emissions from agricultural and upstream activities and thus for mitigating agriculture's contribution to anthropogenic climate change. These include i) production of second-generation biofuels; ii) nitrogen fixation by legumes; iii) carbon storage in grassland soils and vegetation, and iv) changes in farming systems to reduce emissions of CO<sub>2</sub> and other GHGs.

### **1.1.14 Surface Runoff Simulator (SIMU) hastens the research on phosphorus losses from grassland**

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In Finland the most important grass production areas are located on areas with severe winter conditions, soil frost and snow cover that affect the runoff patterns. To study the effects of changing winter conditions on surface runoff, we developed a surface runoff simulator device (SIMU). With the SIMU it is possible to simultaneously test several methods to reduce phosphorus losses from grassland in artificial winter/spring conditions. The aims of this study were to determine the accuracy of the device and to evaluate its practical value in surface runoff research. The treatments were: control, 20 t and 40 t slurry per ha, 20 t slurry + 3 t of fine lime, and 40 t slurry + 3 t of fine lime per ha. The SIMU detected differences in runoff total P and dissolved Ca concentrations and tendency in dissolved P concentration, although soil water extractable P was the same for all treatments. The results are not straightforwardly transferable on a field scale due to small size, but SIMU is useful in studying the differences between the treatments. SIMU is a useful tool when estimating the P losses from grassland as it is economical, easy to use, fast and adjustable.

### **1.1.15 Effect of climate change on grassland production for herbivorous livestock systems in France**

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We used estimations of climate change from a GCM as inputs of a crop model to study the behaviour of grass and alfalfa in the future. We adapted the crop model to account for negative effects of high temperatures and positive effects of CO<sub>2</sub> on plant growth and transpiration. The main results concern crop phenology and yield. Annual yields were generally predicted to increase in the near future, but decrease sometimes in the distant future, despite the positive effect of CO<sub>2</sub>. We predict marked differences between regions in France as a consequence of the variability of climate changes with the region. The distribution of production will probably change over the years and lead to new organization of livestock feeding. Likely, alfalfa yields will not decreased by climate change, unlike grass yields.

### **1.1.16 Fertilising practices to reduce nitrous oxide emissions from managed grasslands**

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Fertiliser and manure applications on grassland are important sources of nitrous oxide (N<sub>2</sub>O) emissions. This paper assesses strategies to reduce N<sub>2</sub>O emissions from fertiliser and manure application on grassland, either by reducing the amounts of applied nitrogen and carbon, or by preventing the simultaneous availability of fertiliser nitrate and manure carbon to prevent detrimental interactions. Three mitigation options were tested in three consecutive years on a sandy soil in the Netherlands: (i) application of ammonium based fertilisers, (ii) split fertiliser applications and (iii) separate application of fertiliser and manure. The observed N<sub>2</sub>O emission factors for the calcium ammonium nitrate were rather low: 0.52%, 0.17% and 0.12% of applied N, in the three consecutive years. Application of ammonium sulphate and split application of calcium ammonium nitrate resulted in a significant reduction of emissions in the first year. In the second and third year however, none of the mitigation strategies resulted in a lower emission. It is concluded that choice of fertiliser type and timing can reduce N<sub>2</sub>O emissions, but solid recommendations on when to apply these strategies are still lacking.

### **1.1.17 Nitrous oxide emissions from highly productive grassland as a function of soil compaction and nitrogen fertilization**

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Emissions of the greenhouse gas nitrous oxide (N<sub>2</sub>O) that are contributed by agricultural systems represent 50% of the world's N<sub>2</sub>O emissions. This can significantly be attributed to the intensification of modern agriculture, which includes increased nitrogen fertilization and the employment of larger and heavier machines. Heavier machines cause an increase in soil compaction and a reduction in the consistent soil pore system, which often results in more anaerobic conditions in the upper soil layers. In combination with intensive nitrogen fertilization these contribute to an undesirable increase of N<sub>2</sub>O emissions. Our main aim was to study the interaction between soil compaction and nitrogen fertilization and its impact on N<sub>2</sub>O emissions of highly productive grassland. A three-year (2006-2008) field trial was carried out at Hohenschulen experimental station in Northern Germany. Soil compaction (t228 kPa contact area pressure) was applied at the beginning of vegetation in early April. Before applying compaction, the plots had been treated with either 0 or 360 kg ha<sup>-1</sup> of N as calcium ammonium nitrate resulting in grass-legume mixtures and pure grass swards, respectively. Both experimental factors, as well as their interaction, caused significant effects on N<sub>2</sub>O emissions. The magnitude of treatment effects was dependent on soil moisture.

### **1.1.18 Grazing intensity and precipitation affects herbage accumulation, herbage quality and animal performance in semi-arid grassland**

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The experiment was performed during four grazing seasons (2005-2008) in semi-arid Inner Mongolia to gain information on grazing-induced grassland degradation. Effects of sheep stocking rate and precipitation on herbage mass, herbage accumulation, herbage quality, and animal performance were analysed under seven grazing intensities (from ungrazed to very heavily grazed). End-of-season herbage mass, herbage accumulation, and herbage quality varied greatly between years ( $P < 0.001$ ), correlating with inter-annual variation in precipitation. The accumulation and quality of herbage were inversely affected by grazing intensity. While herbage accumulation decreased ( $P < 0.001$ ) herbage quality increased ( $P < 0.001$ ) with increasing grazing intensity. The relationship between animal performance and grazing intensity were expressed by quadratic functions. Highest live weight gains per sheep and per ha were achieved at light (3 sheep ha<sup>-1</sup>) and very heavy (13 sheep ha<sup>-1</sup>) grazing, respectively. Precipitation appeared to be most crucial for the accumulation and quality of herbage, while grazing intensity was the key factor determining animal performance.

### **1.1.19 Effect of precipitation on dry matter production of a meadow with varied cutting frequency**

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Grassland dry matter yield was investigated at a site where plant growth is temporarily restricted by inadequate water supply. In a field experiment defoliation frequency was varied from two to five cuts per year at two nitrogen levels over 13 years. Under low nitrogen fertilization maximum yield was obtained at two cuts per year in most years. Under higher nitrogen input, the highest yield was obtained with three cuttings. Positive relationships between precipitation and biomass production were only observed occasionally. It seems that the impact of restricted water supply was often negligible compared to other factors like botanical composition and soil conditions at this site. Additionally, the effect of rainfall deficiency will vary strongly depending on season and growth stage of the grassland sward.

### **1.1.20 Adaptability of permanent grassland to the drought**

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Ongoing climate change is associated strongly with changes in water availability, threatening many ecosystems including grasslands. Climate change primarily affects botanical composition of grassland and this in turn affects the above-ground phytomass which is the feed for ruminants. We analysed data for a long-term period (23 years) to assess the impact of climate changes on grassland ecosystems. We obtained a picture of the development in botanical composition, based on the assumption that expected climate change will disturb botanical composition especially in the grassland biome. The results from 1986 to 2008 showed a significant change in botanical composition with a low proportion of legumes. It was not possible to confirm a strict relation between precipitation during vegetation season and changes in the proportions of botanical groups. Analysis of long-term development of the botanical composition of grassland affected by different pratotechnical interventions showed significant flexibility in this community in response to changing climatic conditions.

### **1.1.21 Modelling the aboveground productivity in Cantabrian mountain grassland: the effect of available moisture and grazing**

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The sustainable development of grazing systems in the Cantabrian Mountains will be affected by global climate change. Experts have predicted an increase in evapotranspiration and hence

decrease in available moisture (AM), unless balanced by increasing precipitation. We propose a Generalized Linear Model which includes aboveground productivity (APP) of *Jasiono-Danthonietum* grassland as response variable and AM (defined as precipitation minus potential evapotranspiration) and grazing as predictors. For that purpose, we determined the effect of grazers on grassland production in three grazing periods (from May to October in 2006-2008). Aboveground productivity (APP) was measured inside and outside permanent fences. Shoot growth in grazed grassland was measured using temporary exclosures. Monthly APP was defined as a statistically significant ( $\alpha = 0.05$ ) increment in standing crop of live biomass inside temporary exclosures and fences. APP increased exponentially with AM, even more under ungrazed conditions. Our model indicated that all predictors explained a significant part of the variability of APP and clarified that APP is primarily conditioned by climatic factors (like AM). Furthermore, the effect of grazing depends on AM, detecting a negative trend between grazing and AM.

### **1.1.22 Management of a *Nardetum strictae* – results of a fifty year experiment**

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An experiment of permanent grassland (*Nardetum strictae*; Oberd. 1995) was carried out on a mountain place in Thuringia (acid soil, 820 m above sea level) over a fifty year period from 1960 up to 2009. Treatments were: 1 – two cuts per year without any fertilization, 2 – two cuts per year with mineral fertilization (nitrogen, potassium and phosphorus). Utilization without any fertilization resulted in a continuously declining yield and insufficient contents of crude protein and potassium in the biomass but the community *Nardetum strictae* persisted in a typical species rich plant composition. Mineral fertilization caused significant higher yields and a better forage quality but a quickly change of the sward into a *Festuca rubra* – *Agrostis tenuis*-community.

### **1.1.23 Effects of nutrient availability on intrinsic water-use efficiency of temperate semi-natural grassland under rising atmospheric CO<sub>2</sub> during the last century**

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We derived a 150 years-long record of intrinsic water-use efficiency ( $W_i$ ) from community-level carbon isotope discrimination ( $^{13}\Delta$ ) in the herbage of the unfertilized, unlimed control treatment (plot 3) of the Park Grass Experiment at Rothamsted (England) between 1857 and 2007 (Köhler *et al.*, 2009).  $W_i$  during spring growth has increased by 33 % since the beginning of the experiment, and  $W_i$  of summer / autumn growth has increased by 18% on the nutrient- limited plot. In the 1857-2007 period yields have not increased, suggesting that community-level photosynthesis has not increased either. Therefore, the increased  $W_i$

probably resulted from a decreased stomatal conductance. Our results suggest that vegetation has adjusted physiologically to elevated CO<sub>2</sub> by decreasing stomatal conductance in this nutrient-limited grassland. We now extended our sampling to contrasting fertilizer treatments, to investigate if nutrient availability influences the CO<sub>2</sub> response. We will present long-term trends (1915-2009) of  $W_i$  in five grassland communities, differing in nutrient availability (N, P, K).

Köhler IH, Poulton PR, Auerswald K, Schnyder H (2009) Intrinsic water-use efficiency of temperate semi-natural grassland has increased since 1857: an analysis of carbon isotope discrimination of herbage from the Park Grass Experiment. *Global Change Biology*, DOI: 10.1111/j.1365-2486.2009.02067.x

### **1.1.24 Can the dehesa system work as a carbon sink? Analysis of the case of the ‘deheson del encinar’ (Toledo, Spain)**

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Agroforestry systems are considered to be multi-purpose ecosystems, especially in zones where high yield is compromised, as in Mediterranean areas, where non-timber goods and services are the main ecosystems products. Spanish holm-oak *dehesas* constitute a paradigmatic example of agroforestry systems in south-west Europe managed in a traditional and very intensive way that provides essential environmental services. In spite of their importance, there is a lack of knowledge of multiple issues regarding their ecosystem functioning and dynamics. The potential of *dehesa* as a C sink was analysed in the framework of a Spanish Research National Plan project developed in several *dehesa* system locations in Spain. The case of the ‘Deheson del Encinar’ (Toledo) was studied in depth since the end of 2007 through the monitoring of the main carbon stocks and flows: wood, acorn and grassland biomass, tree growth, litter fall, carbon in top soil horizons, etc. Detailed meteorological data were available for the same area. Geostatistical and modelling techniques were used to describe and generalize the situation. The influence of different ecological and management factors on the *dehesa* C sink capacity is discussed according to the case-study analysis.

## Session 1.2 Grassland and socio-economic change

### Case-control studies for risk-assessment in ecology and agriculture

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This paper introduces the principles of case-control studies to investigate complex research questions that cannot be easily unravelled by experimentation. Case-control designs were originally developed in human health research but can also be applied to agronomy and ecology. They allow for the inclusion of many different management, ecological, and social factors and for thorough statistical testing using generalised linear models.

The principle of case-control studies is demonstrated by a study assessing the risk for the occurrence of the poisonous *Senecio jacobaea* in agricultural grassland, an increasing problem in Central Europe. Based on this example, we demonstrate that case-control studies provide reliable results in a relatively short timeframe. Effects can be assigned to factors that have acted over the long term, under real and natural conditions, and may have manifold influence on targets. We conclude that case-control studies offer a great opportunity in surveys and on-farm research and can be applied to a wide range of research topics in agronomy and ecology.

### Extensive grasslands beyond the year 2013 – present situation and options for the future?

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Extensive high nature value (HNV) grasslands belong to the most threatened anthropogenic ecosystems in Europe. In a recent research study, the status of extensive grasslands (and associated agricultural systems) in the South-West of Germany were found to be representative of many other less favoured rural areas in Europe. Major interest was given to the socio-economic situation of related agricultural systems. The present economic situation of farming with extensive grasslands and policy obstacles are depicted from the farmers' perspectives. There is a clear outcome of the study that grasslands with high biodiversity and importance for conservation are declining dramatically. The reasons are mainly qualitative losses due to intensification processes of various reasons. If HNV grasslands are to survive the common agricultural policy reforms following 2013, new land-use systems have to be developed.



## **Simulation of the effect of grass intake on the farmer's income**

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Grazing affects people, planet and profit. In general, the farmer's income will be higher when grazing of dairy cows is applied. We studied the economic effects of grazing for situations where we expect that grazing is difficult to apply. These situations could result in lower incomes for grazing. Farms with automatic milking systems, a small grazing surface, a large herd and/or a high milk yield per cow were studied. For the situations with automatic milking systems, large herds and high milk yields per cow, the farmer's income remained the highest for grazing. The difference between grazing and zero-grazing, however, was smaller than for farm situations without restrictions. In situations with more than 10 dairy cows ha<sup>-1</sup> grazing surface, zero-grazing was more profitable than grazing. There was a strong relationship between intake of grass in pasture, on a typical farm, and the difference in income between grazing and zero-grazing. The more grass the cows eat in the pasture, the larger the income profit from grazing compared to zero-grazing.

### **1.2.01 Socio-economic changes and their effects on agro-pastoral goat husbandry systems in semi-arid, sub-tropical mountain regions**

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In Oman's mountain regions, lifestyles and infrastructure in rural communities are rapidly modernizing. To determine the effects on the agro-pastoral goat husbandry, activities and herd sizes of goat-keeping households (HH) in three Al-Jabal-al-Akhdar oases were assessed by semi-quantitative interviews (n = 28) in autumn 2006. Labour input into goat husbandry was quantified in 15 HH. Map-based interviews (n = 10) were used to identify village pastures and to calculate stocking rates. In September 2007, herbaceous ground cover and biomass yields were estimated in 10x10m<sup>2</sup> plots at grazed (n = 14) and ungrazed (n = 11) sites. At 18 ± 16.3 goats HH<sup>-1</sup>, daily labour input was 13 ± 8.3 min goat<sup>-1</sup>. Livestock herding additionally required ≤8 h d<sup>-1</sup>, but since 6 ± 4.8 persons HH<sup>-1</sup> pursue an off-farm activity, farmers increasingly abandon this practice. Stocking rates on village pastures were ≤0.29 goats ha<sup>-1</sup>, but housing construction continuously decreases the available grazing area and village pastures overlap, so that >0.8 goats ha<sup>-1</sup> graze near settlements. Ground cover (%) and dry mass (kg ha<sup>-1</sup>) of the herbaceous vegetation were strongly reduced at grazed (45 ± 10.1; 20 ± 8.2) compared to ungrazed sites (82 ± 11.7; 573 ± 179; *P* < 0.01). Modernization processes in Oman's mountain communities thus amplify the degradation of the natural vegetation and threaten the future of the agro-pastoral goat husbandry.

## **1.2.02 Management and legislation affecting the conservation of mountain grasslands subjected to common use in Central Apennine**

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This paper presents a survey on long-term effects of management and socio-economic factors on the evolution of mountain grasslands in Central Apennine. The grasslands are subjected to common use, and we aimed to identify sustainable measures for their conservation. Recording of the vegetation and land use changes over the last fifty years highlighted the abandonment of arable land and a strong decrease of stocking rates. The associated increase of the surface area of open grasslands was followed by shrub encroachment. It is argued that the legislation and the public administration may have influenced the observed patterns. Management strategies are discussed to conciliate grassland production and conservation according to the need for direct financial supports to collective bodies.

## **1.2.03 Structural analysis of the dairy industry and its evolution in Central Switzerland**

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Since Switzerland is not a member of the European Community, EU, it pursues its own agricultural policy, which imposes increased competition and an incremental approach to EU conditions. In Central-Switzerland, situated in the northern foothills of the Alps, there are grassland areas and mountain areas of high natural value with particularly unfavourable topographical and climatic conditions. In 2008, the average agricultural area of the 3817 Central-Swiss dairy farms was 16.8 ha with a milk supply on contract of 106366 kg y<sup>-1</sup>. Full costs analysis showed that lowland farms are more productive than mountain farms. The dairy industry, especially the cheese factories, which process 49% of the total milk production, plays an important role in adding value in remote valleys. A promising prospect under these challenging conditions, (e.g. free cheese trade with the EU and the abandoning of milk quotas) is the processing of niche products including specialities and brand merchandising.

### **1.2.04 Grassland management on the ‘Low Cost Farm’: an overview of an eight-year period**

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From 1998 to 2006 grassland management has been monitored on the Low Cost research farm in Flevoland, the Netherlands, on young marine clay. Targets for the management costs on this farm were: low input of mineral fertilizers (N, P), minimal use of herbicides, long grazing season, efficient use of labour and minimal grassland renewal. Rotational grazing and permanent grazing were successively implemented and monitored. The type of management that matched the targets closest, turned out to be a system of continuous grazing. Nitrogen (N) fertilization was reduced from 275 kg ha<sup>-1</sup> in 1998 to 145 kg ha<sup>-1</sup> in 2003 (including N from slurry). The net average grassland dry matter yield was 11.5 t ha<sup>-1</sup>. The N and phosphorus (P) content of manure strongly decreased over the years. Permanent grazing reduced labour, improved efficiency of fodder production with lower costs, but lowered the yield.

### **1.2.05 Global economic crisis impacts on dairy cattle in the Czech Republic**

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In the Czech Republic (CR) dairy cow numbers fell from 1.248 million in 1989 to 384000 in 2009, which negatively influences the utilization of permanent grasslands (about 975000 ha and 22.8% of agricultural land). Due to the global economic crisis the farmers' milk price in the CR, as well as in other countries, dropped by 20-30% to 0.18-0.20 € kg<sup>-1</sup>. This is about 0.10-0.15 € kg<sup>-1</sup> below production costs. The considerable economic loss is the main reason why many Czech farms ceased milk production. This situation is unfavourable in the light of production (milk, live and beef cattle) and non-productive functions (landscape maintenance, soil erosion protection etc.) and the observance of the common agricultural policy rules.

### **1.2.06 Values and image of pasture-based milk production systems**

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In a series of scientific presentations in the years 2007-2009 on the topic of 'values and image of pasture-based milk production systems', the current state of knowledge on the special characteristics of this milk production system and the dairy products derived from it were gathered and the market potential for dairy products from pasture-based production systems was described. Compared to milk from cows fed with mainly maize silage and concentrate

supplements, milk from pasture-based production systems has higher levels of nutrient contents that are important for human health (e.g. poly-unsaturated fatty acids). Furthermore, pasture-based milk production plays an important role for agriculture in fulfilling the various multifunctional tasks as required by the Swiss Constitution. Consequently, pasture-based dairy products have a very positive image. Furthermore, studies show that actual consumer behaviour is favouring naturally produced domestic products. Thus pasture-based milk products, even though sold at a higher price, do have a market potential.

### **1.2.07 The role of agri-environmental programmes in grassland conservation and environmental protection**

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The aim of this study was the estimation of practical realisation of agri-environmental agreements on the Podlaskie voivodship in Poland. The studies were carried out in the years 2007-2009. 110 and 126 farms were randomly selected in 2007 and 2009, respectively. On the basis of questionnaires and direct visits to the farms we wanted to know how many farmers decided to join agri-environmental programmes and what they expected from the government. Special attention was paid to the reasons for choosing the specific packages and what was the percentage of beneficiaries in comparison to all farmers on Podlaskie voivodship. It was found that only 4.2% of farmers applied for agri-environmental programmes. The most popular packages were 'soil and water protection' and 'extensive grassland management'.

### **1.2.08 Assessment of energy consumption pattern in a sample of Walloon livestock farming systems**

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In order to have a better understanding of the energy consumption pattern in Walloon farms, energy consumption assessments were made for different farm types. Results showed the important variability that exists between and within farm types and the importance of direct energies (fuel and electricity), fertilizers and animal feed on the total energy consumption.

## **1.2.09 Threats to grassland plant diversity in Transylvania, Romania**

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The Transylvanian region of Romania is home to some of the last truly intact semi-natural grasslands in Europe. Low rates of intensification and fragmented land-ownership have led to the retention of substantial areas of extremely biodiverse grassland. This biodiversity is inextricably linked to the traditional small scale pastoral sheep and cattle farming typical for Romania; however, land management practices are beginning to change. The increase in costs and outside competition, as well as the introduction of new EU regulations and subsidies, are causing an increase in farm size and in an intensification of their practices in order to remain competitive. One particular difficulty is the widespread reduction in cattle numbers due to a drop in milk prices. This, alongside the incipient socioeconomic changes and rural depopulation, is also already leading to the abandonment of marginal areas. Based on a description of the pressures facing grassland in the study region of Southern Transylvania and vegetation surveys in different grassland types, this paper will discuss the impacts that the predicted changes may have on lowland grassland plant diversity.

## **1.2.10 Environmental aspects of grazing animals in a European context**

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Ruminants spend a part of the year in the meadow and the length of the grazing period for ruminants has multiple effects on the environment. In general, increasing the grazing period leads to lower emissions of ammonia and methane and to higher leaching of nitrate and higher consumption of synthetic fertilizer. The effect on nitrous oxide emissions depends on the application method of the animal manure, whether surface spread or incorporated.

## **1.2.11 Abandonment of farming practices: impact on vegetation**

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Socio-economic changes reduce the profitability of agriculture and cause many people to migrate from mountain areas and abandon grassland farming in the mountains. The aim of the study was to distinguish plant communities which are at most endangered by abandonment of mowing and to assess habitat conditions in uncultivated areas as compared to areas that are still under cultivation. Based on phytosociological relevés of different types of meadow plant communities in the Beskid Sądecki Mountains (Western Carpathians) and analysis of some habitat-related factors, it was determined that uncultivated areas were characterized by a smaller number of species, lower Shannon-Wiener diversity indices, and a higher proportion

of grasses in relation to the other species. The abandonment of farming practices was especially widespread at higher altitudes and where soils had low pH. Analysis of Ellenberg indicator values showed that the species found on unmowed areas were characterized by lower indices of light (L), soil acidity (R) and soil fertility (N). Ryegrass meadows were least affected by the abandonment of farming. Only 16% of phytosociological relevés of this community were recorded in uncultivated areas. Mat-grass meadows were abandoned to the largest extent. As many as 48% of the relevés of *Nardetum* were recorded in uncultivated areas. The most frequent was the abandonment of mowing plant communities typical of less fertile habitats. This is undesirable from a nature conservation perspective because species associated with these types of habitat are of great natural value.

### **1.2.12 Master Cattleman: a comprehensive-interdisciplinary approach for delivering forage-livestock information to producers**

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Kentucky is one of fifty states in the USA. It has over 1.16 million head of beef cows and over 38000 producers. Most of its beef producers have off-farm jobs and many of the full-time producers have other farming enterprises such as corn, soybeans, wheat or tobacco. To address the needs of this important group more efficiently, the Master Cattleman Program was implemented in 2000. The program involves University Specialists in Agronomy, Animal Science, Engineering, Veterinary Science and Agricultural Economics. In addition, county agents, industry personnel and other commodity organizations serve in leadership roles. The program involves ten four-hour evening sessions and at least one eight hour field event. Participants pay a small fee to cover meals and refreshments. Since the program began, over 3000 farmers from 118 counties have attended. Evaluations show that producers prefer this more in-depth interdisciplinary approach and have utilized information gained to improve their overall forage-livestock operation. Two additional programs, Advanced Master Cattleman and Master Grazer, have been introduced following the success of this program.



## **Session 2**

### **The Future of Grassland Productions Systems**





## **The role of genetic resources for sustainable and productive grassland agriculture**

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Plant genetic resources (PGR) are not only fundamental for any plant breeding effort, but targeted utilization of PGR may also contribute to sustainable grassland agriculture through enhanced resilience to environmental influences. For forage crop species such as ryegrasses, fescues or clovers, wild relatives and semi-natural ecotype populations often co-exist with cultivated species. These PGR are characteristic for forage crop species and present an invaluable resource of genetic diversity readily accessible to plant breeders. For targeted utilisation of PGR for the improvement of agronomically important traits and for conserving diversity in natural and semi-natural grasslands, a detailed characterisation is indispensable. Besides the phenotypic characterisation based on agronomically important traits such as flowering time, growth habit or disease resistance, molecular genetic tools offer additional means to efficiently characterise forage crop PGR. Such tools have been successfully used to demonstrate that wild red clover populations most likely were introduced into Europe independently of the introduction of cultivated forms. For species such as meadow fescue or Italian ryegrass, natural, semi-natural and cultivated forms appear to have co-evolved in their respective areas of cultivation. Permanent grasslands not only provide valuable habitats for *in situ* conservation of PGR, they may also harbour ecotype populations which outperform cultivars in terms of dry matter yield or disease resistance.

## **Grass biomethane: A sustainable alternative industry for grassland**

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The food fuel debate has lead to a negative perception of biofuels. This influenced EU policy in that targets for biofuels have been replaced with targets for renewable energy in transport. Furthermore, the Renewable Energy Directive states that a biofuel must reduce the greenhouse gas (GHG) emissions of the fossil fuel replaced by 60% (post 2017) if the fuel is to be classed as a biofuel for the purposes of the 2020 target of 10% renewable energy in transport. Grass is a low energy-input crop which does not require annual ploughing; because of this biomethane (renewable natural gas) produced from grass has a superior energy balance to indigenous liquid biofuel systems and comparable to tropical biofuel systems. The use of grasslands for biofuel is encouraged by Cross Compliance Regulations requiring the ratio of permanent pasture to arable land to remain constant. Grasslands are also known to act as significant carbon sinks and, as such, ploughing grassland to produce biofuel crops does not lead to a sustainable biofuel. Proposed reductions in the cattle herd will free grass for biomethane production. Grass biomethane may readily effect a 67% reduction in GHG emissions leading to a sustainable biofuel.

## Session 2.1 Grassland systems and technology

### Dry matter and protein yields of red clover, Italian ryegrass and their mixtures

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Red clover (*Trifolium pratense* L.) is very important legume in Bosnia and Herzegovina, in terms of its good adaptation to a wide range of soil conditions, its high yield potential and its good nutritional value. It is usually sown in mixtures with Italian ryegrass (*Lolium multiflorum* Lam.) in order to facilitate its management and to reduce problems associated with animal nutrition or to acid soils. Lastly, it contributes to healthier environment and is very useful in organic farming.

An experiment was established in order to determine dry matter (DM) and protein yields of red clover and Italian ryegrass in pure stands, and in mixtures with three different proportions. Small rates of mineral nitrogen ( $30 \text{ kg ha}^{-1}$ ) were also tested.

Results of this study indicated that a small rate of nitrogen affected positively both DM and protein yields. Effect of nitrogen was higher in pure stands for both species than that in mixtures. Two years DM yield for red clover in pure stand ( $34.4 \text{ t ha}^{-1}$ ) was similar to that of the mixtures ( $33.3$  and  $31.6 \text{ t ha}^{-1}$ ) with the proportion of red clover up to 50%, while DM yield of Italian ryegrass was only  $19.0 \text{ t ha}^{-1}$ . Differences for protein yield were even higher.

### Analysis of hyperspectral data to estimate forage quality in legume-grass mixtures

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This study was undertaken to explore the potential of field spectral measurements for a non-destructive prediction of metabolisable energy (ME), ash content, crude protein (CP), and acid detergent fibre (ADF) of legume-grass mixtures. A population of 200 legume-grass swards [*Lolium perenne* (L.), *Trifolium repens* (L.), *Trifolium pratense* (L.)] representing a wide range of legume proportions (0 to 100% of dry matter), and growth stages (beginning of tillering to end of flowering) were used in this investigation. One day before harvesting the reflection of incident light on the swards was measured with a spectrometer (FieldSpec, Analytical Spectral Devices) in the range 350-2500 nm. For further data processing, modified partial least square regressions (MPLS) were calculated and related to the forage quality variables of each sward. The results show high prediction accuracy for all quality variables ( $0.70 \leq R^2 \leq 0.83$ ). Even with a reduced spectral data set (630 to 1000 nm), estimates of MPLS models are still acceptable for forage ash ( $0.62 \leq R^2 \leq 0.78$ ) and CP ( $0.83 \leq R^2 \leq 0.86$ ), a finding, which could facilitate an application of field spectroscopy in practice.

## **Modelling ammonia emissions after field application of biogas slurries on grassland sites**

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In Germany the production of biogas from energy cropping systems is in the focus of the bio-energy strategy for the reduction of greenhouse gas emissions. In particular, at typical sites for grassland and fodder production, e.g. the coastal regions in Northern Germany, grasses have the potential to serve as an alternative to maize as the predominant biogas crop. Ammonia emissions are unavoidable in these systems as biogas residues have to be stored and are re-transferred to the field as N-fertilizers. For scenario analysis and regionalisation, model approaches for NH<sub>3</sub> emissions after field applications of biogas slurries are of particular interest. In this study, one dynamic and one empirical model approach for the calculation of NH<sub>3</sub> losses from grasses and other energy crops after application of biogas slurries were developed and tested. With respect to validation data the models showed a quantitative accuracy of cumulated NH<sub>3</sub>-N losses of between 2 and 4 kg ha<sup>-1</sup> which is in the range of the accuracy of commonly used measurement methods.

## **Influence of cutting date and pre-conditioning on the energy production from grassland through the integrated generation of solid fuel and biogas from biomass (IFBB)**

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A novel procedure, the integrated generation of solid fuel and biogas from biomass (IFBB), is suggested to improve the conversion of biomass from permanent grasslands into energy. The objective of this project was to determine the influence of cutting date and pre-conditioning of the biomass on the net energy yield of IFBB in comparison with anaerobic digestion of whole-crop silage (WCD) and combustion of hay (CH). Biomass samples were taken from a permanent lowland grassland (*Arrhenaterion*) on eight consecutive cutting dates between 27 April and 21 June 2007, ensiled for three months and subjected to a hydrothermal conditioning at different temperatures (10, 30, 50, 70 and 90 °C), followed by a mechanical separation into a press fluid and a press cake. Net energy yields based on methane yields and heating values were higher in CH and lower in WCD compared with IFBB. Highest net energy yield of the IFBB process (9.31 MWh ha<sup>-1</sup>) was obtained with biomass cut on 31 May and a conditioning temperature of 50 °C. Energy production from press fluids (electricity and heat as proportion of gross energy yield) showed a significant relationship ( $R^2 = 0.81$ ,  $P < 0.001$ ) to the dry matter concentration in the silage and to the conditioning temperature.

## **Microwave for dock control on grassland**

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Experiments with microwave technology were carried out in order to provide an alternative method of controlling dock weed on grassland. Two microwave devices of 4.8 kW and 18 kW were therefore tested under different site and weather conditions. The microwaves were applied to heat the extremely regenerative dock roots to their physiological collapse. Time series were used to obtain optimum treatment times for a minimum plant dying rate of 80%; therefore, four different trial varieties were chosen. In general, microwave technology is suitable for the treatment of dock plants and to prevent re-sprouting. The optimum heating time with an 18 kW microwave device is 28 s, which means 0.09 l diesel per plant. The required length of all treatment variants, and hence the amount of energy to be applied, were shown to be high.

## **Grassland yield response to knife/tine slurry injection equipment – benefit or crop damage?**

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Slurry injection into grassland has advantages over slurry spreading as it decreases ammonia losses and odour and improves forage hygiene. However, injection may harm grassland plants, although similar knife-based equipment is used on lawns to stimulate growth.

In split-split-plot field experiments, four different types of knife/tine equipment were tested on three different grassland swards (monocultures of red clover, perennial ryegrass, red fescue), with or without added nitrogen. In two separate experiments, the injection treatments were applied in spring (late April) or after the first cut in mid-June. Different methods were used to measure crop damage during growth in order to predict yield decreases due to knife/tine damage, but not all results are presented here. Statistical analyses of total dry matter yields determined in three cuts per year showed significant differences between knife/injector tine treatments and the control. During the first year, sward yield decreased by 1-8% in the treatments with knives/injector tines compared with no knives/injector tines, whereas during the second year the yield decrease was 3-9%. All techniques had the same effect on all grassland species, with or without added mineral nitrogen. The least reduction in yields was obtained with vertical cut or angled disc injection applied in mid-June.

## **Better grazing opportunities with a mobile milking robot**

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Although grazing of dairy cows is very common in the Netherlands, the number of grazing cows is decreasing. Mobile milking robots might support grazing, in particular in situations of large herds, in remote grassland areas and in extensive natural grasslands. In the Netherlands, a stand-alone mobile milking robot has been developed using caterpillar tracks. Every day, this milking robot moves to a new part of the pasture and every two days concentrates, fuel, water and milk are separately transported from and to the mobile milking robot. The system was tested in the 2008 grazing season using a herd of 35 dairy cows. During the 2009 grazing season the project was scaled up to a herd of 60 cows on an area of 20 ha peat soil. In 2009 a strip grazing system with controlled as well as free cow traffic was used in order to increase the visit and milking frequency. The mobile milking robot was capable of managing a 60-cow herd grazing 24 hours while producing a rolling milk average of 7500 kg cow<sup>-1</sup> yr<sup>-1</sup>. The challenge is to improve the milk yield per cow and year by increasing the milking frequency.

## **Slurry seeding in grassland in Norway**

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A method of mixing seeds of different crops and liquid animal manure is called slurry seeding or wet seeding. The method is so far more used for seeding forage crops than for grasses and clover. A Norwegian company has developed a system for adding and mixing seeds into animal slurry at the liquid manure spreader. The seed-enriched slurry is either applied on the surface by a trailing hose (band spreading) or injected in the soil. Thus, the process combines manure application, seeding of forage or cover crops, and aeration tillage if the slurry is injected. The method may also contribute to an increased sward age. During the last three years the system of slurry seeding has been investigated at different sites in Norway, from dry inland areas to coastal areas with a high annual precipitation. Slurry seeding by use of the injector or the band spreader was compared to direct drilling of seeds only, and full renovation of the swards including ploughing. Where the sward was killed by herbicides, slurry seeding resulted in about the same DM yields and botanical composition as traditional renovation. In the case of swards not destroyed by chemical treatment the results were more variable, particularly at the first cut.

## **Continuous and rotational grazing system with horses: effects on gorse production understorey developed under *Pinus radiata* stand**

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Grazing systems have different effects on understorey productivity and biodiversity, and these effects should be evaluated to obtain better understorey management and sustainable production systems. This experiment aimed to evaluate the effects of two different grazing systems (continuous vs. rotational) on two different types of gorse understorey (*Ulex europaeus* (European gorse) and *Ulex gallii* (Galician gorse)) in terms of productivity (biomass and its fractions). The results of this study will promote more sustainable techniques for rangeland management. Both continuous and rotational grazing systems on each understorey are useful tools for reducing biomass and, therefore, fire risk, because gorse biomass is the fuel that is fired. The rotational grazing system caused significant damage to the European gorse shrub, limiting its recovery once grazing was stopped. In contrast, the more intensive grazing of European gorse plants under rotational, rather than continuous grazing, had a positive effect on the reduction of fire risk by decreasing the biomass. Under the conditions of our study area, the decline was more noted under European gorse rotational grazing system, but on the Galician gorse this decline was found under continuous grazing.

### **2.1.01 Productivity and yield quality of white clover-grass mixed swards depending on cutting frequency**

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Field trials were carried out in 2005-2008 with the aim of studying continuous green forage production from white clover-grass swards in the stage of intensive growth. The 16 mixed binary swards were developed on silt loam cutanic luvisol and were fertilized with N 0, N 90<sub>(45+45)</sub>, P 78 and K 90 kg ha<sup>-1</sup>. The binary swards were composed of white clover cv. Rivendell and six perennial ryegrass, six *Festulolium* and four hybrid ryegrass cultivars. Swards were cut two to four times during the growing season. The white clover Rivendell in mixtures with grasses of various growth patterns provided continuous green forage production during the whole summer season. The botanical composition and frequency of cutting affected the average dry matter (DM) productivity of a sward (5.78 to 8.60 Mg ha<sup>-1</sup>). The ratio of white clover, and the interaction between clover and different grass cultivars in clover-grass swards, determined the crude protein content in the total DM yield of each sward as well as the CP content for each component in a sward. The average net energy of lactation (NEL) content of DM of mixed stands was 5.76-5.88 MJ kg<sup>-1</sup>.

### **2.1.02 Comparison of three traditional uses of forage production of mountain meadows in western Azerbaijan, Iran**

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The world's meadows are the most productive kind of rangelands. The development of croplands and overgrazing has led to a decline in diversity and reduced meadow areas. In Iran, mountain meadows mostly occur in north-west of the country, especially in the Chaldran areas. The people of Chaldran have different uses of mountain meadows which affects directly the forage production. The objective of this research was to investigate the effects of utilization methods on forage production of mountain meadows. To sample the study locations in Chaldran based on the current traditional uses and the soil moisture percentages, nine study units were selected and were randomly sampled by using 25×60 cm<sup>2</sup> plots. In each location, production and soil characteristics were measured and analysed by using completely randomized design with two factors of traditional uses and soil moisture regimes. The effects of edaphically factors on traditional uses were analysed by using canonical correlation analysis (CCA) as ordination technique. Significant differences were observed among traditional uses in different soil moisture contents ( $P < 0.05$ ). Therefore, the forage yield increased with increasing soil moisture. There was a significant difference among application of harvesting method so the forage production highly increased. The yield under direct grazing method was less than the other traditional uses.

### **2.1.03 Pastures feeding value response to humic fertilizers**

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Humus content determines soil fertility and affects crop yield. Natural formation of humus is important, but this is a long and slow process. This process could be improved by applying different organic fertilizers. The humic fertilizer 'Turbo Grass' containing 9.7% of organic acids was applied at different rates to improve the feeding value of grass on dairy farms. The objective was to evaluate the impact of humic fertilizers (up to 32 l ha<sup>-1</sup>) on grass chemical composition, yield, metabolisable energy, net energy (NEL) and digestibility of intensively managed sown pastures in combination with different rates of mineral fertilization. Rates of humic and complex fertilizers had different effects on recorded parameters.



#### **2.1.04 Soil fertility and forage yield in a maize-Italian ryegrass rotation fertilized with pelletized broiler litter**

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Effects of two rates of dried pelletized broiler litter on soil fertility characteristics and forage production, as compared with conventional mineral fertilization, were studied in a rotation of maize (*Zea mays* L.) and annual Italian ryegrass (*Lolium multiflorum* L.). Forage yield of Italian ryegrass and maize in both broiler litter treatments were similar to, or above, those achieved with the conventional mineral fertilization, indicating a rapid mineralization and subsequent plant availability of broiler litter N. Compared to the mineral fertilizer treatment, application of dried pelletized broiler litter resulted in similar available P and higher soil K and Mg contents. At the end of the rotation, the organic fertilizer also reduced soil acidity compared with that of the mineral fertilizer and control treatments, thus improving the availability of phosphorus for both forage crops.

#### **2.1.05 Natural lucerne populations of Estonia: yielding ability, herbage quality and prospective ways of use**

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A plot trial was established in 2003 with seeds gathered in 2001–2002 from semi-natural grasslands of Estonia in order to determine the yielding ability of lucerne populations and their prospective uses. The total dry matter yields of one natural population exceeded the standard variety by 6.0%, in the sowing year and in three harvest years. From a plant breeding perspective this population is of interest. The remaining populations can be divided into two groups based on their growth rhythm, DM and CP yield. These are: 1) modest regrowth, predominantly yellow-flowered, spreading vegetatively by rhizomes, type *Medicago falcata* L. (DM and CP yields accounted for 48.0–55.7% and 49.6–59.2% of these of the standard variety, respectively) attracts attention as a source material for breeding specific varieties for landscape management; 2) populations of *M. media* Pers. with yellow and variegated flowers (range of DM and CP yields 65.8–92.0% and 64.5–86.2%, respectively). The seeds of these populations can successfully be used for improvement of semi-natural grasslands.

### **2.1.06 A preliminary study on new biodegradable films to cover silages**

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Two different silage cover films, one made of standard polyethylene (PE) and the other made of Mater-Bi® biodegradable plastic (MB), with two different thicknesses (60 and 120 µm) have been compared. A whole maize crop was chopped, treated with a mixture of *Lactobacillus plantarum*, *L. buchneri*, and *Enterococcus faecium*, and ensiled in plastic bags with four replications for each treatment. After 55 and 110 d of conservation, all the silages were well fermented with no differences in fermentative and nutritional quality between the treatments, and few differences in mould count and aerobic stability after 110 d of conservation. These results showed the possibility of successfully developing a biodegradable cover for silage for 4 months after ensiling.

### **2.1.07 Utilisation of clover-grass silage of different cutting dates for solid fuel production**

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Clover-grass swards play a major role in crop rotations in organic farming systems due to their ability to fix nitrogen. On farms without livestock, an efficient utilisation of clover-grass swards is often not possible, and alternative applications with economic benefits are warranted. This work is aimed at the assessment of energy recovery from clover-grass silages by the integrated generation of solid fuel and biogas from biomass (IFBB), particularly the consideration of nitrogen flows within the biomass conversion procedure. A clover-grass sward was cut at four different dates in the spring of 2008 and the biomass was separated into a liquid fraction for biogas production and a solid fraction for combustion. Methane yields of 420 - 500 normal litres (l<sub>N</sub>) per kg volatile solids (VS) were obtained by the liquids which contained 0.69 of the initial nitrogen of the biomass if the harvest was at an early growth stage, but only 0.35 if the harvest was delayed. The liquid, which also contains 0.78 - 0.92 of the initial phosphorus and potassium, can be used as fertiliser. On the other hand, the corresponding solid shows significantly reduced concentrations of elements detrimental for combustion, such as potassium and chloride.

### **2.1.08 PROGRASS – A mobile plant to produce solid fuel from grass harvested in the NATURA grassland habitats**

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Species-rich grasslands are seriously threatened in many European countries. For the conservation of these areas, nature protection agencies propose an extensive grassland management with regular harvesting. However, the strongly lignified biomass has a low nutritional value even for ruminants and, therefore, provides poor economic returns through extensive grazing. Equally, there are technical constraints in energy recovery because of low degradability in conventional biogas plants and of high mineral and nitrogen concentrations in combustion systems. An innovative technical approach has been developed to produce solid fuel with improved combustion characteristics through hydrothermal conditioning and mechanical dehydration of the biomass (IFBB – integrated generation of solid fuel and biogas from biomass). Within the European wide PROGRASS project, the feasibility of this bioenergy system will be demonstrated and investigated on a pilot-plant scale. The mobile prototype will be operated in Germany, Wales and Estonia where six representative experimental areas per country have been chosen. In addition to technical considerations, the project comprises investigations on grassland biodiversity, economics and life cycle assessment. This paper reports the first results obtained for the productivity of the grasslands and a technical description of the prototype.

### **2.1.09 White clover effect on yield and quality of a *Lolium perenne* sward under cutting conditions**

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In this experiment, we compared perennial ryegrass (PRG, *Lolium perenne* L.) with and without white clover (WC), under cutting conditions and under the maximum fertiliser rates stated in the Flemish decree on fertilisation. The experiment started in 2007 on a sandy loam soil (Merelbeke) and the results after two years are presented here. In this management regime with a annual total N fertilisation between 170 N<sub>slurry</sub> + 100 N<sub>mineral</sub> and 250 N<sub>slurry</sub> + 180 N<sub>mineral</sub>, the presence of white clover stimulated dry matter and crude protein production and forage quality of a PRG sward significantly in 2008. A higher crude protein content resulted in significantly higher level of true protein digested in the small intestine and in a non-significant higher level of degradable protein. In 2007 only a significant increase in crude protein content was measured. Leachable N-residue in the soil was low for a PRG-WC sward, but it was significantly higher than the PRG sward.

### **2.1.10 Crop-livestock system: Influence of different sward heights in cattle performance**

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The objective of this study was to evaluate the influence of different sward heights on cattle performance in a crop-livestock system. The study was conducted in a crop-livestock system in Tupancireta, Rio Grande do Sul, from May to November 2008. A forage mixture of oats (*Avena strigosa* Schreb.) and annual ryegrass (*Lolium multiflorum* Lam) was cultivated in the winter before soybean (*Glycine max* (L.) Merr.) cultivation. A group of crossbred steers, mean age of 10 months and mean initial weight of  $202 \pm 1.73$  kg, was distributed in a randomized block design with three replications. The experimental area was adjusted in relation to the stocking rate required to achieve and maintain sward heights of 10, 20, 30 and 40 cm. The individual performance of steers was less in pastures with sward heights of 10 cm. The sward heights of 10 and 20 cm resulted in higher live weight gains per hectare (LWG) than the 30 and 40 cm sward heights, with linear regression of this variable as the sward height was increased.

### **2.1.11 Grazing with a mobile milking robot**

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The size of dairy cow herds in Europe is increasing. Farmers have to manage larger herds but want, at the same time, to benefit from a normal social life. So, the milking robot can bring solutions. Its use can reduce physical labour and allow flexibility. During the past 10 years, the number of milking robots has been increased in Europe. In farm practice, this technology has resulted in a reduction in the amount of grazing, even though grazing appears as a natural practice which is appreciated by the consumers. At the experimental farm of the University of Liège we are developing the concept of a mobile milking robot in collaboration with a private company. This prototype will allow cows to graze and could be moved to different locations on pastures during the grazing season. The prototype will be used indoors during the end of the winter season and will be moved outdoor during the 2010 grazing season. The feasibility of this prototype has to be tested in the field. Milk production and quality, the number of visits and the grazing parameters will be recorded. Different equipments in view to attract the cows to the robot as the presence of a cow brush, the location of the drinking point, will be compared. The behaviour of animals will be also assessed.

### **2.1.12 Fermentation residues of biogas co-fermentation and their effects on grassland**

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Fermentation of grass and maize as co-ferments with cattle slurry is common in Baden-Wuerttemberg (Southern Germany), where more than 600 biogas plants for bioenergy production are installed. The effects of biogas fermentation residues of different origins as fertilizers on grassland have not yet been investigated, particularly in the context of the amount of nutrients permitted by the EU Nitrates Directive. LAZBW tests the effects of two different biogas slurries on yield and botanical composition of permanent grassland at two different locations with eleven treatments and four replications. Slurry 1 is half and half coferment and cattle slurry, Slurry 2 is from pure co-fermentation of maize and grass. The treatments differ in the amount of slurry, the number and time of application and the supplementation of mineral N, P and K. The preliminary results show that not only different nutrient contents of the substrates, but that also various effects on grassland and higher DM yields by additional fertilization of mineral nutrients. The date of additional mineral nitrogen application had no significant effect. N-removal with grassland biomass ranged from 250 kg ha<sup>-1</sup> to a maximum of 420 kg ha<sup>-1</sup>. The botanical composition of the grassland swards changed due to different fertilisation.

### **2.1.13 Forage yield and N<sub>2</sub> fixation of *Trifolium alexandrinum* in pure stand and in mixture with *Lolium multiflorum***

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The efficiency of grass-legume intercrop systems is affected by various agronomic factors such as crop density, plant spacing and arrangement that may alter the competitive relationships between component crops. The aim of this study was to evaluate yield, N concentration, and symbiotic N<sub>2</sub> fixation of berseem clover (*Trifolium alexandrinum* L.) grown in pure stand or in mixture with annual ryegrass (*Lolium multiflorum* Lam) either in alternating rows or in the same row. The experiment was conducted in two consecutive growing seasons in a semi-arid Mediterranean environment (Sicily, Italy). Dry matter (DM) yields were similar in the mixed stands and in the berseem pure stand; the annual ryegrass pure stand produced the lowest yields. Plant arrangement did not significantly affect the yield of the mixtures, but it did influence the proportion of the two components. Intercropped berseem had a significantly higher percentage of N derived from the atmosphere than the monocropped berseem, but no differences were observed by plant arrangement. The apparent transfer of fixed N from berseem to ryegrass was not detected in any arrangement treatment.

### **2.1.14 Effect of different methods of sward renovation on selected physical and chemical soil properties**

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In permanent grassland renovation, the productivity, quality and ecological aspects (N and C cycles and soil quality dynamics) should be taken into consideration. During 2006-2008 an experiment was carried out with the aim of evaluating the effect of different renovation methods (old sward preparation by low cutting at a height of 3 cm and overdrilling, soil preparation by rototiller and overdrilling, spraying with glyphosate and direct drilling, ploughing and reseeding) on the selected physical and chemical properties of a soil of organic origin (Histosol). The following parameters were determined: soil moisture, bulk density, porosity, capillary water capacity, specific conductivity, content of N-NO<sub>3</sub><sup>-</sup>, P-PO<sub>4</sub><sup>-3</sup>, K<sup>+</sup> in soil solution. Sward renovation methods significantly influenced physical and chemical properties of the soil. The observed effects were different in successive years after renovation. It is concluded that overdrilling and direct drilling are pro-ecological forms of grassland renovation on organic soils.

### **2.1.15 Biogas-Expert: grassland methane yield and short-term N efficiency of biogas residues**

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Biogas production has expanded substantially in Germany - often in areas, where intensive livestock production is located, and large organic nutrient amounts are available. A field study was conducted to investigate the short-term N efficiency of different fertiliser types (mineral, biogas residue, cattle slurry) applied to grassland. Fertiliser type significantly influenced annual dry matter and methane yield, mainly explained by the NH<sub>4</sub>-N ratio. With respect to Relative N Fertiliser Value, differences between fertiliser types were pronounced only in the low N input range, where biogas residue showed a higher N availability than cattle slurry.

### **2.1.16 Using digital image analysis to estimate legume contents in legume-grass swards**

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An efficient and accurate detection of legume dry matter (DM) contribution in legume-grass mixtures is of great importance for a targeted management of legume-based swards. Digital image analysis (DIA) procedure was recently introduced to estimate legume contents in legume-grass swards based on greyscale pictures of swards. DIA was identified as a promising tool to estimate legume contributions (% of DM) with  $R^2$  0.87, 0.85 and 0.79 for red clover (*Trifolium pratense* L.), white clover (*T. repens* L.) and lucerne (*Medicago sativa* L.), respectively. The present paper describes a DIA procedure that improved classification accuracy by inclusion of colour information and the use of an improved algorithm for the relationship between legume coverage (% area) and legume contribution (% of DM). With this approach the estimation of legume contribution (% of DM) in legume-grass mixtures was significantly enhanced.

### **2.1.17 Grassland potassium balance in a pot experiment using soils with different management histories**

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Potassium (K) management is important in grassland systems, especially in dairy farming. The interactions of potassium with other nutrients, such as magnesium (Mg), and enhanced potassium levels can have impacts on yields, product quality and on metabolic health issues of dairy cattle. A deeper understanding of potassium cycling is thus necessary for sustainable management. We used four sandy soils of similar genesis but with contrasting concentrations of available K and combined these with different levels of mineral K fertilisation in a glasshouse pot trial. A mass balance approach was used to examine soil K history and treatment fertiliser K effects on plant K and Mg uptake. The duration of the experiment was 5 months, growing Italian Ryegrass (*Lolium multiflorum* Lamark). Potassium concentrations in shoots were relatively high and were influenced by initial soil K and K input. Magnesium concentrations decreased the most in the soil with the lowest initial K and with increasing K input. Uptake of K by shoots and retention in soil were the main sinks for input K. The short-term reaction of the plant-available soil K pool seemed to be very dynamic but limited for soils with high initial K.

### **2.1.18 The intensity of grassland management on farms in the north-eastern part of Lublin province**

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The aim of this work is to demonstrate how the production potential of grassland agrees with the strategy of the CAP (Common Agricultural Policy) with regard to commodity milk production. The study involved studying a sample of 1656 randomly selected farms from the north-eastern part of Lublin province that had breeding dairy cattle. In the studied farms, the contribution of grasslands in the structure of agricultural lands was significantly higher than the average in the region and in the country. The largest research group accounted 49.5% of farms and they produced 20-50 thousand l of milk, had an average area of 21.23 ha and kept an average 9.8 cows. A large share of permanent grassland in the structure of agricultural lands, and a high stocking density per 100 ha of grasslands in north-eastern Lublin province, indicate a change in direction of grassland management from 'existing' to 'integrated'.

### **2.1.19 Formation of hayland productivity and hay quality in the forest steppe of Ukraine depending on the methods of fertilization of perennial grasses**

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Supplies of nutrients and moisture favourable for growth are important for the productivity of haylands, and for obtaining high-quality forage material. Except for the use of the cheapest renewable resources, mainly in the form of symbiotic legume-N, and surface application of elements in the form of traditional mineral fertilizers, in the nutrition of haycrop legume-grass stands a significant role is played by microelements. Among the types and forms of micro-fertilizers available in agriculture, water-soluble complex fertilizers with a balanced content of macro- and microelements on a chelate basis, which are non-toxic and completely available to plants, are of great interest for the production of ecologically safe and high quality fodders from haylands. Research carried out on dark-grey podzol soils of the forest steppe of Ukraine has studied the influence of outside root nutrition with phosphorus-potassium fertilizers ( $P_{90}K_{90}$ ), full mineral fertilizer ( $N_{90}P_{90}K_{90}$ ), outside root nutrition with water-soluble complex *Kristalon*<sup>TM</sup> and their combination, on the indices of productivity of legume-grass stands and chemical composition of hay. The most effective fertilization of a grass-legume mixture of *Phleum pratensis* L.), *Festuca orientalis*, *Trifolium pratense* L. and *Lotus corniculatus* L. under three cuts during the vegetation period was determined. This was a complex supply with macro- and microelements combining surface application of starting doses of mineral nitrogen ( $N_{30}$ ) with the outside root nutrition with *Kristalon*<sup>TM</sup> ( $4 \text{ kg ha}^{-1}$ ) under each hay-crop against a background of  $90 \text{ kg ha}^{-1}$  of nutrient elements of phosphorus-potassium fertilizers applied as a reserve before the beginning of the grass vegetation season.



### **2.1.20 Effects of *Trifolium incarnatum* proportion in binary mixtures with *Lolium multiflorum* on the soil N<sub>min</sub> content and the amount of symbiotically fixed N**

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Wwinter cover crops have gained importance in sustainable farming because they accumulate N in organic matter. Aiming to find a compromise between the efficiency of *Trifolium incarnatum* L. and *Lolium multiflorum* Lam. in decreasing soil N<sub>min</sub> content and the efficiency of *T. incarnatum* in N fixation, a field experiment (designed as randomized complete blocks with eight replications) was carried out in eastern Slovenia in 2008-2009. *T. incarnatum* and *L. multiflorum* were sown in late August 2008 in pure stands in binary mixtures. Control treatment was without cover crop (bare fallow). At the end of April 2009, the contents of soil N<sub>min</sub> under *T. incarnatum* and mixtures with a high proportion of *T. incarnatum* were statistically at the same level as the control treatment, but significantly higher were the N<sub>min</sub> contents under *L. multiflorum* in a pure stand and under mixtures with a low proportion of *T. incarnatum*. The calculated amount of symbiotically fixed N was highest under *T. incarnatum* in the pure stand and decreased with decreasing proportion of *T. incarnatum* in binary mixtures. Because of the positive relationship between soil N<sub>min</sub> content and symbiotically fixed N, the results do not allow the overall advantage of any of treatment to be clearly stated.

### **2.1.21 Use of portable NIRS equipment in field conditions to determine the nutritional value of mountain pastures**

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The main objective of the current study was to obtain, by means of using portable NIRS equipment under field conditions, NIRS calibrations useful to determine the nutritional value of mountain pastures in the Basque Country (northern Spain). To this aim, NIRS spectral data were acquired *in situ* on grass samples (without cutting the grass) from a Basque pastoral agroecosystem. Afterwards, the grass was cut and immediately taken to the laboratory, where spectral data were acquired on the freshly cut grass. Grass samples were collected in a spatially homogeneous area in order to avoid the spatial heterogeneity caused by slope, aspect, vegetation, etc. Grass samples were taken in May and October 2008 (at the beginning and at the end of the grazing season) so that part of the temporal heterogeneity typical of these mountain pastures was considered. Nutritional parameters of pasture, such as dry matter and crude protein, were determined in the grass samples. Nitrogen was determined by the Kjeldahl method and thus crude protein calculated. GRAMS AI Chemometrics software was used to search for correlations between analytical data and NIRS spectral data. NIRS calibrations for freshly cut samples for dry matter ( $R^2 = 0.89$ , SECV = 0.35) and crude protein were obtained ( $R^2 = 0.63$ , SECV = 1.03). NIRS calibrations can be of great use for local decision-takers involved in the sustainable management and conservation of these Basque

mountain pastures. Portable NIRS technology offers great potential for the fast acquisition of accurate data on nutritional quality of mountain pastures.

### **2.1.22 Dairy soiled water as an organic fertilizer for perennial ryegrass pasture**

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Soiled water is produced through the washing-down of milking parlours and holding areas. It contains significant quantities of nutrients (N, P, K) that are potentially available to plants. Substitution of soiled water for inorganic fertilizer N may help achieve both these goals. A field plot experiment was carried out to assess the fertilizer potential of soiled water when applied to grassland. Treatments included a control, soiled water and inorganic fertilizer N application at three rates (15, 22 and 30 kg ha<sup>-1</sup>). Treatments were applied every 6 weeks on fresh plots and were carried out over 1 year. Soiled water application significantly increased yields at 8 weeks and there were no significant differences between soiled water and chemical fertilizer yields at any of the application rates. Fertiliser replacement values of 60-93% were found, suggesting that land application of soiled water has potential to decrease inorganic fertiliser use. The effectiveness of soiled water as a fertiliser varied through the year with significant yield responses from March to September. Results indicate that soiled water has potential as a fertiliser but management should account for the seasonality in yield response to application.

### **2.1.23 Fertilisation with different types of sewage sludge on pasture production and protein concentration in a silvopastoral system developed under *Fraxinus excelsior* L.**

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The use of sewage sludge as fertilizer on grasslands is an adequate and suitable way to improve pasture production and to recycle the nutrients of this residue. Sewage sludge should be stabilised before using as fertilizer. The stabilisation process could cause differences in the mineralisation rates and therefore in the fertiliser efficiency. The aim of this study was to evaluate the effects of municipal sewage sludge stabilised using anaerobic digestion, composting and pelletisation on pasture production, and on concentration of crude protein in pasture compared with control treatments (mineral and no fertilisation) in a silvopastoral system established under *Fraxinus excelsior* L. (ash) and a sown sward with *Dactylis glomerata* L. (cocksfoot), *Lolium perenne* L. (ryegrass) and *Trifolium repens* L. (clover) in Galicia (Spain). The results showed that pelletised sewage sludge increased the pasture production and the concentration of crude protein in pasture. Moreover, the proportion of

water in pelletised sludge was lower than in anaerobic sludge and composted sludge, which reduces application and storage costs.

#### **2.1.24 Liming and sewage sludge influence on Ca soil and understorey development in reforested *Pinus radiata* D. Don plantations**

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The acidity of Galician natural soils is very high due to the type of rock and high annual precipitation. Therefore, it is advisable to carry out liming and fertilization to improve soil fertility and vegetation productivity. The result of these management practices could be modified depending on the date of application. The objective of the study was to evaluate the effects of liming and of three sewage sludge doses applied at different dates on Ca evolution (soil and pasture), in a silvopastoral system established on a very acid soil with *Pinus radiata* D. Don, and after a pasture was sown. The different results show that the application of lime and doses of sewage sludge increased the Ca concentration in the soil and in the pasture. However, late fertilization and high dose of sewage sludge added in April reduced the concentration of calcium in the pasture.

#### **2.1.25 Impact of different levels of inorganic and organic fertilizers on sward production**

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Rational use of sewage sludge as fertilizer is highly relevant for Europe, since the production of this residue has increased in the last years due to the implementation of the European directive 91/271/CEE. Moreover, increased fertilizer prices in recent years made the recycling of this residue even more important for farmers to reduce production costs. However, both the slow rate of sludge incorporation at the start of the year and the low proportion of potassium in the sludge may cause unbalanced fertilizer inputs. The objective of this experiment was to evaluate the effect of different sewage sludge doses, combined or not, with nitrogen and K, and two varieties of cocksfoot (*Dactylis glomerata* L. Artabro and Cambria) on forage biomass production and effect of this residue. If low doses of sewage sludge were applied complementary inputs of N and K were needed to supply N pasture needs at the start of the year, thereby enhancing pasture production. However, medium and high doses of sewage sludge enable adequate pasture production without inorganic complementation. Sward production in the third harvest was lower than at others because of low summer rainfall. Biomass production with variety Artabro was lower than Cambria during spring and autumn.

### **2.1.26 The organic-mineral fertilization of a *Festuca rubra* L. grassland for eight years**

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Organic-mineral fertilization could be a realistic method of management of the grasslands in Romania while there is a strong decrease taking place in the number of animals. On the grasslands in the Apuseni Mountains this type of management is not yet being practised, but it could provide a chance to maintain the oligotrophic grasslands in the mountainous landscape. The combined and long effect of organic and mineral fertilizers upon the dry matter is already understood, but the influence upon the phyto-diversity has been less studied. The objective of this paper was a survey of the effect of application of organic and mineral fertilizers upon the phyto-diversity of a meadow from the boreal floor. After an eight-year period, the administration of mineral and organic fertilizers produces important changes at the herbaceous canopy level. The floristic structure of the treated variants was noted, and certain species were characteristic to each type of management. The floristic structure of the treated variants was significantly correlated with the general cover, mineral and organic fertilization and with the length of the period of fertilization. The administration of technical inputs produces a considerable decrease in phyto-diversity, especially in the case of the variants treated with larger quantities of fertilizers.

### **2.1.27 Effect of frost on regrowth ability and frost tolerance of rush (*Juncus* spp.)**

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Soft rush (*Juncus effusus* L.) and compact rush (*J. conglomeratus* L.) have spread significantly in coastal parts of Norway during the past two decades, an increase that seems to have coincided with an observed rise in winter temperatures. This study investigated the effects of exposure to frost on plant regrowth of both species. Exposure to temperatures of –8 °C to –10 °C for more than 6 h resulted in significantly lower regrowth ability compared with non-frozen controls. Regrowth was still observed after 72 h, but with significantly lower regrowth ability for soft rush than for compact rush at 48 h and 72 h. These initial results indicate that soft rush is more susceptible to frost than compact rush. However, the species did not differ significantly in frost tolerance.

### **2.1.28 Hyperspectral measurements in maize (*Zea mays* L.) for silage**

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In a 3-yr experiment nadir and off-nadir hyperspectral measurements were conducted inside maize canopies. For off-nadir measurements different angle/height combinations were used to cover the whole maize plant. In general, off-nadir angle/height combinations showed improved prediction accuracies for dry matter yield (DM yield) and metabolisable energy (ME) of the whole crop compared to nadir measurements, whereas results of nadir measurements for crude protein (CP) could hardly be reached by off-nadir adjustments.

### **2.1.29 Effects of additional illumination under changing simulated sky cover on field spectroscopic measurements in clover-grass swards**

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The paper presents results of a one-year field experiment in which spectral reflectance of a binary legume-grass mixture was measured depending on the influence of an artificial lamp at different simulated cloud stages. Artificial illumination led to spectral accentuation at defined wavelengths due to the mixed energy provision from solar and artificial radiation.

### **2.1.30 Analysis of land utilisation by red deer in the Apennine Mountains**

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Wild ungulates usually utilise for their activities wide ranges, constituted by different habitat types such as woodland, grassland, unproductive surfaces and also suburban areas. The knowledge of the home range extent and characteristics is important with regards to conflicts with agriculture and forest management and useful for best management practices of wildlife. We investigated the spatial behaviour and habitat use of 12 female red deer (*Cervus elaphus*) in a protected area in central Italy from spring to autumn 2009. Animals were equipped with GPS collars able to record locations (fix) taken once an hour. Seasonal home ranges were generated for each hind in a GIS system. Home range sizes were highly variable between individuals but generally consistent in time. Habitat composition within individual spring and summer home ranges differed from overall availability, showing marked preference for pastures and meadows. Moreover, within home ranges the animals used these open habitats more than suggested by their availability in spring and autumn. Our results confirm the great importance of pastures and meadows for red deer, especially in areas with a prevalence of woods with low availability of undergrowth.

### 2.1.31 Ammonia volatilization after application of biogas slurries in a coastal marsh region of Northern Germany

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Biogas production has increased rapidly in Germany, resulting in large amounts of biogas slurries. Physico-chemical properties of biogas slurries differ from those of conventional animal slurries. Due to this fact a field study has been established to determine ammonia losses by volatilization after supply of biogas slurries in grassland. Perennial ryegrass (*Lolium perenne*) was tested as an alternative to conventional biogas crops (silage maize, silage cereals) in the marsh region of Schleswig-Holstein in Northern Germany. Yield was determined under different N-fertilisation-levels of mineral fertiliser (CAN) and biogas slurry applied by trail hoses. Ammonia losses are mainly influenced by climate conditions and were investigated by a micrometeorological approach, backwards Lagrangian stochastic dispersion method. Because of strong wind in the coastal region the major fraction of the ammonia emissions were observed within the first 10 hours after application. The NH<sub>3</sub>-losses by volatilization were higher than in other regions of Schleswig-Holstein and substantially decreased yield of perennial ryegrass.

### 2.1.32 Changes in soil P status of grassland in the Netherlands between 1971 and 2009

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In many EU countries, agricultural land has been heavily manured and/or fertilised in past decades. Many of these lands now have high soil phosphorus (P) status and are characterised as high risk areas for phosphorus (P) leaching. Here we report on regional and temporal changes in the soil P status of grassland in the Netherlands, using a database with ~ 2 million results of soil P determinations from farmers' fields over the period 1970-2009. Mean soil P-status of grasslands remained rather constant during the period, but there are large differences between regions and soil types. In general, soil P status increased in the order: loess soils < clay soils < peat soils < sandy soils. Manure policy has put increasingly tight restrictions on P application from 1984 onwards, but the effect on soil P status is not significant ( $P < 0.05$ ) yet. The relatively high soil P status of grasslands will have major implications for future livestock farming and manure management in these areas, because P application limits will be increasingly tightened to decrease the vulnerability of the soils to P leaching.

### **2.1.33 A comparison of different conversion techniques for the production of energy from permanent grasslands**

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The integrated generation of solid fuel and biogas from biomass (IFBB) is aimed at an efficient conversion of biomass from semi-natural grassland into energy, which is otherwise problematic with conventional conversion techniques (hay combustion, anaerobic digestion), due to high contents of detrimental minerals and high contents of lignin. The objective of this study was to compare various conversion techniques (anaerobic whole-crop digestion [WCD], combustion of hay [CH] and IFBB) across a broad range of permanent grassland vegetations. Biomass from nine different grassland swards was conserved as silage which was directly used for WCD and separated according to the IFBB process into a press fluid for anaerobic digestion and a press cake for combustion. The press fluids obtained higher specific methane yields than the whole-crop silage. The press cakes showed significantly reduced concentrations of elements detrimental for combustion as compared to CH. The energy conversion efficiency of IFBB was higher compared to WCD and lower compared to CH. Differences between grassland communities in IFBB were marginal.

### **2.1.34 Improvement of permanent grasslands in NE Romania**

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The total pastoral area of Romania, about 4.9 million ha, of which 3.4 million ha is grassland and 1.5 million ha is hay meadow, is an important source of fodder for feeding livestock. This experience was carried out on a degraded pastureland with *Festuca valesiaca* L, 120 m a.s.l., in the forest-steppe zone. In the experiment we investigated the influence of organic and mineral fertilizers, applied at rates of 10-40 Mg ha<sup>-1</sup> on the background of N50-100 kg ha<sup>-1</sup> P36-72 kg ha<sup>-1</sup>, on the production and content of crude protein, cellulose, phosphorus and ash. The *Festuca valesiaca* L. pasturelands from the Romania's forest steppe react positively to medium-level inputs of organic and mineral fertilization, through the improvement of botanical composition and structure and through increasing the crude protein content of the feed. The best results were obtained at 20-40 t ha<sup>-1</sup> manure applied at 2-3 years intervals, associated with annual mineral fertilizer applications of N 50-100 and P 36-72 kg ha<sup>-1</sup>.

### **2.1.35 Effects of different methods of meadow maintenance and non-tillage seeding on yield and plant composition**

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This paper gives results from different alternative methods of meadow maintenance in spring, coupled with and without seeding of valuable plants. The following methods were used: grass-harrow technique, comb weeder, meadow aerator and a scarifier used mainly in golf-course maintenance. After two years of treatment no significant yield differences occurred. The botanical composition of all seeded areas tended to higher amounts of *Lolium perenne* than the unseeded areas. No significant interactions were found in this relationship, nor were there interactions between the different techniques used.

### **2.1.36 Suitability of perennial grasses and legume-grass-mixtures for methane production**

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The aim of the investigation was to evaluate the suitability of perennial forage crops for methane production. Therefore, field grasses and legume-grass-mixtures grown under water limited conditions of the North-Eastern German Plain were tested for dry matter yield ( $8.3 - 26.0 \text{ Mg ha}^{-1}$ ) and potential methane yield ( $2108 - 6323 \text{ m}^3 \text{ ha}^{-1} \text{ CH}_4$ ). Furthermore, the ensiling potentials of grass and legume-grass mixtures were estimated by analysis of dry matter content and water-soluble carbohydrates / buffering capacity ratio as well as nitrate content. All forage crops showed particularly low contents of nitrate up to  $4.4 \text{ g kg}^{-1} \text{ NO}_3$  in dry matter and were therefore moderately difficult or difficult to ensile. For production of anaerobically stable and butyric acid-free silages it is necessary to combine wilting with the use of silage additives.

### **2.1.37 Defining optimum practices for Italian ryegrass seed production in Serbia**

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Italian ryegrass (*Lolium multiflorum* Lam.) cv. Tetraflorum sown at different inter-row spacings (IRS), seeding rates (SR) and spring nitrogen fertilization rates (SNR), was tested under the agroecological conditions of Western Serbia. The field experiments were carried out for four growing seasons (2002-2006) and seed yield (SY), straw yield (SDM) and harvest index (HI) were measured during the first production year. The highest SY in the first



production year varied among treatments depending on seasonal conditions. SY was affected markedly by IRS; however, by an opposite effect under arid and humid weather conditions, and IRS of 40 cm was found to be the least uncertain for seed production. The increase in SR provided higher seed yields in years with unfavourable weather conditions, while in the years with favourable conditions, the SR had either no impact on SY, or decreased SY as a result of ryegrass lodging following seed shedding. Spring nitrogen fertilization decreased SY by increasing vegetative biomass as well as crop lodging. Abundant SDM was obtained in some treatments, but there was no linear correlation between seed and straw yield.

### **2.1.38 Influence of sod seeding grassland on the quality of the first cut**

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Sod seeding was carried out in the pasture sward in Bartošovice (Czech Republic). Four different ways of sowing into the existing vegetation were used. The mixture for sod seeding contained *Festulolium pabulare*, *Dactylis glomerata*, *Arrhenatherum elatius* and *Lotus corniculatus*. The first cut was used for conservation. Grassland quality (botanical composition) and content of nutrients in the silages were evaluated. Different technologies of sod seeding improve dominance of new sown species in a grass stand. The most successful was a radical disturbance of the original grass sward with technology Horsch Exaktor. Sod seeding improves grassland quality in terms of botanical composition (EGQ). Dominance of the sown species up to 20% was not sufficient to influence the nutrients in ensilaging of biomass. Content of CF and NDF was influenced by use of inoculants at ensilaging ( $P < 0.05$ ). Probiotic and probioenzymatic inoculants improve quality of the silage-making process, with a lower content of butyric acid ( $P < 0.01$ ).

### 2.1.39 The benefits of long-term legume swards in an organic farming system

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We studied long-yielding legume species grown pure and in mixed swards with other legumes and *Festulolium*. Seven sward types were managed according to organic farming system, over 7 years, under a 2-cut and 3-cut system. No mineral or organic fertiliser was applied. The highest Dry matter (DM) yield and metabolisable energy in herbage were recorded in the third year of use. The results averaged over seven years suggest that the highest DM yields were obtained with a mixed sward composed of fodder galega, alfalfa and *Festulolium*, or pure alfalfa. Even in the seventh year of use, the sown legumes persisted well enough in the swards. They accounted for 29-75% of the DM yield. Fodder galega and sainfoin persisted better than alfalfa. The annual DM yield did not differ between two or three cut management. Two-cut management gave lower protein contents than three cuts. Moreover, the frequent cuts resulted in thin swards followed by higher infestation of forbs of which *Taraxacum officinale* prevailed.

### 2.1.40 Grass and grass-legume mixtures for methane production

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At three sites in northern Germany (site 1: Braunschweig; site 2: Hannover; site 3: Kiel) dry matter (DM) and methane production of grass and grass-legume mixtures were compared to maize (*Zea mays*). Two cutting regimes were conducted for all 5 cuts: normal-cut, i.e. emergence of grass heads and late-cut, i.e. grass flowering. Pure stands of perennial ryegrass (*Lolium perenne*) and annual ryegrass (*L. multiflorum*) were sown as well as mixtures of perennial ryegrass with crimson clover (*Trifolium incarnatum*) and vetch (*Vicia villosa*) (grass-LEG) and annual ryegrass with red clover (*T. pratense*). At site 1, a late cut of grass and grass-LEG had similar DM and methane yields compared to maize. At site 2, grass under both cutting regimes did not differ from maize in DM yield, whereas in methane yield normal cut grass did not differ from maize. The third site had similar DM and methane yields of late cut grass compared to maize. The other treatments had lower yields in comparison to maize. In conclusion, late cut grass can be an alternative to maize.

### **2.1.41 Biogas-Expert: Sustainable biomethane production in northern Germany - Nitrogen leaching after application of biogas residue**

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In order to ensure the largest possible benefit from replacing fossil fuels by bioenergy, it is mandatory to produce bioenergy in a sustainable way. With respect to biomethane production there are limited data on its risk of contaminating the groundwater with nitrogen. A two-year trial located in two landscapes in northern Germany was conducted to analyse the N leaching potential of biogas residue compared with other N fertiliser types for monocropped maize. Nitrogen load was obtained from measured N concentration in leachate and simulated soil water flow. Significant differences in N load among the different N fertiliser types were detected, which could be attributed mainly to the mineral share of N input.

### **2.1.42 Biogas-Expert: Nitrous oxide emission from biogas production systems on a coastal marsh soil**

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Nitrous oxide (N<sub>2</sub>O) emission was investigated in two biogas substrate production systems (grassland vs. maize-winter wheat-Italian ryegrass rotation) over eight months on a heavy clay soil in the marsh region of Northern Germany. N<sub>2</sub>O flux rates were measured after application of mineral N fertiliser or biogas residue in each system at two N levels (control, oversupply). Gas samples were taken daily after fertiliser applications with successive expansion of the sampling intervals up to one week. N<sub>2</sub>O emission usually followed fertiliser application events in all crops. Overall, cumulative emission was rather low, which may be attributed partly to low precipitation during the vegetation period. Neither the type of N fertiliser nor the biogas production system had a significant effect on N<sub>2</sub>O losses.

### **2.1.43 The evaluation of tall fescue, cocksfoot and reed canary grass as energy crops for biogas production**

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Cultivation of grasses should contribute to developing more profitable systems dealing not only with plants and animals, but also for people and their needs. Major changes in grassland management and utilization result from socio-economic, technological and political developments and global environmental change. Recently, the demand for biomass for bioenergy and fibre in many countries has been changing the traditional utilization of grasses for forage. Successful development of a bioenergy industry as well as animal husbandry depend on identifying species and cultivars with high yield potential and acceptable biochemical quality. The investigations of cocksfoot (*Dactylis glomerata* L.), tall fescue (*Festuca arundinacea* Schreb.) and reed canary grass (*Phalaris arundinacea* L.) were carried out to evaluate the biomass yield and chemical composition for alternative use of grasses. Four and three cuts per season were combined with two nitrogen fertilization levels. The results suggest that biomass of perennial grasses could be used for biogas production.

### **2.1.44 Potential of leaching to optimise fuel quality of semi-natural grassland biomass**

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Energy generation through combustion is a potential alternative use for biomass from species-rich, semi-natural grasslands that are no longer needed for animal feed. Fuel quality (particularly high K, Cl, and N concentrations) is a limiting factor for this utilisation strategy. Precipitation during the field drying period is thought to improve the quality of herbaceous biomass fuels by leaching unwanted elements. The leaching potential of K, Cl and N was determined for biomass from five semi-natural grasslands by a laboratory method for standardised assessment. While N was hardly leached from the biomass, both K and Cl had a high leaching potential of up to 55-82%. This is comparable to that found in other studies for rice or cereal straw and perennial energy grasses. In practice, the field period is limited by the regrowth below the swaths. If the probability of sufficient rainfall during this field period is high, then leaching offers a low-cost strategy for fuel quality optimisation of grassland biomass.

## **2.1.45 Improving grasslands of *Agrostis capillaris* and *Festuca rubra* in the Carpathian Mountains of Romania by organic fertilization**

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In Romania, grasslands occupy over 4.8 million ha, of which more than half are in the mountainous areas. In the intra-mountainous Depression of Campulung – Suceava County, in the North-Eastern Carpathians of Romania (770 m a.s.l.), we have investigated the influence of organic fertilizers on productivity, vegetal canopy and crude protein content, for application rates of 10-40 Mg ha<sup>-1</sup> and for three frequencies of application of cattle manure: every year, every 2-3 years, or by split application. The goal of this scientific paper was to emphasize the dynamics of productivity and the vegetal canopy composition, by the application of some technical and practical measures for improving the fodder production and the canopy of *Agrostis capillaris* and *Festuca rubra* in permanent grasslands, with a minimum impact on the environment. The applied fertilizers have determined changes in the dominant species of *Agrostis capillaris* and *Festuca rubra* in grasslands, by increasing the percentage of *Trisetum flavescens* and *Trifolium repens* by 1-9% and 2-15%, respectively, and the productivity by 22-28%, compared to the unfertilized control.

## **2.1.46 Assessing small-scale soil spatial variability and depth to groundwater on shallow grassland soils with electromagnetic induction**

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Grazed ecosystems and their soils are likely to have small-scale spatial variability due to selective and punctual actions of the grazers and the absence of homogenisation through tillage. Measuring soil apparent electrical conductivity (ECa) with electromagnetic induction (EM) can be a valuable tool for assessing soil spatial variability. However, ECa is integrated over soil depth in varying proportions. Although the integration function can be theoretically derived, there is little experimental evidence available to evaluate it. We measured ECa with EM-technology (EM38) at high spatial density on a 135 ha grassland site with mostly thin (20 cm to 70 cm), fine-grained soils over fluvial gravels and sands, over shallow groundwater (at 0-150 cm depth). This provided a physical three-layer model that allowed evaluating the integration function. Soil cores were taken at 62 locations and depth to groundwater was estimated from the groundwater surface obtained from 22 wells and a detailed (2x2 m<sup>2</sup>) digital elevation model. Influence of soil thickness, skeleton content and depth to groundwater in soil ECa were analysed with linear and non-linear regressions. Measured ECa increased with increasing soil depth and decreasing skeleton content as expected, but the influence of groundwater was considerably less than predicted by the integration function. Therefore, the measured ECa reflected more the overlaying soil and its lateral variability. Although this is advantageous, the correlation to point-scale soil properties was low.

### **2.1.47 High quality grass – Potential for biogas production**

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Field experiments were carried out with four different tetraploid perennial ryegrass grass varieties (Twymax, Delphin, Kubus, Trend) under the climate conditions of North Germany. The trial site was located on a sandy loam. Nitrogen fertilization in the first cut was 120 kg ha<sup>-1</sup> of N. Silage trials with different silage inoculants indicated the ability to optimize the fermentation pattern for an improved biogas production. Biogas batch tests were performed and a preliminary methane yield of 280 m<sup>3</sup> per t of dry matter was achieved. Taking into account the calculation of gross and net energy production per hectare, tetraploid varieties of perennial ryegrass offer the opportunity to broaden the substrate mix of biogas plants and therefore ensure the biomass supply under uncertain future climate conditions.

### **2.1.48 Strategies for optimizing light interception in grass-clover swards – effects on yield and quality**

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In order to maximize photosynthetic efficiency of grass-clover swards we studied the influence of cutting frequency and height. It was hypothesized that a higher residual leaf area after cutting would ensure increased light interception leading to a higher Crop Growth Rate and the possibility of more frequent cutting. In addition, a positive influence on parameters of quality was expected. Two main components of the swards, Italian ryegrass (*Lolium multiflorum*) and red clover (*Trifolium pratense*), were subject to different combinations of increased cutting frequency and cutting height (2 weeks/12 cm, 4 weeks/10 cm and 6 weeks/6 cm) in a greenhouse vessel experiment from May to October 2009. Dry matter, NEL and crude protein yield, as well as crude fibre content were highest (significant) for 6w./6cm, while NEL, crude protein and crude ash content increased significantly with increasing cutting frequency and cutting height. The results are in accordance to the findings of our field experiments and support the initial hypothesis only to a lesser extent.

### **2.1.49 Methods of the accelerated reestablishment of grasslands on arable lands of the Ukrainian Forest-Steppe**

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A three-year research was conducted under the conditions of the left-bank Forest-Steppe zone on chernozemic podzolized soils (Poltava Region, Ukraine) to study the influence of grass

stand type and different fertilizer systems on the dry meadow productivity, the symbiotic nitrogen fixation, mineral nitrogen return, botanical and chemical composition of forage. The advantage of sown alfalfa (lucerne) – and sainfoin-grass stands was shown.

### **2.1.50 Feeding cows with grasses in different keeping systems**

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To ensure qualitative and economically favourable grass feed for cows housed throughout the year, it is essential to choose the right technology of grass feed for all the production period – beginning with the growing of perennial grasses, their harvest, conservation and storage until feeding. The aim of this investigation was to estimate how different grass-feed making technologies influence feed quality, health, quality of production and economics. In first variant for providing dairy cows with high value feed 106 ha of grassland were needed, while in the second variant only 94 ha were necessary. Comparing the costs and income of both variants showed about 56.2 % more profit in the second variant. It is economically profitable to introduce an unchanged grass/feed ratio on the farm by feeding dairy cows with a uniform feed all the year. By introducing different early harvested grasses it is possible to obtain a comparatively greater harvest than from pastures, and thereby to release agricultural land in order to obtain additional income.

## **Session 2.2 The role of genetic resources**

### **The effect of evaluation protocol on the dry matter yield performance of *Lolium perenne* varieties**

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An experiment was undertaken to identify the effect of management on the performance of perennial ryegrass (*Lolium perenne* L.) varieties. Twelve perennial ryegrass varieties were sown as monocultures. Three managements were imposed on the plots across 3 years representing a simulated grazing system with 10 defoliations, a 2-cut conservation system, with 2 silage cuts and four simulated grazing defoliations and a 3-cut conservation system, with 3 silage cuts and 2 simulated grazing defoliations. Results show an interaction ( $P < 0.001$ ) between management and variety. A change in the rank order of the varieties relative to the mean dry matter (DM) yield ( $t\ ha^{-1}$ ) was evident depending on which management a variety was exposed to. These results highlight that certain varieties are suited to grazing-only systems, while other varieties are more suited to use in silage systems. The evidence of re-ranking of cultivars based on their total DM production highlights the need to ensure that grass varieties are evaluated using the optimum protocol to represent the current and anticipated future needs of the industry.

## **A system to optimize forage crop variety trials for regionalized Recommended Lists in Germany**

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The expenses for testing crop varieties are an increasing burden on all involved. This often leads to staff reduction in governmental institutions engaged in this activity. In many cases the result has been a decline in the density of testing, especially for so-called ‘minor crops’ like forage crops. However, a functioning system of field trials is the basis of any scientifically validated improvement in crop production. To make the federal system of variety trials for forage crop varieties in Germany more efficient, a new system of trials was implemented by a group of agricultural research centres in the mid and south of Germany. This system integrates crop-specific extra trials with design-checking characteristics of special interest, such as persistence and resistance. The data of the trials for registration are used as a first check for their dedication to the local target environment, and varieties can be grouped depending on these data. In consequence for each group, the scope of testing in expensive yield trials can be adjusted to the expected dedication to the local target environment. The result is a well nested system of coordinated unbalanced field trials.

## **Genetic shift in white clover (*Trifolium repens* L.) after natural selection in a marginal area**

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Studies of genetic diversity are a prerequisite for any plant breeding programme. Where the primary breeding aims are to combine yield and survival it is important to be able to identify traits associated with these two factors. This is particularly important where species or cultivars are being grown at the margin of their distribution. The current study used AFLP markers and a traditional spaced plant trial to compare the genetic diversity of white clover cultivars of contrasting climatic origin with that of semi-wild and wild populations adapted to a marginal environment, and to monitor genetic shift in one of the cultivars after survival for four years in this environment. Observed patterns of genetic variation within and between populations were similar for both approaches used.



### **2.2.01 Some plant characteristics of accessions of fescue species (*Festuca* sp.) collected from the Central-Black Sea Region of Turkey**

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Accessions of *Festuca arundinacea* (Schreb.), *Festuca drymeja* (Mertens and Koch) and *Festuca woronowii* (Hackel) subsp. *turcica* were collected from natural habitats to develop new cultivars for forage and pastoral use and to establish green areas. In total, 127 accessions were collected in 2007 and the quantitative characteristics of these samples were examined. The values and variation ranges of the measured and inspected characters of the accessions of *F. drymeja* and *F. arundinacea* were similar to each other, but they were larger in these two species than in accessions of *F. woronowii*.

### **2.2.02 Habitat of *Camphorosma monspeliaca* L. species in semi-arid regions of Iran**

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The relationship between topography, soil factors, and distribution of *Camphorosma monspeliaca* L. was investigated in the Chaharmahal-Bakhtyari province (Iran). The species present were recorded in each stand, following a randomized-systematic sampling method. Soil was sampled from 0-10 and 10-30 cm depths in each quadrat. The correlations between soil properties and plant parameters of *C. monspeliaca* were calculated using Spearman's correlation coefficient. This species can establish in non-saline soil and at low levels of phosphorus and potassium. *C. monspeliaca* cover, frequency and abundance were correlated positively with soil sodium, organic matter and sand.

### **2.2.03 White clover (*Trifolium repens* L.) germplasm evaluation under two levels of soil phosphorus: growth and phosphorus absorption**

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White clover is the most important forage legume in grazing pastures in the central irrigated and southern humid Chile. To extend the use of the species in marginal areas of these regions, genotypes are required that combine phosphorus deficiency tolerance with high nutritive value, forage productivity, persistence and grazing resistance. Naturalized germplasm was collected in 1994 from the central and southern regions of the country. The objective of this work was to identify phosphorous deficiency tolerant populations for breeding programmes

from nine populations. The clover populations were grown with perennial ryegrass under grazing with two contrasting levels of soil phosphorus. Growth indicators, dry matter yield and plant and soil phosphorus were measured. Two populations had high yields and the highest phosphorus uptake at low level of soil phosphorus. The two were also statistically equal in stolon length and dry weight at different levels of phosphorus. Tiller density and dry matter yield of the perennial ryegrass grown in mixture was also affected by the clover population and phosphorus treatments. It can be concluded that there is genetic variability among white clover populations in relation to phosphorus deficiencies in soil.

#### **2.2.04 Influence of the cutting regime on sainfoin yield (*Onobrychis viciifolia* Scop.)**

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The influence of the cutting regime on agronomic parameters of sainfoin (*Onobrychis viciifolia* Scop.) was assessed in a pot trial in 2009, in Zaragoza (Spain). Two varieties of sainfoin, giant and common type, were grown in 50L pots and cut at the phenological stages of early bloom, mid bloom or late bloom. Aboveground production and proportion of leaves and stems, as well as morphological parameters (root and crown weight, number of leaflets, stems and inflorescences) were regularly assessed. Common type of sainfoin showed smaller but more numerous leaflets and stems than giant type; crown and root weights were also higher for common type. Common type showed inflorescence only in the two first cut, whereas giant type flowered in all cuts. Depending on treatment, four, five or six cuts were applied for late, mid or early bloom treatments respectively. No difference was found between treatments in aboveground weight or in its partition, which decreased from 42% in the first cut to 10% in the last. Under a more intensive cutting regime, common type sainfoin increased the root weight to the detriment of the crown weight; giant type was not affected.

#### **2.2.05 Legumes increase forage *Brassica* yield in low-input systems**

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*Brassica* sp. are interesting forages in late summer and autumn. Since they have high nitrogen requirements, intercropping with legumes may increase yield in low-input systems. However, brassica/legume intercrops still remain poorly documented. Using rhizotrons in a greenhouse, we compared root development of (1) forage rapeseed either grown with faba bean or crimson clover to that of forage rapeseed monoculture and (2) fodder cabbage grown with common vetch to that of fodder cabbage monoculture. Legumes were labelled with <sup>15</sup>N urea. Seven to eight weeks after sowing, *Brassica* yield and N content were higher under intercropping than in pure stand. Under intercropping, distribution of root ramifications along the taproot differed from that of monoculture, which reduced the effect of competition. In addition, N transfer from legumes to *Brassica* was found to be significant.

## **2.2.06 Morphogenetic and structural characterization of seven tropical forage grasses**

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The objective of this experiment was to characterize the developmental patterns of tropical forage grasses by means of morphogenetic and structural characteristics. The grasses were planted in experimental units of 1.0 m<sup>2</sup>, each containing 24 plants, arranged in a completely randomized block design with three replicates. Morphological and structural data were subjected to a factor analysis. Four factors were obtained, which revealed contrasting developmental patterns between groups of grasses. Our results indicate that the same features can be used in different ways by grasses of the same genus and/or species. This information could be valuable in improving current evaluation protocols for forage grasses.

## **2.2.07 Morphogenetic and structural characteristics of *Andropogon gayanus* cut to different heights over seasons**

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Morphogenetic and structural characteristics of *Andropogon gayanus* cv. Planaltina (gamba grass), were evaluated under three different cutting heights (20, 27 and 34 cm) when the canopy reached 95% light interception during regrowth. The cutting heights were allocated to experimental units (12 m<sup>2</sup>) in a completely randomized block design with three replicates. The lowest cutting height (20 cm) negatively influenced the final leaf length (FLL - leaf lamina), number of living leaves (NLL) and leaf lifespan (LL), and it positively affected the phyllochron (PHYL) and leaf senescence rate (LSR). Cutting to 20 cm probably caused increased decapitation and death of tillers. The least favourable conditions for growth and flowering occurred during autumn, resulting in greater stem elongation rate (SER) and NLL and lower values of PHYL, FLL and LL during this season. Under conditions of intermittent maintenance, defoliation of gamba grass should be interrupted when the stubble height is approximately 27 cm.

## 2.2.08 Influence of 1000-grain weight on predicted density of selected varieties of pasture grass species

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Laboratory studies dealt with the evaluation of germination ability and 1000-grain (seed) weight of 31 Polish varieties of 4 pasture grass species: *Festuca pratensis*, *Dactylis glomerata*, *Lolium perenne*, and *Phleum pratense*. Investigations revealed that 1000-grain weight varied most among varieties of *D. glomerata* (0.82 g to 1.85 g), followed by *L. perenne* (1.39 g to 2.90 g), and *F. pratensis* (1.52 g to 2.36 g), and least with *Ph. pratense* (0.40 g to 0.54 g). The grain germination ability for the majority of the assessed varieties complied with the standards. The predicted plant density ( $\text{m}^{-2}$ ), calculated on the basis of current seeding density recommendations and taking into account 1000-grain weight and grain germination ability, depending on a variety, ranged from 1555 to 2841 for *Ph. pratense*, from 914 to 2197 for *L. perenne*, from 1067 to 2290 for *D. glomerata*, and from 1865 to 2662 for *F. pratensis*.

## 2.2.09 Genetic diversity of red clover varieties listed in Germany concerning the resistance to Southern Anthracnose

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Recently, there has been evidence both from testing sites and agriculturally used fields concerning the appearance of *Colletotrichum trifolii* Bain et Essary, causing Southern Anthracnose in red clover and red clover pasture stands. This disease is able to cause large losses in yield. The aim of this investigation was to evaluate all red clover cultivars listed in Germany (in 2009) with regard to their resistance against the pathogen. One foreign genotype ‘Starfire’, bred in the USA and known to be highly resistant to Southern Anthracnose, was also incorporated into this research. A ranking of the cultivars could be generated based on a test for resistance performed in the greenhouse. The resistance of the cultivars was expressed as a percentage of plant survival seven weeks after inoculation. Results showed a wide range in quantitative resistance characteristics towards *Colletotrichum trifolii* from 29 to 87% survival. Hence the evaluated genotypes can be classified into resistant to susceptible forms. Another important finding was that among the screened varieties diploid cultivars overall seemed to be more resistant than tetraploid genotypes.

### 2.2.10 Osmotic adjustment and water use efficiency of seven cultivars of *Lotus corniculatus* L.

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Two physiological mechanisms, osmotic adjustment (OA) and water use efficiency (WUE) were evaluated in seven cultivars of *L. corniculatus* to determine their contribution to drought tolerance of this species. A greenhouse experiment was carried out during the spring of 2008 in Chillán, Chile. The seven cultivars were planted in pots (3l capacity) containing soil as a substrate. The plants were grown under two soil water treatments: with water stress (WWS; -0.01 MPa soil water potential) and with non water stress (NWS; -1.0 MPa soil water potential). The experiment was arranged in a randomized complete block design with four replicates. Osmotic ( $\Psi\pi$ ) and xylematic ( $\Psi_x$ ) water potentials were measured and water pressure potential was estimated ( $\Psi_p = \Psi\pi - \Psi_x$ ). Transpired water (T) was recorded daily by weighing the pots. Dry matter growth (DM = leaf + shoot) was measured and WUE was calculated (DM/T). No differences were found among cultivars for  $\Psi_x$ ,  $\Psi_p$  and  $\Psi\pi$  ( $P > 0.05$ ). However, a highly significant effect was observed due to the water treatments ( $P \leq 0.001$ ). The  $\Psi\pi$  value decreased by 44% under WWS conditions compared to NWS conditions. However, OA was not associated with DM production. WUE varied broadly among cultivars and was positively correlated ( $r = 0.90$ ;  $P \leq 0.01$ ) to DM production under drought conditions.

### 2.2.11 Root system development of *Lolium perenne* under different management of landscape lawns

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The objective of this study was to compare the weight of roots and their stratification under 2-mow and 5-mow management of landscape lawns of *Lolium perenne*. Trials were carried out at Rousínov in the Czech Republic from 2007 to 2009. Nitrogen (N) was applied as fertilizers differing in forms and actions and at different levels of N rate (0, 50 and 100 kg ha<sup>-1</sup> y<sup>-1</sup>). Samples of root biomass were obtained using a soil probe in the 0-200 mm soil layer. The root samples were collected after the last mowing, at the end of the growing season. The 0-20 mm layer and the 21-200 mm layer were evaluated separately. In the third year of the experiment the root weight of *Lolium perenne* was the highest. High doses of nitrogen (100 kg ha<sup>-1</sup> y<sup>-1</sup>) increased the weight of the root biomass in the 21-200 mm layer.

### **2.2.12 Genotypic differences in maize phenology, growth and biomass in response to different N fertilizer sources applied at variable rates**

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Declining nitrogen (N) fertility is the most widespread and dominant factor limiting maize (*Zea mays* L.) productivity in the wheat-maize cropping systems in Northwestern Pakistan. The objective of this experiment was to investigate the response of different maize genotypes [local high yielding cultivars (Azam and Jalal) vs. hybrid (Pioneer-3025)] to variable N rates (50, 100, 150 and 200 kg ha<sup>-1</sup>) and sources [urea, calcium ammonium nitrate (CAN) and ammonium sulphate (AS)] of N in comparison with a control (N not applied) on calcareous soils having wheat-maize cropping system for long time. A field study was conducted at the Agriculture Research Farm of NWFP (Northwest Frontier Province) Agricultural University, Peshawar, during summer 2008. Hybrid Pioneer-3025 applied with 150 or 200 kg ha<sup>-1</sup> N either as CAN or urea resulted in higher maize productivity in the study area.

### **2.2.13 Conservation characteristics of maize cultivars ensiled as whole-crop, cob or stover at sequential stages of maturity**

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This study evaluated the effects of stage of maturity at harvest on the conservation characteristics of cob, stover and whole-crop silages made using contrasting maize cultivars. Cultivars selected for conventional forage maize silage use (Tassilo and Beethoven), cold tolerance (Andante and Nescio) and high biomass (Atletico and KXA 7211) were sown in field plots (72 m<sup>2</sup>) under plastic mulch on 7 May 2008. Triplicate plots were harvested on 16 September, 7 October and 28 October. Representative samples of each plant component were precision-chopped and ensiled in laboratory silos for 130 days. Later maturity at harvest restricted fermentation and increased the lactic acid bacteria numbers on maize silage. The high biomass cultivars tended to have higher concentrations of fermentation products compared to the conventional cultivars and the cold-tolerant cultivar Andante. The low dry matter concentrations for crops harvested at early maturity and for the high biomass cultivars likely contributed to the increased fermentation observed.

### 2.2.14 Response of *Dactylis glomerata* to low temperature stress

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The aim of this study was to estimate the freezing tolerance of two Polish varieties of *Dactylis glomerata* L. – Amera and Amila. Plants were exposed to two levels of temperature stress (-5 °C and -10 °C) for 24 hours at emergence and tillering-growth phases. Leaf greenness index and chlorophyll *a* fluorescence were measured. The number of shoots which survived one week after the application of thermal stress was also registered. Exposure to low temperatures caused a significant decrease in chlorophyll content and maximum quantum efficiency of Photosystem II (Fv/Fm) of both varieties as compared to control treatment. After 48 hours of application of low temperature (-5 °C) both varieties showed recovery of photosynthetic efficiency of photosynthetic apparatus only at emergence phase, while at lower temperature (-10 °C) none of the tested varieties were able to recover (neither at emergence nor tillering phase). After one week of low temperature stress application (-5 °C) the survival percentage of shoots at tillering phase was higher than at emergence phase.

### 2.2.15 The aesthetic value of turfgrass varieties

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Turfgrass varieties sold in Romania should be evaluated by trials conducted at as many geographic locations as possible around the country. This necessity comes from the poor performance of turf varieties produced in countries with climatic conditions that differ from the local climate. However, the aesthetic quality of some turf varieties could be excellent and we must identify which ones are the most suitable for the local climatic conditions. Experiments have been made with varieties from cool-season grasses such as *Poa pratensis* and *Lolium perenne*. The aesthetic value of turf varieties was evaluated using visual ratings from 1 to 9, according to the rating scale of the National Turfgrass Evaluation Programme. Due to conditions of low-frequency irrigation, the performance of turf varieties was greatly influenced by weather conditions, the bluegrass varieties exhibiting a better adaptation to drought and high temperatures in the summer.

### 2.2.16 Apex development and stem morphology of vernalized and regrowing tillers of timothy

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The transition of apex from vegetative to reproductive stage is considered to be necessary for the formation of true stem. The progressive lignification during maturation of yield-forming stems reduces digestibility and so there is a negative correlation between the quantity and quality of grass biomass. The canopy structure of spring growth consists mainly of flowering and stemforming tillers, whereas in the regrowing sward only few stems can be found. Spring growth is affected by vernalization which induces flowering. We have studied in greenhouse and field experiments the effect of vernalization on canopy structure, stem morphology and expression of flowering genes *VRN1* and *VRN2* in timothy (*Phleum pratense* L.). Our results show that the lignified sclerenchyma ring formed in vernalized and non-vernalized elongating tillers irrespective of the developmental stage of the apex. The result uncouples the processes of stem elongation, lignification and reduced digestibility from flowering. The peak expression of vernalization genes *VRN1* and *VRN2* coincided with the transition of apex to reproductive stage in vernalized tillers but not in regrowing non-vernalized tillers. This indicates that the regulatory processes leading to the development of flowering and elongating tillers in the first and second harvests is different.

### 2.2.17 Lifespan of white clover (*Trifolium repens* L.) plant organs under northern temperate climatic conditions

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Sturite *et al.* (2007) investigated growth and death of the major parts of white clover (*Trifolium repens* L. cv. 'Snowy') plants in pure stand and in mixture with meadow fescue (*Festuca pratensis* L. cv. 'Fure') in a combined plot and root window experiment in Norway (60°42' N, 10°51' E). Leaves, stolons and roots were tagged and their lifespan was monitored in harvested and non-harvested stands during two experimental years. The longevity of leaves and petioles ranged from 21 to 86 d (mean = 59 d). About 60% of the leaves produced during the growing season turned over before the autumn. Of the remaining leaves, 70–80% were dead or had disappeared by the subsequent spring. The lifespan of sections of the main stolons ranged from 111 to over 677 d (mean = 411 d). In particular, stolon sections close to the parent fragment of undisturbed plants were long lived, whereas sections towards the terminal bud overwintered more poorly and had a much shorter lifespan. The longevity of roots was



from 27 to 621 d (mean = 290 d) and was higher for roots appearing in spring and autumn than in summer. Harvesting significantly reduced the longevity of stolons and caused an increased fragmentation of the white clover plant but did not decrease leaf/petiole or root lifespan.

### **2.2.18 Effects of fungal endophyte infection in the grass *Festuca rubra* on germination and growth of four legume species**

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Red fescue (*Festuca rubra*) is a perennial grass present in a wide range of ecological conditions. It is also included in mixtures with other grasses and legumes for several purposes. The objective of this paper was to determine the effect of *Festuca rubra* plants, infected and non-infected by the endophyte *Epichloë festucae*, on the germination and seedling growth of four legume species. During three weeks, a greenhouse experiment was carried out with infected and non-infected plants of *F. rubra*, and four legume species: *Trifolium pratense*, *Trifolium repens*, *Trifolium subterraneum* and *Lotus corniculatus*. The emergence of the legumes was not affected by the presence of *F. rubra* plants. However, the length and biomass production of the four legumes was reduced in the presence of *F. rubra* plants. The decrease in shoot length was greater than that in root length. There was a significant effect of endophyte infection status of *F. rubra* plants on the root length and root biomass of legumes. The reduction in root length and root dry weight of legume seedlings was greater in the presence of infected plants than in the presence of non-infected plants.

### **2.2.19 Cytoplasmic genetic diversity in molecular markers within and between *Lolium* cultivars**

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The current study investigated whether genetic distance using molecular markers may be used to describe the genetic relationships between registered *Lolium* cultivars and determine levels of shared plant identities across different species and cultivars. Twenty-four ryegrass cultivars, representative of current commercial diversity, were screened by sequencing chloroplast genome regions to identify ten single nucleotide polymorphisms, using allele-specific PCR. Nineteen haplotypes were identified. The same haplotype was found in individual plants across five *Lolium* species. Four of the cultivars showed no variation, not only within but also over the four cultivars. Twelve haplotypes were unique to eight cultivars. However, demarcation of species was not maintained by these markers. It was concluded that further gene markers would be required to more accurately describe the genetic relationships.

### **2.2.20 Effect of maturity type of *Lolium perenne* cultivars on performance of grass-clover mixtures under frequent cutting**

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*Lolium perenne* L. is the main companion grass in grass-white clover mixtures of north Germany. The main aim of this investigation is to quantify the influence of maturity type (early, late, mixture) of *Lolium perenne* cultivars in grass-white clover mixtures on productivity, forage quality parameters and white clover (*Trifolium repens* L.) compatibility. In this paper data of a three-year field experiment are presented. The field experiment was carried out on a loamy, sandy soil in Schleswig-Holstein. The swards were managed with different nitrogen levels (0 to 200 kg ha<sup>-1</sup> y<sup>-1</sup>) in a frequent cutting system. Harvesting dates were adjusted to a defined stage of maturity of the grass part of the mixtures. Compared with mixtures with late varieties of *Lolium perenne*, performance of grass-clover mixtures with early varieties of *Lolium perenne* was clearly superior, had a higher proportion of white clover, produced higher yields (DM: +3.5%, NE<sub>L</sub>: +5.9%, N: +13%), had a better quality (NE<sub>L</sub>: +0.08 MJ kg TM<sup>-1</sup>, CP: +0.5%) but required a higher cutting frequency. Marked differences between mixtures were found especially at low nitrogen fertilisation because of reduced yield in mixtures with late varieties of *Lolium perenne*.

### **2.2.21 Evaluation of yield potential and genetic variances for nine cultivars of alfalfa under the New Valley environment**

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During 2004-2006, a field trial was conducted at the New Valley Research Station to evaluate the yield potential and genetic variation among the following alfalfa cultivars: a new synthetic (Wady Syn.), four promising populations (Serw<sub>1</sub>, Serw<sub>2</sub>, Nitrogen fixation and salt tolerant), three commercial varieties (Siwa, Ismailia<sub>1</sub> and Ismailia<sub>94</sub>) and a local cultivar (Wady). Twenty cuts were obtained during 2005 and 2006. The combined analysis of variance over two years indicated that Wady Syn. population ranked first for fresh and dry yields (72.3 t and 18.9 t) and other traits differed significantly from other tested cultivars. Wady Syn. showed the highest plant height, number of tillers and leaf to stem ratio (48.2 cm, 416.7 m<sup>-2</sup> and 47.6%), which differed significantly from Ismailia<sub>94</sub>. Relative genetic variations among the tested cultivars were found. The environmental variation ranged from 4.4% to 33.3% and the genetic advance ranged from 3.9% to 14.5%.

### **2.2.22 Technology for seed production in three cultivars of white clover (*Trifolium repens* L.) under irrigation conditions in the south of Chile**

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Two cover crops were used with three white clover cultivars for seed production. This study demonstrates the possibility of achieving efficient seed yields by seeding clover under a cover crop (*Lolium perenne* L. or *Avena strigosa* Schreb), with and without desiccant application. The study was carried out during 2008-2009 at Carillanca Experimental station located in Temuco Chile. Three clover cultivars, Huia, Will and Haifa, were sown in autumn 2008-2009. The experiment was arranged in a RCB design with four replicates. The flower number correlated positively with seed production ( $P < 0.05$ ). Seed production differed between cultivars. The highest yield of 339 kg ha<sup>-1</sup> was achieved by seeding white clover with Lopsided Oat as a cover crop during autumn compared with ryegrass as cover crop. The use of desiccant improved the clover yield mainly in the medium leaves cultivars, Huia and Haifa; differences were statistically significant with the large leaves cultivar Will ( $P < 0.05$ ).

### **2.2.23 Selection of red clover (*Trifolium pratense* L.) genotypes in north-western Russia**

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Favourable red clover genotypes were collected and compared for growth and winterhardiness.

## **Session 3**

### **From Grass to Milk and Meat**



## **Authenticity and traceability of grassland production and products**

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Grassland-based production of meat and milk products has ‘added value’ among both food producers and consumers because of the perceived healthiness of the food products derived from it and its perceived environmental acceptability. This added value carries with it an onus to be able to trace and authenticate the food products derived from grassland. In recent years a range of techniques has been used to gather data with the potential to discriminate between food products of grassland production and other production systems. Chromatographic and spectroscopic methods, along with mass spectrometry, have been widely used to quantify fatty acids, volatile compounds, carotenoids, tocopherols and stable isotope ratios and to obtain fingerprint data capable, following multivariate statistical analysis, of discriminating between production systems. Among the challenges to the discrimination process and ultimately to the authentication and traceability of grassland products are, firstly, defining grassland production, secondly, the seasonal and geographic variation in the composition of grassland feedstuffs consumed by animals and, thirdly, the difficulty of detecting the consumption of non-grass feedstuffs in a grassland production system. To overcome these challenges, the potential of analysing incremental animal tissues and minimising factors likely to contribute to variation in potential markers of grassland production are discussed.

## **Forage conservation, feeding value and milk quality**

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This paper provides an overview of the effects of conservation methods on forage nutritive value, considers recent developments in the estimation of forage feeding value and examines the impact of conservation method and forage specific factors on milk composition and quality. The changes in nutritive value during conservation are relatively small provided that extensive wilting and ensiling losses are avoided. These losses are inevitably due to feed fractions that have complete or almost complete true digestibility. Accurate and precise evaluation of the nutritive value is essential in order to optimize the amount and composition of supplementary feeding and minimize nutrient emissions to the environment. Empirical equations based on forage chemical components are not sufficiently accurate for practical forage evaluation, because they do not describe mechanisms related to lignification and maturation of plant cell walls. Biological methods based either on rumen fluid or fungal enzymes often predict forage digestibility with acceptable accuracy and precision. Fractionating the forage cell walls into potentially indigestible and digestible fractions is

essential in mechanistic feed evaluation models, and empirical indigestible neutral detergent fibre models have provided accurate predictions of *in vivo* organic matter digestibility. Relative silage intake potential is a step forward in estimating relative feeding value of forages. Evaluation of published experiments strongly suggests that intake and digestibility are the most important forage factors influencing milk protein yield, whereas protein factors (concentration, soluble non-ammonia N, predicted degradability) had a minimal or no effect on milk protein yield. This suggests that ideal forage for milk production should have a high intake potential and digestibility and moderate crude protein concentration in order to minimise N emissions to the environment.

Forage factors can substantially influence milk fat, protein concentrations, nutritive value (vitamins, fatty acids), sensory properties and physical characteristics of milk and milk products. Fresh forages represent a low-cost approach to enhance the nutritional quality of milk compared with plant oils or oilseeds and offer the advantage of minimizing increases in *trans* fatty acids other than *trans*-11 18:1 during attempts to decrease milk 12:0, 14:0 and 16:0 concentrations and increase milk fat *cis*-9, *trans*-11 conjugated linoleic acid, 18:2*n*-6 and 18:3*n*-3 content. The impact of forage on milk fat composition depends on several factors including forage species, conservation method, and the proportion of forage in the diet and composition of concentrate supplements. Available data would tend to suggest that milk from hay diets containing higher polyunsaturated fatty acid concentrations and lower levels of  $\alpha$ -tocopherol and  $\beta$ -carotene would be more susceptible to oxidation and the development of off-flavours compared with silage based diets. Off-flavours in milk may originate from concentration differences of a common set of substances rather than being due to the absence or presence of specific compounds.

## Session 3.1 Forage conservation, feeding value and product quality

### Harvest dates affect fungal counts and fungal composition of baled haylage

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The use of baled forage with dry matter (DM) contents between 500 and 800 g kg<sup>-1</sup>, also known as haylage, has increased in recent years, particularly for the feeding of equines. Haylage contains less fermentation products and more residual sugars, and it has a higher pH compared to silage, as lactic acid fermentation is restricted in haylage. These factors may favour fungal growth, but the fungal flora of haylage is not well-known at present. One factor that may be important is the harvest date, as it is often delayed when forage is produced for horses. To improve our understanding of fungal flora in both grass and haylage, an experiment with three harvest dates (June, July, August) of the primary growth of a grass-clover ley was conducted, with samples for fungal analysis taken both pre- and post conservation. Delaying harvest resulted in higher yeast counts both pre- and post-conservation, but mould counts were generally low and they were less affected by than yeast counts. The number of mould species was higher pre- than post-conservation.

## **Influence of genotype and mechanical stress on the specific polyphenol oxidase activity in pure red clover swards**

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Increasing the nitrogen use efficiency in ruminant nutrition may reduce N losses in specialized dairy farms. Red clover is known to have high polyphenol oxidase (PPO) activity among forage legumes. The enzyme oxidizes phenols to quinones. These highly reactive quinones undergo further reactions with other phenols or proteins forming stabilized quinone-protein-complexes, protecting protein from fast degradation. However, the variation in specific PPO-activity due to genotype, season and management is not clearly defined. The aim of the study is to investigate differences in the specific PPO-activity determined between several genotypes submitted in two management systems (with and without stress). In total, twelve red clover genotypes with different origins were grown in pure stands in a four-cut-system. In one system plots were rolled with a Cambridge-roller about three weeks before harvest to generate mechanical stress. The results show that for almost all genotypes the specific PPO-activity increased after applying mechanical stress. Seasonal effects were observed, and the autumn harvest showed the highest specific PPO-activity for both systems. In conclusion, the variation in specific PPO-activity among the genotypes was present. However, effect of the management system and seasonal effects were also pronounced.

## **Variation of fatty acid content in grass and milk during the grazing season**

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Fatty acid composition in grass varies during the growth season. Grass fed to dairy cows may yield corresponding changes in milk fatty acid content. To investigate this, monthly individual milk samples of 16 (2005) and 20 cows (2007) and corresponding grass samples were analysed throughout the grazing season. The cows were grazing full time in a rotational system on a mixed sward. As supplements, the cows were offered carbohydrate-type concentrate restrictively according to their milk production. In spring and autumn, the grass had lower crude fibre and higher crude protein contents than in summer.  $\alpha$ -linolenic acid (C18:3) was the most important fatty acid in the grass. With higher crude fibre contents, the grass had less  $\alpha$ -linolenic acid. In 2005, conjugated linoleic acid (CLA) concentration in milk was higher in spring and in autumn than in summer. In 2007, CLA increased continuously from spring to autumn. In both years, the mean CLA content was 1.5 g per 100 g fat. The concentration of omega-3 fatty acids did not vary much during the pasture season in 2005. In 2007, the omega-3 increased during the grazing season. The average content was 1.4 g per 100 g fat.



## Effect of pasture botanical composition on milk composition in organic production

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Milk samples from sixteen Norwegian Red dairy cows grazing mixed swards of either grass-red clover (GR) or mixed swards of sown and unsown species of grass, clover and other herbs (GCH) were collected during four periods. Both pastures were organically managed. Pasture botanical composition had no effect on milk fat, protein or vitamin concentration and only minor effects on fatty acid composition. Milk from GR had higher concentrations of the phytoestrogens equol, genistein and biochanin A than the milk from GCH. Concentrations of equol in milk from GR were higher than concentrations reported from experiments with red clover silage. The oxidative stability of the milk lipids was not affected by pasture type.

## Top losses in maize silage sealed with different plastic films

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Proper sealing with a plastic cover is essential to reduce surface losses from silage. The objective of this work was to study the effectiveness of different plastic films to reduce the top losses in maize silage. The treatments evaluated were: 1) oxygen barrier film, 125-µm thick (OB), 2) black-on-white (200-µm thick) PE film (PE), 3) black-on-white (300-µm thick) polyvinyl chloride film (PVC), 4) black-on-white (200-µm thick) polyvinyl alcohol film (PVOH). The forage was ensiled in macro silos (500 L) which were opened 162 days after ensiling. During the silo filling, one plastic net bag with well-mixed fresh material and one data logger were buried in the upper layer of the silo. The quality of the sealing was assessed by temperature measurements. Top losses in the silages were also evaluated by chemical and microbiological analyses. Oxygen permeability of the films influenced the DM losses in the upper 30 cm of the silage. The OB film reduced the DM losses of the silage ( $P < 0.05$ ). More lactic acid was produced in the silage sealed with the OB film, and the yeast counts were always under the detection limit ( $1 \times 10^5$  cfu g<sup>-1</sup>) in the OB-sealed maize silage.

## **Comparison of grazed grass and a TMR diet on early lactation milk production performance**

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In Ireland, winter milk producers tend to house freshly calved cows and offer them a Total Mixed Ration (TMR) diet. However, this feeding regime results in increased feed input costs, especially when compared with grazed grass, a cheaper feed. An experiment was undertaken at Teagasc Moorepark, Ireland in autumn 2008 to compare a TMR diet with grazed grass-based diets with three levels of concentrate. Forty-eight Holstein Friesian autumn-calving dairy cows were balanced and randomly assigned to one of four treatments which investigated: i) grazed grass + 1 kg concentrate (G1), ii) grazed grass + 4 kg concentrate (G4), iii) grazed grass + 8 kg concentrate (G8), and iv) indoors fulltime offered TMR (TMR). Treatments were applied for 6 weeks; following this all cows were housed and offered a common TMR diet for a further 13 weeks to monitor carryover effects. Milk production, milk composition, dry matter intake, bodyweight and body condition score were measured. Results indicate that offering 1 kg concentrate reduced milk yield compared to all other treatments. There was, however, no difference in milk solids yield between the TMR and G8 treatments during the 6-week period when treatments were applied. There was no difference between any of the four treatments during the carryover period in terms of milk production.

## **Influence of tree and shrub presence on plant nutrient content of pasture in dehesa system**

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Iberian dehesa is usually defined as a two-layered silvopastoral system, where native grasses cohabit with a scattered, widely spaced tree layer. The failure of natural regeneration of the trees is one of the most outstanding threats. Several works have pointed out the positive role that shrubby vegetation can play in tree regeneration. However, shrubs could also act competitively with herbaceous pasture, and then affect negatively its productivity and quality. We aim to analyse the influence of dehesa encroachment on herbaceous pasture quality (N, P, K and Ca concentration) comparing adjacent wooded plots with and without a shrubby layer. Pasture quality was increased underneath trees. The response of pasture to the shrub presence depended on both the herbaceous and the shrub species.

## Enrichment of $^{13}\text{C}$ in *Medicago sativa* and *Lolium multiflorum* n-alkanes

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n-alkanes are often used to study digestibility and feed intake. Our main objective was to test whether the  $^{13}\text{C}$  enrichment of n-alkanes can be modified in order to use them as inert plant markers for fractional passage-rate studies in ruminants. Lucerne and Italian ryegrass were grown under a  $\text{CO}_2$  atmosphere that was enriched with  $^{13}\text{C}$  for seven days. Carbon isotope ratios in different plant fractions and the enrichment of  $^{13}\text{C}$  in n-alkanes extracted from leaves and stems was measured with an isotope ratio mass spectrometer. Native  $\delta^{13}\text{C}$  abundances ( $[‰]_{\text{PDB}}$ ) of lucerne and Italian ryegrass prior to labelling was in a typical range between -21 and -31 ‰. One day after labelling was stopped, plant samples showed  $^{13}\text{C}$  -APE values in the range of 1.6 to 2.3 for leaves and from 2.8 to 3.8 for stems. In the subsequent 30 days,  $^{13}\text{C}$  -APE decreased. n-alkanes showed different  $\delta^{13}\text{C}$ -values in leaves and stems at 1 and 30 days after labelling was stopped. It can be concluded that a  $^{13}\text{C}$  enrichment of plant n-alkanes is possible and that they may be suitable markers in fractional passage-rate studies.

## The condensed tannins in sainfoin cause digestive synergy on *in vitro* rumen fermentation of cocksfoot

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This study investigated the role of condensed tannins (CT) in sainfoin (*Onobrychis viciifolia*) on the rumen fermentation of mixtures of cocksfoot (*Dactylis glomerata* L.) and sainfoin. Freeze-dried samples of cocksfoot and sainfoin in different proportions (100:0, 75:25, 50:50, 25:75 and 0:100) were fermented in culture bottles containing buffered rumen fluid from sheep in presence or in absence of polyethylene glycol (PEG), a compound that inactivates CT. *In vitro* true dry matter digestibility (IVTDMD), total gas production (GP) and ammonia concentration in the incubation medium were determined at 3.5 and 24 h of incubation. In the absence of PEG, ammonia production decreased dramatically at 3.5 and 24 h of incubation ( $P < 0.001$ ) as the proportion of sainfoin increased in the mixture, with a quadratic effect at 3.5 h ( $P < 0.01$ ). At 24 h of incubation, GP was lower and IVTDMD was slightly greater for mixtures incubated in absence of PEG than in presence of PEG ( $P < 0.001$  and  $P < 0.01$ , respectively). It was concluded that the CT in sainfoin are responsible for the synergy between cocksfoot and sainfoin, making it possible to maximize the degradation of plant substrates while minimizing protein degradation and gas losses.

## **A scheduling model for forage harvesting**

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As estimated by the Danish Advisory Centre, one-third of forage grass is harvested while too dry and another third is harvested while too wet as compared with the optimal moisture content level. This indicates that dedicated systems, supporting decisions that affect grass quality, are highly needed.

This paper presents the preliminary results on the functionalities and performance of a scheduling model for forage harvesting. The model input consists of weather forecast data, expected yield data, availability of required resources, and machinery-related specifications. It comprises sub-models for the prediction of the grass moisture content based on weather forecast data. The system provides, as a result, one of three types of decisions or suggestions, namely: (i) harvest, (ii) harvest under uncertainty, and (iii) no harvest.

The model was tested for a five-month harvesting period. Based on the preliminary results, the suggestions presented to the farmer were proven to be successful in 80% of the examined cases.

### **3.1.01 Forage botanical and chemical composition on dairy farms with different grassland systems and production systems**

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Thirty-two dairy farms in Middle-Norway with different grassland systems (short-term (<4 years) grassland (S) or long-term (>7 years) grassland (L)) and different production systems (organic (O) or conventional (C)) were compared in a field study in 2007. In a principal component analysis on variables including farm details, botanical composition and chemical forage composition, the farms were separated into organic and conventional farms with the exception of one farm. Amongst the organic farms most SO farms were distinguished from LO farms. Concentration of forage crude protein was positively correlated with proportion of grass. Concentration of non-fibrous carbohydrates, in vitro digestibility and net energy lactation was positively correlated with proportion of legumes. Species diversity and cutting time at first cut was positively correlated with proportion of non-legume herbs.

### **3.1.02 Using NIR spectroscopy to determine cow diet and geographical origin from milk samples**

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An experiment was done to evaluate the ability of NIR spectroscopy to discriminate among tanker milk samples according to cow diet and geographical origin in relation to production systems. Milk from cows fed maize silage (121 samples) vs. pasture (245 samples) and of lowland (151 samples) vs. upland (180 samples) origin were used. Near-infrared reflectance spectra of oven-dried milk samples were recorded. PLS-DA multivariate analysis correctly classified 93% of the pasture vs. maize silage fed cow milk but only 81% of the samples by geographical origin. NIR spectroscopy can thus classify milk samples by cow diet, but not reliably by origin.

### **3.1.03 Development and nutritive value of three varieties of sainfoin compared to lucerne during primary growth**

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Sainfoin (*Onobrychis viciifolia*) is a temperate legume plant containing condensed tannins (CT), which are polyphenols able to bind proteins and thus reduce protein degradation in the rumen. This study focused on five dates in the first growth cycle to track the time-course evolution of phenological stage, morphological composition (leaf proportions), nitrogen content and organic matter digestibility (OMd) of three varieties of sainfoin (Espace, Ambra, Villahoz) compared with a tannin-free legume, lucerne (var. Aubigny). Although sainfoin developed earlier than lucerne, its digestibility was higher or close to that of lucerne. Among the three varieties of sainfoin, Villahoz had the highest OMd and N content and the lowest CT content. Although nitrogen content was lower in sainfoin than lucerne, the tannins contained in sainfoin lead to similar nitrogen values. These results highlight sainfoin as a valuable alternative legume forage to lucerne.

### **3.1.04 Quality of grass silages wilted as swathed or wide-spread crop**

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In experiments on farms on the western coast of Norway, a dry matter (DM) content regarded as acceptable for baling was reached within 6-8 h after mowing in wide-spread crops, as

opposed to within 24 h for swathed crops. Samples containing *Clostridiaceae* and butyric acid were more frequent in silages that were wilted wide-spread for 24 h and then windrowed, than in silages wilted in swaths for an equal period. This difference in hygienic quality might have been caused by differences in DM content and fermentation in the two types of silages, as well as by contamination with soil-borne organisms through additional handling and wheeling of wide-spread crops. Rapidly wilted crops and silages had a higher concentration of water soluble carbohydrates (WSC).

### 3.1.05 Top losses of corn silage sealed with oxygen barrier film

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The aim of this trial was to study the effectiveness of oxygen barrier film on the reduction of top-silage losses. One trial was carried out on a commercial farm in Jaboticabal, Brazil in 2009. Whole-corn crops (264 g kg<sup>-1</sup> of fresh weight) were harvested and ensiled in a stack silo. The covering treatments were: a sheet of 200-µm-thick black-on-white polyethylene film (ST) and a sheet of 45-µm-thick transparent oxygen barrier film (OB) plus a sheet of ST over the OB film. The stack silo was divided into two parts along its length: half was covered with ST film and half with OB + ST film. During the filling of the silo, 20 bags containing herbage were buried at the peripheral zone of the silos to determine losses. Samples were collected for measured dry matter (DM) content and microorganism counts in acidified potato agar. Twice during the feed-out period, temperatures were recorded at the silo face with data loggers at 12 locations on the silo face. The corn silage under the OB+ST film showed higher DM content and lower occurrence of moulds compared to the silage under only the ST film ( $P < 0.05$ ). The DM losses were lower under OB+ST film (10.2 vs. 7.4% for ST and OB+ST film, respectively). During the feed-out phase the top temperatures at the silo face exceeded 40 °C in the silage covered with ST film, while in the silage sealed with OB+ST film the top temperature was 32 °C. Oxygen barrier film plus polyethylene film reduced the occurrence of moulds and the top losses of corn silage in the stack silo.

### 3.1.06 *Propionibacterium acidipropionici*, *Lactobacillus plantarum* or its combination on the aerobic stability and microbial dynamics of corn silage

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Our objective was to evaluate the effects of microbial inoculation with *Propionibacterium acidipropionici* MA26/4U, *Lactobacillus plantarum* MA18/5U, or their combination, on aerobic stability and microbial dynamics of corn silage. Whole-plant corn (350 g kg<sup>-1</sup> fresh weight) was ensiled in quadruplicate laboratory silos (7 L) after the following treatments: untreated (control), *P. acidipropionici* (1 x 10<sup>5</sup> CFU g<sup>-1</sup> of fresh forage), *L. plantarum* (1 x 10<sup>5</sup> CFU g<sup>-1</sup> of fresh forage) and *P. acidipropionici* plus *L. plantarum*. After 96 days of ensilage,

DM content was lower in silages treated ( $P < 0.05$ ). DM recovery and gas losses were not different ( $P > 0.05$ ) among treatments. Under aerobic conditions, silages treated with *P. acidipropionici* showed lower yeasts and mould numbers up to 96 h. Aerobic stability was improved ( $P < 0.05$ ) in silages treated. Silages inoculated with *Propionibacterium acidipropionici* and their combination with *L. plantarum* enhanced the aerobic stability of the corn silage without affect on the gas losses, under laboratory conditions.

### **3.1.07 *Lactobacillus buchneri*, *Lactobacillus plantarum* or their combination effects on aerobic stability and microbial dynamics of corn silage**

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The aim of this trial was to evaluate the effects of microbial inoculation with *L. buchneri* NCIMB 40788, *L. plantarum* MA18/5U, or their combination, on aerobic stability and microbial dynamics of corn silage. Whole-plant corn (350 g kg<sup>-1</sup> of fresh weight) was ensiled in quadruplicate laboratory silos (7 L) after the following treatments: untreated (control), *L. buchneri* (1 x 10<sup>5</sup> CFU g<sup>-1</sup> of fresh forage), *L. plantarum* (1 x 10<sup>5</sup> CFU g<sup>-1</sup> of fresh forage) and *L. buchneri* plus *L. plantarum*. After 96 days of ensilage dry matter (DM) content was lower in silages treated ( $P < 0.05$ ). DM recovery and gas losses were not different ( $P > 0.05$ ) among treatments. Under aerobic conditions, silages treated with *L. buchneri* and *L. buchneri* plus *L. plantarum* presented lower yeast numbers up to 96 h and silages treated with *L. buchneri* plus *L. plantarum* presented lower mould numbers up to 192 h. Aerobic stability was improved ( $P < 0.05$ ) in silages treated with *L. buchneri* by 100 h and *L. buchneri* plus *L. plantarum* by 87 h, while the untreated corn silage did not deteriorate until 23 h of aerobic exposure. The *L. buchneri* and their association with *L. plantarum* were effective in protecting corn silages exposed to air under laboratory conditions.

### **3.1.08 The effect of forage species on kinetics of large and small particles in dairy cows**

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The objective of this study was to compare ruminal pool sizes and digesta kinetics of large (>1.25 mm; LP) and small (1.25-0.038 mm; SP) particles in dairy cows fed grass and red clover silage diets in a cross-over experiment. Grass (timothy-meadow fescue) and red clover silages were used as dietary treatments and comprised 0.55 of total dry matter intake. Ruminal contents and faeces were divided into LP and SP by wet sieving. Indigestible NDF (iNDF) was determined by a 12d ruminal *in situ* incubation followed by NDF extraction. Ruminal iNDF content was greater in LP of red clover compared to grass silage diet. Potentially digestible NDF (pdNDF) content in ruminal LP and SP was smaller with red clover compared

to grass silage diet and the difference was more considerable in SP. Passage rates of iNDF and pdNDF increased with decreasing particle size for both treatments. Particle breakdown rate tended to be slower for LP of red clover compared to grass silage diet. Contribution of particle breakdown to turnover of LP of rumen iNDF was numerically lower in red clover compared to grass silage diet.

### **3.1.09 Forage species effects on particle digestion kinetics estimated by rumen evacuation or gas production technique**

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Digestion rate ( $k_d$ ) is an important determinant of fibre digestion in ruminants. This study provides digestion kinetic information for different particle sizes of grass and red clover silage diets fed to dairy cows. Dietary treatments and *in vivo* digesta kinetic measurements are described in a companion summary. Ruminal and faecal particles were divided into large (>1.25 mm; LP), medium (1.25-0.315 mm; MP) and small (1.25-0.038 mm; SP) sizes by wet sieving and *in vitro* gas production from potentially digestible NDF (pdNDF) was measured from all particle size fractions. The pdNDF content in ruminal LP, MP and SP was greater with grass compared to red clover silage diet while indigestible NDF (iNDF) content tended to be greater in LP of red clover compared to grass silage diet. The  $k_d$  of pdNDF, estimated by rumen evacuation, was slower for SP compared to LP and MP of both grass and red clover silage diets. Effective  $k_d$  and digestibility of pdNDF, estimated by gas production, of ruminal samples decreased in a quadratic manner by decreasing particle size but were not affected by treatment and were lower for faecal samples compared to ruminal samples. Effective  $k_d$  for ruminal LP and MP was slower but for SP was faster when determined by *in vitro* gas production compared to  $k_d$  estimated by rumen evacuation.

### **3.1.10 Non structural carbohydrate concentration of AM and PM-cut forage species**

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Non structural carbohydrates are a source of readily fermentable energy for rumen microbes. We compared total non structural carbohydrates (TNC) concentration of eight forage species (six grasses and two legumes) cut at 0900 h in the morning (AM) or at 1530 h in the afternoon (PM) in the spring growth and summer regrowth of two harvest years. Starch was determined by colorimetry and other carbohydrates by high-performance liquid chromatography. The



TNC concentration was estimated by the sum of sucrose, glucose, fructose, fructans (grasses) or pinitol (legumes), and starch. Red clover (*Trifolium pratense* L.) and tall fescue [*Lolium arundinaceum* (Schreb.) S.J. Darbyshire] had the greatest TNC concentration (average of 94 mg g<sup>-1</sup> DM for both spring growth and summer regrowth in both species) whereas reed canarygrass (*Phalaris arundinacea* L.) had the lowest TNC concentration (65.5 mg g<sup>-1</sup> DM). Concentration of TNC of all species increased with a delayed cutting during the day but the extent of this increase varied among forage species from 13% in smooth brome (*Bromus inermis* Leyss) to 68% in reed canarygrass. Forage TNC concentration can be increased by choosing species such as tall fescue and red clover and by cutting the forage in the afternoon.

### 3.1.11 Characterization of forages produced and used in the production area of Parmigiano-Reggiano cheese

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In the Parmigiano-Reggiano cheese production area, dairy cow rations are based on local forages: 50% of forage dry matter (DM) must be provided by hay; at least 35% of forage DM must be produced by the farm itself and 75% of forage DM must come from farms located in the production area. For this reason, forage production techniques are very important from both quantitative and qualitative points of view. The objective of this study was to describe and evaluate the nutritional quality of hays produced and used in the Parmigiano-Reggiano cheese production area. To achieve this objective, three monitoring campaigns were conducted involving 163 farms representatively distributed in the Parmigiano-Reggiano cheese production area. During these campaigns, 2105 forage samples were collected and analysed; firstly to determine the nutritional composition, and secondly to calculate the relative feed value (RFV). Results were analysed to make information available describing nutritional characteristics of forage crops broken down by type, altitude and harvest season.

### 3.1.12 Variability in composition of grass samples in a national testing system for *Lolium perenne* L.

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National variety evaluation schemes in Ireland have recently supplemented yield with quality data to improve predictions of the animal production value of perennial ryegrass. Late and intermediate varieties, of two ploidies, were analysed by NIRS for crude protein (CP) ( $R^2 = 0.99$ ), water soluble carbohydrate (WSC) ( $R^2 = 0.97$ ) and digestibility (DMD) ( $R^2 = 0.92$ ). No

significant variation was found in CP, but variety diversity in WSC and DMD was consistent with breeding effort. While transient interactions between variety quality and maturity or ploidy across the season must be accounted for, inclusion of these two parameters in variety evaluation trials was considered beneficial to improving recommendations in Ireland.

### **3.1.13 Aerobic deterioration in maize silages under different covering methods of the plastic film**

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Our aim was to study the effectiveness of covering methods to reduce the top losses in maize silages. The experiment comprised a completely randomized design, with five replicates of each of three treatments: 1) black polyethylene (PE) film 200  $\mu\text{m}$  thick, 2) black PE plus sugarcane bagasse (10 kg  $\text{m}^{-2}$ ) over the film, and 3) black PE plus soil (30 kg  $\text{m}^{-2}$ ) over the film. The forage was packed in macro silos (500 litres) which were opened 95 days after ensiling. During the silo filling one bag with well-mixed fresh forage (approximately 4 kg  $\text{bag}^{-1}$ ) containing one data logger was buried into the upper layer (25 cm) of the silo to measure the temperature and sealing efficiency. Top losses in the silages were also determined by chemical and microbiological analyses. The difference in the covering methods did not affect the mean temperatures during the storage period, but started to rise only for the control silage after 81 days. Lower yeast-counts (colony forming units - cfu) were noticed in the silage covered with soil over the film (2.44 log cfu  $\text{g}^{-1}$ ). Better aerobic stability and hygienic aspects were achieved when the film was covered at ensiling, either with soil or sugarcane bagasse.

### **3.1.14 Influence of conventional versus organic management systems on degradability characteristics of grass silages for dairy cows**

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The purpose of this work was to compare the degradability characteristics of six grass silages from meadows and grazing pastures in temperate areas of northern Spain, grown under organic and conventional systems. The study was carried out using three dairy cows allocated to a metabolism house. The insoluble residues were measured after 0, 2, 4, 8, 16, 24, 48, 72 and 96 hours of incubation. Results showed significant differences in the values of *in situ* degradability between silages made from forages grown under conventional and organic management. The values of potential dry matter degradability in organic silages were higher than those obtained for conventional management, regardless of the type of meadow and the silage cut. This could mean a greater ruminal synthesis of microbial protein, because there is a greater relationship of fermentable energy/fermentable nitrogen under organic conditions. In addition, for both managements and silages, the crude protein effective degradability values were higher than those obtained for dry matter.

### **3.1.15 The use of unstandardized or standardized spectra to expand a NIR calibration model for herbage analysis**

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Several standardization models have been proposed for transferring calibration equations between NIR equipments. Spectra of 900 samples of grass-legume mixtures were recorded and analysed with a calibrated 6500 Foss NIRSystem equipment, Master (M). Samples were simultaneously processed in another 6500 NIRSystem spectrophotometer and their unstandardized (USTD) and standardized (STD) spectra recorded. M spectra of 40 samples were selected to expand the calibration set by using the algorithm SELECT of Win ISI 1.5 software and three calibration models were developed from the calibration set expanded with M, STD and USTD spectra of selected samples. M, STD and USTD spectra of non-selected samples were analysed by these three models and results compared by regression taking master results as reference. Standard error of determination, SED, of STD analysis of master spectra ranged from 0.027 to 0.466 for CP and NDF and from 0.057 to 1.009 for WSC those of USTD analysis. SED values for M and STD analysis of STD spectra ranged from 0.099 to 0.895 and from 0.112 to 0.600 for CP and NDF, respectively. SED values of USTD and M analysis of USTD spectra were higher than those of STD analysis.

### **3.1.16 Description and prediction of multi-species pasture nutritive value across the grazing season**

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Multi-species pastures with grasses and legumes have the potential to enhance ruminant nutrition. The nutritive value of two multi-species pastures was evaluated *in vivo* (standard sheep digestibility measures) during the April to October period, over 5 consecutive years in Normandy. The first multi-species were a mixed sward recommended for use in the Swiss lowlands and the second came from the Loire valley in France. While the nutritive value of both pastures was high on average during the year, the Loire valley mixture had a light advantage in spring and autumn. The high nutritive values observed during autumn reaffirm the nutritional potential of autumn grazing. The results indicate that the prediction of organic matter OM digestibility of multi-species swards using the equation including pepsin-cellulase is imprecise compared to monocultures, but is improved when the age of regrowth is included.

### 3.1.17 Physico-chemical characterisation of forage fibre from different C<sub>3</sub>-grasses in South Brazil

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The physico-chemical characteristics of fibre influence the availability of nutrients and energy in diets for ruminants and monogastric animals. Depending on its buffering capacity (BC), fibre exchange cations with H<sup>+</sup> in the lumen of the gastrointestinal tract. The objective was to examine relations between quality parameters and the linearised form of the BC (the linear buffering rate, LBR) of different forages. Three grass species (*Avena sativa*, *Avena strigosa*, *Lolium multiflorum*) normally grown in the winter in South Brazil were evaluated. CP, NDF, ADF, ash and gas production (GP) were measured. The BC was evaluated in the whole sample and in the residue after NDF extraction, representing the fibre fraction. The results showed a higher BC in the whole sample compared to the NDF fractions. Differences for BC between species were observed in the intact material, but not for their NDF fractions. CP was positively, and cell wall contents were negatively, related to LBR in the whole sample. The relation was weak between accumulated GP and LBR estimated in the whole sample and in the NDF fraction. In conclusion, the LBR showed a clear relationship with nutrients in the forages. This relation was weaker using the NDF fraction of samples.

### 3.1.18 Fatty acid composition of forage herb species

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The use of alternative forage species in grasslands for intensive livestock production is receiving renewed attention. Data on fatty acid composition of herbs are scarce, so four herbs (*Plantago lanceolata*, *Achillea millefolium*, *Cichorium intybus*, *Pastinaca sativa*) and one grass species (timothy, *Phleum pratense*) were sown in a cutting trial. The chemical composition and concentration of fatty acids (FA) of individual species were determined during the growing season. Concentrations of crude protein and FA were generally higher in the herbs than in timothy. *C. intybus* had the highest nutritive value and FA concentrations. FA concentrations were generally lower in June after a heavy cut than in May and August.

### 3.1.19 Effects of row spacing and seeding rate on sorghum whole crop yield and quality

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Sorghum (*Sorghum bicolor*) could be a real alternative to silage maize in areas affected by summer drought. As its ability to feed dairy cows has been demonstrated, it is time to adapt the crop management, inherited from maize management. Therefore, our objective was to determine the best row spacing and seeding rate for optimising biomass yield without lowering maturity and quality of sorghum forage. From 2007 to 2009, comparisons were made of two row spacings: narrow (0.20 m) and wide (0.75 m) with the same seeding rate and the same dwarf cultivar in an experimental design with 2 to 4 replications. In 2007 and 2008 we added a treatment consisting in a higher seeding rate. The main yield components (Forage yield, dry matter content in the whole plant), the plant height and the forage quality (fibre and protein contents, and digestibility) were recorded. The narrow row spacing provided higher forage yield (66 % more) each year, even when the yield was limited by the water supply, and without decreasing the harvest index and the forage quality. Doubling the seeding rate did not lead to better performances and should not be recommended.

### 3.1.20 Yields and contents of condensed tannins of some forage legumes and herbs

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To determine annual dry matter (DM) yields, content of condensed tannins (CT) and total phenolics (TPh) as well as tannin yields, six legumes (*Onobrychis viciifolia*, *Lotus corniculatus*, *Trifolium hybridum*, *T. repens*, *Melilotus officinalis*, *Medicago sativa*), four herb species (*Cichorium intybus*, *Sanguisorba minor*, *Plantago lanceolata*, *Taraxacum officinale*) and the reference species *Trifolium pratense* and *Lolium perenne* were cultivated in 2007 and 2008 at the organic experimental farm 'Lindhof' of the University of Kiel, Germany. The experimental factors species and year had a strong impact on DM yields. The reference species *T. pratense* showed highest yields while the herb species and *O. viciifolia* showed significantly lowest DM yields, in particular in 2008. The highest tannin levels were found in *O. viciifolia*, and medium contents were found for *L. corniculatus*. Calculated tannin yields per hectare indicate highest CT amounts for *L. corniculatus* followed by *O. viciifolia*. Their DM yields, however, were medium or low.

### 3.1.21 Effects of dry matter and additive on wilted bale silage quality and milk production

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First-cut timothy-meadow fescue ley was wilted to two dry matter (DM) contents and ensiled using two additive treatments to study the effects of silage quality on milk production. Grass was cut with a mower conditioner and wilted for 9 or 56 h, aiming at DM of about 300 and 500 g kg<sup>-1</sup>, baled with a chopper baler with no additive or with a buffered formic acid based-additive, and wrapped using six plastic layers. A milk production trial was carried out as a replicated 4 x (4 x 4) Latin square experiment with 16 dairy cows in a 2 x 2 factorial arrangement of treatments. Silage was fed *ad libitum* and concentrate fed at 11 and 13 kg d<sup>-1</sup> for primiparous and multiparous cows, respectively. The fermentation quality of all silages was good, and acid-based additive restricted fermentation in the lower DM silage. Acid additive improved aerobic stability of both silages. Longer wilting time decreased diet organic matter digestibility in dairy cows. No significant differences were found in milk or milk constituent yields, or milk protein and lactose contents, or dietary nitrogen utilization between silage DM contents or additive treatments. Energy utilization was better with higher DM silages.

### 3.1.22 Aerobic stability and fermentation quality of round bale silage treated with inoculants or propionic acid

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A timothy-meadow fescue sward was cut with a mower conditioner. After wilting to a dry matter (DM) concentration of 440 (DM1), 560 (DM2) and 643 (DM3) g kg<sup>-1</sup>, the grass was round baled and ensiled with or without additive treatment. The additives included propionic acid (43%) + ammonium propionate (27%), 8 l Mg<sup>-1</sup> grass (PA), *Lactobacillus plantarum* 10<sup>6</sup> colony forming units (cfu) g<sup>-1</sup> grass + *L. buchneri* 10<sup>5</sup> cfu g<sup>-1</sup> (LP + LB), *L. plantarum* 10<sup>6</sup> cfu g<sup>-1</sup> + sodium benzoate (300 g Mg<sup>-1</sup>) (LP + SB), and *L. rhamnosus* 5 x 10<sup>5</sup> cfu g<sup>-1</sup> (LR). Fermentation quality and aerobic stability of the silages were measured. The inoculants maintained lactic acid fermentation and decreased water soluble carbohydrate concentration (WSC) for DM < 600 g kg<sup>-1</sup>. In DM3 silages, fermentation was suppressed, and only small differences were observed between the treatments in lactic acid and WSC concentrations. However, PA lowered pH as compared to other treatments. Except for LR-treated DM2

silage, all other silages were stable for four days after opening the bales. Thereafter, propionic acid more efficiently prevented silage heating than the inoculants, and the LP + SB treatment was more efficient than the other inoculant treatments.

### **3.1.23 Effects of a combination of selected lactic acid bacteria strains on the fermentation quality and aerobic deterioration of maize silage**

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Chopped whole-plant maize was ensiled at the waxy stage of maturity from five fields in 0.7-L laboratory silos when determining pH after 2 d or in 3-L silos when determining the fermentation parameters and aerobic stability of silages after 100 d. The forage was ensiled without additives (control) or treated with a multicomponent probiotic inoculant (*E. faecium*, *L. casei*, *L. plantarum*, *L. buchneri* and *Pediococcus pentosaceus*) applied at 150000 cfu g<sup>-1</sup> fresh weight. Three replicates were made for each treatment from each field. The inoculant resulted in significantly higher ( $P < 0.01$ ) dry matter concentration, lower ( $P < 0.05$ ) neutral detergent fibre and acid detergent fibre concentrations. Inoculated silages had lower a pH both after 2 d and 100 d than the untreated control. The concentration of lactic acid was generally higher and the concentration of acetic acid lower in the inoculated silages than in the control. The lactic acid concentrations did not differ among treatments. However, the bacterial blend produced less ( $P < 0.01$ ) acetic acid and increased lactate:acetate ratios (3.1 vs. 4.2). Inoculation reduced proteolysis of plant proteins, because ammonia-N concentration was lower ( $P < 0.01$ ) in inoculated silage compared to the control. Treatment significantly ( $P < 0.01$ ) reduced dry matter losses compared with the control. However, the inoculated maize silage was more prone to aerobic deterioration than the control.

### **3.1.24 Evaluation and performance of five maize hybrids for silage cut at different cutting heights**

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The performance of five maize (*Zea mays* L.) hybrids and three cutting heights (15, 35 and 55 cm) on the productivity of dry matter (DM), nutritive value of silage and estimated milk yield using the model Milk 2006 were evaluated. There was no difference in the yield of DM biomass among the hybrids, with an average of 15.0 t ha<sup>-1</sup>. Biomass DM productivity decreased with increasing height of cut, and average values were 14.6, 13.0 and 12.6 t ha<sup>-1</sup> for 15 cm, 35 cm and 55 cm of cutting height, respectively. There was an effect of hybrid and cutting height on the chemical composition of silage. Milk productivity (kg of milk per hectare) was similar in the three heights of cut. The cutting height does not replace the best choice of hybrids for silage production of high quality and productivity.

### **3.1.25 Characterisation of the fibre composition of fresh and ensiled herbage species under varying management conditions**

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This study characterised the fibre concentration of fresh (pre-ensiling) and ensiled herbage species produced under varying management conditions. Five grass species were grown in field plots under two nitrogen fertiliser regimes and harvested at five dates in the primary growth. On each harvest date, the plots were harvested and ensiled in laboratory silos for 100 days. Both fresh and ensiled herbage species were chemically analysed for neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations. In general, fibre concentration increased with advancing plant maturity for all grass species. Timothy and cocksfoot had the highest fibre concentration with the ryegrasses having the lowest. The effect of ensiling on ADF and NDF concentrations in response to harvest date, nitrogen fertiliser and grass species was inconsistent. However, in general, ensiling resulted in a slight increase in the fibre concentration of all grasses, particularly for the early harvest periods where the fermentation of soluble compounds may have been most extensive.

### **3.1.26 Production abilities and forage quality of prospective grasses in the first year after renovation**

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Milk efficiency of dairy cows reached 6 548 kg of FCM with consumption of 0.30 kg of feed concentrates per kg of FCM in 2007 in the CR. The economic crisis requires the farm holdings to reduce production costs by using quality forage from renovated grasslands instead of expensive feed concentrates. Therefore an accurate small-plot trial was established at the Jevíčko site (elevation 342 m) in 2008 with four replications and treatments using 15 selected grass species: hybrid ryegrass (1 variety), Italian ryegrass (1), perennial ryegrass (5), timothy (2), cocksfoot (3), tall fescue (3), Festulolium (6), tall oat-grass (1), meadow foxtail (2), red fescue (2), mountain brome (1), smooth brome (1) and Alaska brome-grass (1), yellow oat-grass (1). The trial was fertilized with 180 kg ha<sup>-1</sup> N in the form of ammonium nitrate with lime applied in three doses per 60 kg ha<sup>-1</sup> (in spring, after the first and second harvests), 35 kg ha<sup>-1</sup> P (superphosphate) and 100 kg ha<sup>-1</sup> K (potassium salt); with a four-cut utilization, first cut on 29 April, then 45 days between cuts. The contribution evaluates dry matter production and fodder quality in terms of the following parameters: CP, fibre, NEL, NEF, PDIE, PDIN.



### **3.1.27 Silage fermentation characteristics as influenced by red clover/ryegrass-mixing ratio, degree of wilting and silage inoculants**

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Pure red clover stands are difficult to ensile. Therefore, a laboratory ensiling trial was conducted to investigate the effects of varying proportions of red clover and perennial ryegrass (100/0, 66/33, 33/66, 0/100) on silage fermentation quality. In addition, the efficiency of the ensiling management, consist of lactic acid bacteria (LAB) inoculants combined with two levels of wilting (target dry matter: 300 vs. 400 g kg<sup>-1</sup>) were tested. Herbage was ensiled, either untreated or with inoculation of homofermentative LAB (low wilted herbage) or homo- and heterofermentative LAB (heavy wilted herbage). Early-July and mid-August growths were used. After 90 days of storage, each of the analysed parameters (lactic acid, acetic acid, pH, ammonia-N) showed a significant interaction cutting date x mixing ratio x ensiling management. Silages inoculated with homofermentative LAB increased the lactic acid production, but additives consist of heterofermentative LAB resulted in higher acetic acid concentrations, irrespective of harvest date and mixing ratio. These facts led to significant differences in silage pH between the applied LAB inoculants. However, wilting had only minor effects on the fermentation patterns. The influence of the mixing ratio was dependent on cutting date. Overall, the ensiling management was effective to improve the fermentation process.

### **3.1.28 The effect of different fodder galega-grass mixtures and nitrogen fertilization on forage yield and chemical composition**

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Fodder galega (*Galega orientalis*) is a forage legume. As a pure crop, galega is rich in nutrients, in particular crude protein, but is poor in soluble sugars. In order to improve fermentation properties, optimize nutrient concentrations and increase dry matter yield, galega usually is grown in mixture with suitable grass species. In this study, galega mixtures with timothy 'Tika', meadow fescue 'Arni' and brome grass 'Lincoln' were investigated in two successive years, 2008-2009. Three cuts were carried out during the vegetation period. Nitrogen fertilization rates applied were N0, N50, N100 and nitrogen was applied in spring prior to the first and second cut. The total dry matter (DM) yield varied from 7.2 to 12.4 t ha<sup>-1</sup>. DM yield was dependent on the year, mixture and fertilization level. The yields of the first cut were approximately 53% of total yield. The crude protein (CP) concentration in the DM varied from 125-226 g kg<sup>-1</sup>. CP was dependent on the year, mixture and fertilization. High N fertilization rate favoured grass growth and reduced the role of galega in the sward.

### **3.1.29 Insights into carbohydrate and protein fractionation in perennial ryegrass (*Lolium perenne* L.) genotypes using the Cornell Net Carbohydrate and Protein System. 1. Carbohydrate and protein fractionation**

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Perennial ryegrass is considered to be the most important grassland species in North-west Europe, due to its high nutritive value among temperate grasses. However, the imbalance between the supply of rumen degradable protein and fermentable energy resulting from inefficient carbohydrate fermentation enhances the risk of environmental pollution and leads to higher feed costs. Within the framework of a two-year field trial (2006-2007), carried out at three experimental sites in Northern Germany, the variation in the composition of crude protein (CP) and carbohydrate fractions among a set of twenty diploid *Lolium perenne* L. genotypes was examined. The result of the first cut revealed genotypic variation for the carbohydrate and protein fractions as well as for the total carbohydrate and protein contents. However, the magnitude of variation detected for the carbohydrates was very small except for the simple sugars (Fraction A). An even smaller variation was found for the protein fractions which could be partially attributed to low CP content of the genotypes.

### **3.1.30 Performance of ewes fed long or chopped grass silage using different feeding strategies**

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Effects of chopping of grass silage and mixing of grass silage and concentrate on performance of ewes in late pregnancy and lactation were studied. Twenty-one ewes were fed long grass silage and concentrate separately (LS) or chopped grass silage and concentrate separately (CS) or in a total mixed ration (TMR). The silage averaged 10.9 MJ metabolizable energy and 578 g NDF per kg DM. The daily DM intake in late pregnancy was 2.6, 2.5 and 2.6 kg and in lactation 3.5, 2.9 and 3.8 kg for LS, CS and TMR, respectively ( $P < 0.10$ ). The effective chewing time per kg DM intake was 272, 289 and 264 minutes in late pregnancy and 198, 253 and 210 minutes in lactation for LS, CS and TMR, respectively, with a significant effect of metabolic state ( $P < 0.001$ ). Mixing chopped grass silage with concentrate increased the feed intake by 19% in lactating ewes. Chopping of silage increased ruminating time ( $P < 0.001$ ) with no increase in DM intake. Ewes had a higher intake but a shorter ruminating time in minutes per day and per kg of DM intake and silage NDF intake during lactation than during late pregnancy ( $P < 0.05$ ).

### **3.1.31 Volatile fraction from sugarcane silage and forage proportion on the ingestive behaviour of beef steers**

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This study aimed to evaluate whether volatile fermentation end-products from sugarcane silage and the forage:concentrate ratio might affect the ingestive and feed sorting behaviour by the animals. Six Nellore steers were randomly assigned in a replicated 3x3 Latin square design over a 14-d period. Dietary treatments were: 75D – 75% sugarcane silage without volatile fraction (dried and re-hydrated) and 25% concentrate; 75W – 75% wet sugarcane silage and 25% concentrate; and 40W – 40% wet sugarcane silage and 60% concentrate (dry matter (DM) basis). The volatile fraction from silage did not impair intake and ingestive behaviour. Despite presenting higher DM intake, steers fed lower forage:concentrate ratio (40W) spent less time eating and ruminating. Sorting was unaffected by treatment, whereas sorting index showed increased orts percentage for longer particles. Feeding sugarcane silage with shorter particle size may reduce sorting and keep the DM intake of the diet according to the predicted formulation.

### **3.1.32 Effect of additive treatment on fermentation quality and ruminal degradability of red clover-timothy silage**

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The objective of this study was to investigate the effect of biological additives on fermentation quality and ruminal degradation of red clover-timothy mixture silages. During ensiling, a chemical additive and selected biological inoculants were used. Silage chemical composition and fermentation parameters were analysed and dry matter (DM), crude protein (CP), neutral detergent fibre (NDF) and acid detergent fibre (ADF) degradability, using the *in sacco* method, were assessed. Silages treated with biological and chemical additives had higher DM and nitrogen-free extractives contents and lower contents of CP and cell wall fractions. Additives also improved the silage fermentation quality. The pH was lower in the silages with the biological inoculants, which had a mean pH of 4.2. Ruminal degradability of CP and fibre fraction in the well fermented silages was slower compared to the untreated silage. The effective DM degradability of all silages was within the range 622 to 650 g kg<sup>-1</sup>.

### **3.1.33 Effect of fungicidal control of *Festuca rubra* L. ssp. *commutata* and *F. rubra* L. ssp. *rubra* on seed infection with fungi**

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We determined the influence of fungicidal control of chewing's fescue and strong creeping red fescue crops grown for seed on kernels infection by fungi. Fungicides were applied twice before yield harvest. Seed infection with fungi was analysed. There was a significant effect of fungicidal control on the occurrence of fungi on kernels. Almost 89% of fungi, including grass pathogens, were detected more often on seeds obtained from non-protected plots. Lower infection of seeds harvested in the first year of full use than in the second one was observed.

### **3.1.34 Suitability of seed mixtures for intensively farmed permanent meadows in a mountain environment**

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In a 7-year field trial, persistency, yield and forage quality of newly sown permanent meadows were investigated in South Tyrol (890 m a.s.l.) under a 4-cut regime. Two recommended seed mixtures: DWi-t (lead species *Lolium perenne*) and DWi-h (lead species *Alopecurus pratensis*) were compared with two new seed mixtures: DWi-Lp, containing high proportion of *Lolium perenne* (30% by weight) and DWi-Fa, containing 40% by weight of *Festuca arundinacea*. Each treatment developed a distinctive botanical composition over time. In DWi-t and DWi-Lp, the share of *Lolium perenne* was low in 2009 and DWi-Lp had the largest share of opportunistic species and weeds. Forage yield was affected by the seed mixture only in the beginning, with DWi-Lp and DWi-Fa being the most productive treatment in 2004 and 2005 respectively. Since *Alopecurus pratensis* became dominant in DWi-h, higher herbage fibre contents were found in this treatment, due to its earliness. No such effect was observed for DWi-Fa at an average share of *Festuca arundinacea* around 20%.

### **3.1.35 A simple model for the estimation of protein content of first-cut meadow forage**

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A project aiming at the development of an affordable tool for estimating the forage quality of permanent meadows at the first cut was conducted in South Tyrol (I) from 2003 to 2007. Forage quality was investigated at 35 sites scattered across the whole province and

representing a wide range of climatic conditions and management practices. At each site, small-size samples were collected in 4 replications on a weekly basis for 7 weeks, starting at an average vegetation height of 15 cm (BE). Eleven factors related to geomorphology, vegetation, soil and agronomic management significantly explained the crude protein content in a stepwise logistic regression; 86.7% of the observations were correctly classified. As years explained a significant part of the variation of the dependent variable, a replacement of this factor was attempted using at each site cumulative and/or average values of the potential solar radiation and of the temperature departure from the long-term average of the respective agricultural district; all of them referred to the time period between BE and each sampling date. Their inclusion in the statistical analysis in replacement of years maintained a satisfactory level of correctly classified observations (86.8%).

### **3.1.36 A test of sampling methods for the investigation of forage quality in permanent meadows**

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In order to optimise the sampling method for a larger project aiming at estimating the first-cut forage quality of permanent mountain meadows in South Tyrol (I), a three-year investigation was conducted at three different sites at altitudes between 1210 and 1290 m a.s.l. Two small-scale sampling methods were applied: the sampling of a stripe-shaped area of 0.2 m<sup>2</sup> and 10 cm width was compared to the sampling of a square-shaped area of 0.25 m<sup>2</sup>. Starting at the beginning of stem elongation of the main grass species, forage samples were taken weekly in 6 replications during a time period of 7 weeks. The content of ash, crude protein, crude fibre and neutral detergent fibre were analytically determined. All quality traits were unaffected by the sampling method with the exception of crude fibre, which was slightly higher in the square-shaped sampling areas. Sampling of square-shaped areas seems to be a suitable method because of a smaller work load and easier sampling collection. Four replications per site and sampling year allowed to estimate the investigated traits with reasonable accuracy.

### **3.1.37 The effect of Na-buffered acid-based additives on wilted roundbale grass silage**

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Silage additives buffered by sodium, instead of ammonium as used formerly, were recently launched on the Norwegian market. The main objective of this study was to evaluate the effect of three sodium formate or/and -propionate-based silage additives (Ensil 1 Na (E), Ensil Pluss Na (EP) and GrasAAT N-Plus (GP)) on the quality of wilted roundbale silage. Untreated control silage (C) and Kofasil Ultra (KU) were included. The crop was wilted to reach 30% dry matter. All additives significantly improved fermentation quality and aerobic stability of roundbale grass silage. The effect of EP and GP was similar in spite of slightly different composition. When used at the same dose, the pure formate-based additive (E)

restricted lactic acid and acetic acid fermentation somewhat more than the formate/propionate-based EP and GP, but WSC concentration tended to be lower, probably because of increased ethanol fermentation. None of the additives restricted mould growth significantly. When acid-treatment is needed in order to improve fermentation quality or aerobic stability of wilted silage, additives based on both formic and propionic acid may be recommended rather than pure formic acid-based additives in order to restrict ethanol fermentation, improve aerobic stability and, under some circumstances, restrict fungal growth.

### **3.1.38 Relationships between dry matter yield, forage nutritive value, and some canopy parameters of alfalfa crop**

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The cultivar choice is one of the most important factors affecting dry matter yield and forage quality of alfalfa (*Medicago sativa* L.) crops. Canopy parameters such as plant height, Leaf Area Index (LAI), and Stem Area Index (SAI) are often related to the cultivar selection. With the aim to investigate the relationships existing between dry matter (DM) yield, forage nutritive value, and some canopy parameters of alfalfa, a 3-year study was conducted at the experimental farm of Padova University in Legnaro (NE Italy) from March 2005 to November 2007. Sixteen cultivars of alfalfa were compared under two harvest regimes: early bud and early flower. In 2006 and 2007 dry matter yield, plant height, leaf dry weight per area unit, stem dry weight per area unit, LAI, and SAI were measured at each harvest. The forage nutritive value (UFL = French milk forage units) was calculated based on forage nutrient concentrations determined via near infrared reflectance spectroscopy (NIRS). DM yield increased with the increase of plant height. A strong positive correlation existed between plant height and UFL ha<sup>-1</sup>. Furthermore, both leaf to stem ratio and LAI to SAI ratio were positively related to UFL.

### **3.1.39 Insights into carbohydrate and protein fractionation in perennial ryegrass (*Lolium perenne* L.) genotypes using the Cornell Net Carbohydrate and Protein System. 2. Ruminal kinetics**

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The Cornell Net Carbohydrate and Protein System (CNCPS) is used as a tool to provide detailed information about grass nutritional value, involving rumen kinetics. The current study, evaluating 20 diploid perennial ryegrass genotypes, revealed small, but significant variations concerning the ruminally degraded and undegraded proteins (RDP and UDP) and the ruminally digested and undigested carbohydrates (RDC and UDC). Genotypes 6 and 9 represented the maximum variation in the investigated set of genotypes, and helped in the interpretation of the results. The dry-matter based first cut difference between the genotypes 6

and 9 accounted for 24, 1, and 1 g kg<sup>-1</sup> in DM, for the respective parameters RDC, RDP and UDP, in favour of the high-sugar genotype 9, even though the two genotypes had similar total carbohydrate and total protein contents. This highlights the importance of feed fractionation procedures in achieving a detailed view into the fate and utilisation of the different fractions in the rumen, and supports the optimisation of diet composition which meets the animal's requirements to achieve its appropriate maintenance and production levels.

### **3.1.40 Floristic composition and herbage quality changes with tree cover in NW Patagonia, Chile**

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In order to test the feasibility of implementing a silvopastoral system with the native tree species lenga (*Nothofagus pumilio* [Poepp. et Endl.] Krasse), we studied the understorey grasslands in a marginal lenga woodland with varying canopy openness in the Aysén Chilean region. In the present work we examine the influence of tree cover on herbage quality. Concentration of crude protein, fibres by the acid detergent method and water soluble carbohydrates were measured in a range of tree covers at the peak of the growing season. Herbage nutritive quality along the tree cover gradient is discussed with reference to changes in its botanical composition and the chemical composition of two dominant species with forage potential.

### **3.1.41 Aerobic stability evaluation by carbon dioxide (CO<sub>2</sub>) production on corn silages using Infrared Gas Analyzer**

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The silage spoilage process with oxygen exposure caused by the microbial population results in carbon dioxide (CO<sub>2</sub>) production, which is a measure of dry matter losses. This trial evaluated the aerobic stability in corn silages without additives or with a combination of *Lactobacillus plantarum*, *Lactobacillus brevis* and *Enterococcus faecium*, with five replicates. Aerobic stability was measured as hours to reach a temperature increase of 2 °C above ambient, using data loggers buried in the forage. The CO<sub>2</sub> production was measured using an Infrared Gas Analyzer. 30 g of corn silage was used from each replication and the CO<sub>2</sub> measures were taken every hour with the results expressed in parts per million (ppm) of CO<sub>2</sub> produced and detected in aerobic condition. The data were converted to CO<sub>2</sub> microliters per hour per gram of silage, on a dry matter basis (μL h<sup>-1</sup> g<sup>-1</sup>). A good correlation was observed between CO<sub>2</sub> production and temperature increase. The carbon dioxide production was a good indicator of dry matter losses of silage under aerobic conditions.

### 3.1.42 Hygiene is crucial in controlling the heating of total mixed ration

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A factorial experimental design was used to examine ways to control the heating of total mixed ration (TMR). The studied factors were hygienic quality of raw materials, type of preservative and application rate of preservatives. The two levels of hygienic quality were created by using all fresh raw materials or 10 % inclusion of spoiled raw materials. The examined preservatives were a liquid preservative (propionic acid, ammoniumpropionate and ammoniumformiate) or a solid preservative (sodium-calcium-propionate) and the examined application rates were 0, 2 or 3 g kg<sup>-1</sup>. Aerobic stability of the TMR feeds was measured in laboratory scale. Fresh raw materials lead to a clearly better aerobic stability (66.2 h compared to 9.2 h,  $P < 0.001$ ) of the TMR than the partly spoiled raw materials. The preservatives improved aerobic stability only slightly (3.2 hours,  $P < 0.001$ ). No differences between the liquid and the solid preservative nor between the two levels of application were detected.

### 3.1.43 The effect of climate, clover species and swath management on pre-wilting of a mixture of grass and clover

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When ensiling grass it is essential to obtain a specific dry matter content. The climate and swath management have significant effects on the drying rate. Experiments in the field were therefore carried out to quantify these effects with the aim of making a climate-dependent pre-wilting prognosis. Throughout the growing season perennial ryegrass (*Lolium perenne* L.) mixed with either red clover (*Trifolium pratense* L.) or white clover (*Trifolium repens* L.) was harvested with different dry matter yields and different swath management (narrow, broad, and broad combined with inversion three hours after harvesting). The drying rate (increase in dry matter (DM) concentration per hour) was higher in a broad swath than in a narrow, and was higher still in the inverted broad swath. These differences increased with a better drying climate (mainly a higher temperature). Air humidity and radiation also had a significant effect on the drying rate, whereas the wind speed did not. In the narrow swath the drying rate was the same for the two sward types, but in the broad swaths the drying rate was faster in the mixture with white clover than with red clover.



### 3.1.44 Micro-mineral profile in different grassland species

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The aim was to investigate the micro-mineral profile of herbage as affected by grassland species, cutting time and seasonality and in relation to dairy cow requirements. The different grassland species were grown and harvested in mixtures with one grass and one legume for two growing seasons. The species turned out to have very individual mineral profiles, not influenced by year. Among the legumes red clover (*Trifolium pratense*) had high concentrations of Co, Cu and Zn, white clover (*Trifolium repens*) of Mn and Fe, lucerne (*Medicago sativa*) of Se and lotus (*Lotus corniculatus*) of Co, Mn, Zn and Fe. Among the grasses, perennial ryegrass (*Lolium perenne*) generally had the highest concentrations of all the micro-minerals. Hybrid ryegrass (*Lolium hybridum*) had slightly lower concentrations than perennial ryegrass for all minerals. Meadow fescue (*Festuca pratensis*) had lower concentrations still, and timothy (*Phleum pratense*) had, with the exception of Zn, the lowest concentrations. In general, the mineral concentrations were higher in summer than in spring growth. During the growth Cu, Zn and Fe concentrations decreased, whereas Co, Se and Mg were unaffected. It was concluded that a mixture of red clover and perennial ryegrass had the best profile of micro-minerals for cattle feeding.

### 3.1.45 System modelling in studying cultivation, harvesting and storage of grass forage

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Grass forage cultivation - finding new solutions and development of them is a new project that started at the end of 2009. This paper introduces the content of the project, its aims and methods. The first aim of the study is to develop a working tool for farm advisors to compare methods in grass cultivation, harvesting and storage. The second aim is to cut 15 to 20% of the production cost of silage. There are many parameters and data available to create a mathematical model in order to compare complex and versatile process options. It is possible to simulate the effect of different factors of production by the use of a system model to be created with the modelling program. Calculation starts from grass silage needed for cow-herd sizes of 30, 70, 120, 200 and 500. The quality and amount criteria of silage are the deciding factors for time of harvest and the length of the harvesting period. Capacity of the harvesting chain is the most critical variable in the first cut when aiming for optimum 68-70 D-value in Finnish conditions. About 40% of production costs arise from machinery and storage so it is important to use expensive machines more efficiently, or use smaller machines or use a contractor. One solution is to find more area for harvesting, and increasing the length of harvesting period by cultivating new plant mixtures.

### 3.1.46 Yields of forage crops in Schleswig-Holstein 1985-2008 under farm-scale and trial conditions

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The objective of this study was to analyse the impact of climatic conditions on the development of energy yield of maize and grass silage under farm conditions. Additionally, data on silage maize yield obtained from field trials were included. Maize NEL energy yield increased by about 1000 MJ ha<sup>-1</sup> y<sup>-1</sup> to a current level of 70-75 GJ ha<sup>-1</sup>. Correspondingly, energy yield of grass silage increased by 450 MJ ha<sup>-1</sup> annually to a level of 50-55 GJ ha<sup>-1</sup>. With regard to maize, this improvement can be attributed to an increase in dry matter (DM) yield and energy concentration. Grass, in contrast, only revealed a rise in energy concentration. A clear relationship was detected between the increase in temperature, amounting to 0.08 °C y<sup>-1</sup> over the period of April to September, and the improvement in energy yield. An increase in temperature by one degree Celsius resulted in an increase in energy yield by 5930 MJ ha<sup>-1</sup> for maize and by 3217 MJ ha<sup>-1</sup> for grass, respectively.

### 3.1.47 Does tiller type distribution explain the differences in yield and nutritive value of timothy genotypes?

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The basic difficulty in grass breeding for silage is the negative correlation between the amount of herbage mass produced and its nutritive value. The yield of timothy (*Phleum pratense* L.) is composed of three different tiller types (vegetative, vegetative elongated, and generative) that differ in respect of growth process and nutritive value. The aim of the study was to find out if the distribution of these tiller types affects the differences in yield formation and nutritive value of timothy genotypes. The field experiment included 15 different genotypes that were planted at MTT Maaninka, Finland, and the yield and nutritive value was determined in the first and the second cut in 2008 and 2009. The effects of tiller type distribution on the yield formation and the nutritive value of genotypes are presented and the importance of tiller types is discussed.

### 3.1.48 Fermentation quality and dry matter losses of grass-legume silage treated with lactic acid bacteria mixture

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The effect of adding the inoculant blend of *Enterococcus faecium* (BIO 34, DSM 3530), *Lactobacillus brevis* (IFA 92, DSM 19456) and *Lactobacillus plantarum* (IFA 96, DSM 19457), to medium-wilted legume-grass silage was evaluated. Two silages were prepared from a grass-legume sward treated with either inoculant or no additive (control). Herbage was wilted to a dry matter (DM) content of 320 g kg<sup>-1</sup> and mean crude protein and water soluble carbohydrate concentrations in DM at ensiling were 174 and 88 g kg<sup>-1</sup> respectively. Treatment resulted in significantly higher crude protein in DM (149.4 vs. 159 g kg<sup>-1</sup>;  $P < 0.05$ ) and digestible protein (108.9 vs. 117.8 g kg<sup>-1</sup>;  $P < 0.01$ ) concentrations. Inoculant treatment increased fermentation rate, resulting in a significant ( $P < 0.05$ ) pH drop and in a significant ( $P < 0.05$ ) increase of total fermentation acids concentration compared with the control. The inoculant produced higher ( $P < 0.01$ ) lactic acid content and numerically higher acetic acid content compared with that of the control. Butyric acid and ammonia N concentrations were significantly ( $P < 0.01$ ) decreased by application of inoculant blend. DM loss values were significantly ( $P < 0.01$ ) lower for treated grass-legume silages.

### 3.1.49 Effects of grass silage maturity and different grain sources on total dry matter intake and milk yield in high lactating dairy cows: fibre and starch interactions

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This study investigates the hypothesis that the interaction of grass silage maturity and different grain sources could affect total dry matter intake (DMI) in high yielding dairy cows. Twenty-eight multiparous Swedish red dairy cows with an average milk yield of 30 kg d<sup>-1</sup> and a live weight of 625 kg were offered four total mixed rations (TMR): early-cut or late-cut timothy grass silage and barley pellets and early-cut or late-cut timothy grass silage and maize pellets in a 7 replicated 4 x 4 Latin square designs with four 21 d periods. All TMRs contained the identical proportions of forage (51%) and concentrate (49%) and where combined with higher crude protein (CP; 17% vs. 15%) content for early-cut TMRs and higher neutral detergent fibre (NDF; 38% vs. 33%) content for late-cut TMRs. All four TMRs were compared for effects on total DMI, milk yield, organic matter and NDF digestibility. Animals fed early-cut TMRs had higher total DMI but the differences between grain sources were small.

### 3.1.50 A comparison between cut and intensively grazed swards on dry matter yield of perennial ryegrass

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The objective of this study was to compare the total dry matter (DM) and seasonal DM production of perennial ryegrass (*Lolium perenne*) varieties managed under either animal grazing or simulated grazing and to evaluate the effect of incorporating a silage harvest into these managements on total and seasonal DM production. Four managements were employed; i) Animal Grazing (AG), ii) Simulated Grazing (SG), iii) One Cut Silage and AG and iv) One Cut Silage and SG. The SG managements yielded  $14.4 \text{ t ha}^{-1}$ , which was significantly ( $P < 0.001$ ) higher than the AG managements yielding  $11.8 \text{ t ha}^{-1}$ . Incorporation of a silage harvest also had a significant effect ( $P < 0.001$ ) on total DM yield, summer DM yield and autumn DM yield but not on spring DM yield. Managements that incorporated a silage harvest yielded  $14.1 \text{ t ha}^{-1}$ , which was 18.0% higher than managements without a silage harvest. It can be concluded that cultivars evaluated under simulated grazing yielded higher than cultivars evaluated under animal grazing. However, as no re-ranking was found between cultivar and management, it indicates that simulated grazing is representative of the relative performance of a cultivar under animal grazing.

### 3.1.51 The influence of natural fertilisation on quality and nutritive value of grass silage

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The effect of different forms and doses of natural fertilisers (manure/liquid manure) on chemical composition and microflora of grass silage was evaluated. Three different fertilisers were compared: mineral NPK (control), manure (in doses:  $22 \text{ t ha}^{-1}$  and  $33 \text{ t ha}^{-1}$ ) and liquid manure (in doses:  $25 \text{ m}^3 \text{ ha}^{-1}$  and  $37 \text{ m}^3 \text{ ha}^{-1}$ ). Herbage from grassland was ensilaged in cylindrical big bales. There was a significant influence of type and dose of fertilisation on chemical and microbiological parameters. Use of manure had the most unfavourable impact on silage quality. Silages made of grass fertilised with manure had significantly higher pH and ammonium content, lower lactic acid and higher fatty acids content. They also showed higher total aerobic bacteria and *Enterobacteria* counts than other silages. But silages made from swards fertilised with manure had higher nutritive value, with more crude protein, less fibre fractions and a higher value of RFQ index.

## Session 3.2 Authenticity and traceability of grassland production and products

### The effect of allocation frequency in rotational grazing systems on the fatty acid profile in milk fat of dairy cows

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Four Holstein cows were used to evaluate the effect of allocating cows every 4 day (d) to a new 0.5-ha plot of *Lolium perenne* L. on the profile of fatty acids (FA) in milk. The experiment was run during 2 rotations with 2 measuring periods of 4 d each. During the 4 d period, the proportion (g per 100 g FA) of 18:3n-3 and total FA content (mg per g DM) of grass decreased linearly. Similarly, milk FA composition was largely affected by day within the 4 d period. Proportions of t11-18:1 in milk fat increased on d 2 (4.52 g per 100 g FA) and decreased thereafter (3.77 g per 100 g FA on d 4). Proportions of c9t11-18:2 (2.36 and 1.83 g per 100 g FA), t11c15-18:2 (0.81 and 0.63 g per 100 g FA) and 18:3n-3 (0.92 and 0.88 g per 100 g FA) in milk followed the same pattern. Results from this study suggest short term variation in pasture quality during the 4 d affected milk FA composition, with a greater effect on biohydrogenation intermediates in milk fat compared with its major precursor, 18:3n-3.

### Influence of the botanical diversity and development stage of mountain pastures on milk fatty acid composition, carotenoids, fat-soluble vitamins and sensory properties

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The objective of this study was to verify if the botanical diversity of grazed grasslands influences milk fatty acid (FA) composition, carotenoid and vitamin A and E contents and sensory properties. During 3 weeks (W1, W2 and W3), 18 cows divided into 3 homogenous groups grazed 3 mountain grasslands differing in diversity: D0, temporary grassland (17 species); D1, permanent grassland (31 species); D2 species-rich permanent grassland (50 species). The milk FA composition varied according to the grass development stage. Milk C16:0 percentage increased progressively from W1 to W3, stearic and oleic acid percentages reached a maximum in W2 and the percentages of *trans* isomers of C18:1 and CLA decreased from W1 to W3. The influence of the grass botanical diversity on the major milk FA was less

important than that of grass maturity. The milk C18:1t11, C18:2n-6 and C18:3n-3 percentages were slightly higher for D2 than for D0 and D1. The milk  $\beta$ -carotene content decreased from W1 to W3 and vitamin E content was highest at W3. The milk  $\beta$ -carotene and vitamin A and E content were similar between D0, D1 and D2. The milk sensory properties evaluated by non-expert tasters in triangular tests (D0 vs. D1 and D0 vs. D2) did not differ significantly according to the grassland botanical diversity.

## **Meat quality of Norwegian lambs finished on semi-natural pastures, concentrate or ryegrass pastures**

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The effects of different production systems on sensory profile and fatty acid composition were examined in a study performed in northern Norway (65°50'N, 12°28'E) in 2008. For three months or more, 150 Norwegian White Sheep lambs grazed the same semi-natural pasture with their dams. The effect of pre-slaughter fattening on meat quality was compared using a control group of lambs slaughtered directly from the pasture. Four pre-slaughter treatments were established: weaning and indoor-feeding on concentrate and grass silage for either 24 or 44 days before slaughtering (Conc24, Conc44), weaning and grazing on ryegrass (*Lolium multiflorum*) pasture for the same periods (Rye24, Rye44). Loin samples of *M. Longissimus dorsi* including the subcutaneous fat over the muscle from fifteen carcasses from each treatment were analysed for sensory attributes and fatty acid composition. A lower intensity of acid taste was observed in meat from lambs in treatment Conc44 compared with the control. A higher content of the fatty acids C18:1t-11 and C18:3n-3 was found in meat from grazing lambs whereas lambs fed concentrate had the highest n-6/n-3 ratio.

## **Tracing processes in grassland systems with stable isotopes - Results from the EGF master class**

N.N.

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In the last two decades the use of stable isotope analysis has increased greatly in ecology and environmental and land use sciences including grassland science. This stems from the fact that the natural stable isotope composition of organisms and ecosystems hold many clues about their functioning and physical environment, including the relative availability of resources. Stable isotopes offer special advantages in grassland science as they create a methodological bridge between environment, plant and animal as they allow to trace and quantify element flows and associated processes between these essential components of

grassland systems. Thus, stable isotope analysis provides insight into the functioning of ecosystems and organisms, including forage crops. This includes aspects such as the

- water use efficiency of crops and grassland
- the role of biological nitrogen fixation in nitrogen nutrition of crop and rangeland plants,
- the carbon sink/source activity of ecosystems and the terrestrial biosphere,
- C3:C4 vegetation dynamics in grasslands/rangelands,
- the nutritional behaviour of wild and domestic animals,
- biogeochemical cycling of nitrogen, carbon and water, and
- the (agro-)ecology of production systems.

Many of these aspects are important for solving scientific and practical issues of land use, environment, food authentication and forensics. Examples from the EGF Master Class *Stables Isotopes in Grassland Science* will be given in this presentation.

### **3.2.01 Variation of fatty acid profile during the grazing season in cows' milk from mountain permanent meadows**

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Evolution of milk fatty acid (FA) profile derived from three subsequent grazing events (GE) on the same alpine permanent meadow was compared on two farms. Bulk milk produced from two highly biodiverse paddocks (47 species) dominated by *Dactylis glomerata* and *Poa pratensis*, and managed under daily-ration grazing, was sampled for 3 days in succession during each GE, after 4 days of rumen adaptation on the same vegetation. Botanical composition and herbage dry matter (DM) content were surveyed on the day before each exploitation. GE effects were limited to few a FA: short-chain saturated FA decreased along the season, while C15:0 and cis9trans11-CLA increased. Differences between farms and interactions farm × GE occurred for vaccenic, rumenic, linoleic, linolenic acids and for total polyunsaturated FA (PUFA). PUFA was less (i) when small quantities of hay were supplied to cows or at higher herbage DM content, or (ii) when the specific contribution of forbs to sward composition was high, particularly *Apiaceae* and *Geraniaceae*, which are reported as rich in secondary metabolites that could inhibit rumen PUFA bio-hydrogenation. Total saturated FA showed an opposite trend.

### **3.2.02 Milk fatty acids and cheese from hay based diet and continuous or rotational grazing**

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This work compares Cantal cheeses obtained from three groups of 12 Montbéliarde cows fed either a hay-based diet (H) or grazing two mountain pastures: a diversified pasture (74

species) grazed continuously (E) and a less diversified (31 species) old temporary grassland, grazed rotationally (R). Under controlled conditions 27 cheeses were manufactured during three consecutive days in early June, July and late August in 2008. Cheese H was, on average, firmer, less melting and less yellow than cheeses E and R, which did not differ. Total saturated FA (SFA) and monounsaturated FA (MUFA) percentages were respectively higher and lower in H milks than in pasture milks. Vaccenic and oleic acids and polyunsaturated FA (PUFA), cheese colour and melting texture decreased during the season in E, while they remained constant in R because of a combined effect of the grass vegetative stage and selective grazing. Our results underline the relationship between milk FA profile and cheese texture.

### **3.2.03 Milk production and composition of day and night grazing of cows fed a total mixed ration**

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The possibilities of using high quality pastures in conjunction with total mixed ration (TMR) feeding during the grazing season have been examined. The aim of this study was to determine the influence of time of grazing and TMR type as supplementation on milk production and milk composition. A trial was performed with 16 lactating Holstein cows divided into four groups during four experimental periods of 21 days each. Two TMRs, based on grass or maize silage, combined with 12 hours of grazing at day or at night, were evaluated with a 2 x 2 factorial arrangement change-over design. Total dry matter intake was higher with the grass silage-based TMR than with the maize silage-based TMR. Cows grazing during the day consumed more TMR indoors than cows grazing during the night. Treatments did not affect milk production, milk protein or lactose contents. Milk fat was higher in cows feeding on a grass silage-based TMR and grazing at night than for any of the other treatments.

### **3.2.04 Fatty acids and antioxidant profiles in summer milk from different biodynamic and conventional systems in Southern Germany**

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Milk quality at biodynamic and conventional dairy farms was evaluated. Bulk milk samples were taken bimonthly on 24 farms in Southern Germany. Four groups, each of six farms, were representing characteristic farming systems: biodynamic high-input (BHI), biodynamic low-input (BLI), conventional high-input (CHI) and conventional low-input (CLI). Current feeding, pasture and performance of the cows were registered. The fatty acid (FA) compositions, as well as  $\alpha$ -tocopherol, retinol and  $\beta$ -carotene were analysed. Biodynamic farms had a lower concentrate input in the ration than conventional farms. Otherwise, BLI and CLI cows were essentially fed with grass combined with a small proportion of hay, BHI cows



with about similar quantities of both grass and silage, and CHI cows essentially with silage. BLI and then CLI milk showed the highest levels of conjugated linoleic acid and n-3 FAs compared to both high-input systems due to the highest intake of grass. In both biodynamic milks  $\alpha$ -tocopherol and  $\beta$ -carotene levels were highest. Summer milk from biodynamic and from low-input conventional systems could be differentiated from CHI by FA and antioxidant profiles and shows a nutritional beneficial milk composition.

### **3.2.05 Effect of the reduction of indoor supplementation on grazing time and sheep milk quality**

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During recent years there has been a significant research effort to modify milk composition in order to increase the concentration of healthy compounds as conjugated linoleic acids (CLA). According to these studies, grazing increases CLA content in the resulting milk. The objective of the current study was to evaluate the effect of the amount of indoor supplementation on grazing time and on the amount and quality of the resulting milk. The experiment was conducted with an experimental flock of Latxa dairy sheep during 4 weeks in spring 2008. Sheep were separated into 3 homogeneous groups of 12 sheep each and randomly assigned to different amounts of indoor alfalfa hay supplementation. According to the results, reducing indoor supplementation significantly increased pasture grazing while maintaining milk yield. The resulting milk of these groups showed healthier characteristics (higher content of CLA and higher antioxidant capacity).

### **3.2.06 Forage as a primary source of mycotoxins in the food chain**

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Our objective was to assess the content of mycotoxins entering the food chain from the fodder during two years of observation. The content of mycotoxins was assessed in fresh herbage of the species *Lolium perenne*, *Festulolium pabulare*, *Festulolium braunii*; in a mixture these species with *Festuca rubra* and in a mixture of these species with *Poa pratensis*. The content of mycotoxins was established by the Elisa method. Mycotoxins assessed were deoxynivalenol (DON), fumonisin (FOM), aflatoxin (AFL) and zearalenon (ZEA). DON and ZEA were detected in summer and in autumn. Content was lowest in June (DON 32.5 ppb, ZEA < LOQ) and highest in October (DON 53 ppb, ZEA 173 ppb). AFL and FUM were below the limit of quantifications (< LOQ).

### 3.2.07 Ability of visible spectroscopy to authenticate pasture-fed lambs in three breeds

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The development of rapid analytical methods for diet authentication and quality assessments in animal products is under active investigation. We assessed the ability of visible spectroscopy to distinguish pasture-fed (P) from stall concentrate-fed (S) lamb carcasses using a large database totalling 1054 (418 P and 636 S) male lambs from three sheep breeds, i.e. 148 P and 258 S Romane breed, 102 P and 92 S Ile-de-France breed, and 168 P and 286 S Limousine breed lambs. The reflectance spectrum of perirenal fat was measured 24 h *post-mortem* at wavelengths between 400 and 700 nm using a portable spectrophotometer. We quantified light absorption by carotenoids in the 450-510 nm area (method 1, M1) and performed a multivariate analysis over the full set of reflectance data (method 2, M2). Using M1, the proportion of correctly-classified S lambs was 100%, 95.8% and 93.5% in Romane, Limousine and Ile-de-France breeds, respectively, while the proportion of correctly-classified P lambs was 87.2%, 81.5% and 66.7% in Romane, Limousine and Ile-de-France breeds, respectively. Using M2, the proportion of correctly-classified S lambs was 99.6%, 99.6% and 97.9% in Romane, Limousine and Ile-de-France breeds, respectively, while the proportion of correctly-classified P lambs was 89.9%, 85.7% and 92.2% in Romane, Limousine and Ile-de-France breeds, respectively.

### 3.2.08 Seasonal variation of fatty acid in milk of intensive and extensive dairy systems in Northern Italy

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The effect of dairy farm management practices (intensive or extensive) on the fatty acid (FA) profile of milk transformed in Protected Designation of Origin (PDO) 'Raschera' cheese have been studied over two years. The intensive farms adopted diets based on corn silage, with a high concentrate to forage ratio, whereas the cow diets on the extensive farms were based on hay in the winter season, and on grazing in summer. The milk from the pastures presented the highest contents of human health FA, i.e. conjugated linoleic acid (CLA) and  $\alpha$ -linolenic acid. Furthermore, the extensive production systems allowed milk to be produced with higher odd- and branched-chain FA (OBCFA) content than intensive farms. Therefore, different FA profiles could be used to confer added value to dairy products from extensive systems and to justify their higher prices.

### **3.2.09 Composition and fatty acids profile of bovine milk after supplementation with barley and cottonseed**

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The objective of this study was to investigate the effect of supplementation with oilseeds (C, cottonseed) compared to concentrate with cereal grains (B, barley) on milk composition and fatty acids (FA) profile of Holstein-Friesian dairy cows in an indoor feeding regime. Three groups of twelve cows at the end of lactation (mean calving date 19 February) were studied over ten weeks during autumn. Two groups were supplemented with cottonseed at two levels: (C5), 5 and (C7), 7 kg cow<sup>-1</sup> d<sup>-1</sup> DM and one group was supplemented with barley (B7) at 7 kg cow<sup>-1</sup> d<sup>-1</sup> DM. Milk yield was significantly higher at the high level of supplementation (C7, 16.9 and B7, 17.4 kg cow<sup>-1</sup> day<sup>-1</sup>) compared to the low level (C5, 14.6 kg cow<sup>-1</sup> d<sup>-1</sup>). Milk protein was significantly lower in cotton treatments (C5, 32.9 and C7, 31.9 g kg<sup>-1</sup>) than in barley (B7, 34.4 g kg<sup>-1</sup>). There were no differences between treatments for milk fat. Medium chain FA showed a tendency to be higher with barley supplementation, whereas long chain FA were higher with cottonseed supplementation. The lowest ratio of saturated to unsaturated FA was observed in C7. Polyunsaturated FA and linoleic acid were significantly higher in C7. There were no differences between treatments for conjugated linoleic acid (CLA).

### **3.2.10 Influence of French dairy feeding systems on cow milk fatty acid composition**

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The aim of this study was to assess the impact of diet composition on the fatty acid (FA) composition of dairy cow milk in some French feeding systems. Seventeen farms from six regions were selected. Milk samples and a description of the diet were collected in five periods between May 2008 and February 2009 (May, July, September, January and February). Four feeding systems were identified. The grass-based system presented the best average milk composition over a year ( $P < 0.05$ ). Seven types of diets were also statistically different ( $P < 0.05$ ). The results showed strong correlations between the proportion of grazed grass in the diet and (i) polyunsaturated FA (PUFA) and mono-unsaturated FA (MUFA) (increase), (ii) saturated FA (SFA) and omega-6/omega-3 ratio (decrease). According to their FA composition, the results showed a strong correlation between the milk fatty acid profile and the diet. Grass-based diets produce milks with better nutritional profiles. This was particularly obvious for pasture-based diets.

### 3.2.11 Seasonal variation in the fatty acid composition of cow milk in the mountain regions of the Czech Republic

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The fatty acid composition of milk produced by cows during the grazing season (May-October) and during the period of winter silage feeding (November-April) was examined on three mountain farms in the Czech Republic. There was a higher proportion of long-chain and unsaturated fatty acids in milk from pastured cows than from the indoor-fed cows ( $P < 0.01$ ). Also the content of conjugated linoleic acid (CLA) was higher in the pasture period (on average 1.1%;  $P < 0.01$ ) than in the indoor period (on average 0.7%;  $P < 0.01$ ). The milk produced during the grazing season thus contained fat with a more beneficial composition, in relation to consumer health, than during the winter silage feeding.

### 3.2.12 Diversity of vascular plants and ground beetles (Coleoptera: Carabidae) in mountain cattle pastures

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The diversity of vascular plants and ground beetles (carabids) was examined in pastures of three dairy farms (575-793 m above sea level) in the Czech Republic. The pastures were grazed in rotation in 3-4 cycles from May to October. On each farm, two pasture sites were monitored. The botanical 16 m<sup>2</sup> scans were taken three times a year in two consecutive years and carabid beetles were sampled during two sampling seasons by pitfall trapping. No significant differences in the community alpha diversity (Shannon diversity index,  $H'$ ) and the evenness (Shannon equitability index,  $E$ ) were found between the farms, the sites within farms, and the years in any of the examined organismal groups (hierarchical ANOVA, site nested in farm,  $P > 0.05$ ). Pasture swards belonged to the *Lolio-Cynosuretum* association. In total, 28 to 47 species of vascular plants and 17 to 30 species of ground beetles were recorded. Carabid communities were dominated mainly by *Poecilus versicolor*.

### 3.2.13 The maturity stage of the grass affects milk fatty acids of cows grazing a mountain grassland.

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We aimed to quantify the effect of the growth stage of a mountain grassland pasture on the fatty acid (FA) composition of grass and milk. In June (growth) and October (regrowth), a mountain pasture was continuously grazed by six dairy cows in a strip grazing system. During June, the grass C18:3 $n$ -3 content decreased while C16:0,  $c$ 9-C18:1 and C18:2 $n$ -6 content increased. During October, the grass FA composition was similar to that observed in the first part of June. During June, milk saturated FA (SFA) content increased while the sum of the *trans* FA and polyunsaturated FA (PUFA) content decreased, mainly due to the decrease in C18:3 $n$ -3 and  $c$ 9 $t$ 11-CLA percentages. At the start of October, milk content of PUFA, total *trans* FA,  $t$ 11-C18:1,  $c$ 9 $t$ 11-CLA and C18:3 $n$ -3 was higher than that at the start of June when the grass was still in its vegetative stage. For these FA, the content strongly decreased between the two samplings in October. The variability observed in milk FA composition during one month was high for  $c$ 9 $t$ 11-CLA, C18:3 $n$ -3,  $t$ 11-C18:1 and C16:0.

### 3.2.14 Fatty acid composition of different grassland species

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The fatty acids composition of eight grassland species was investigated. Forage of the first growth and the third regrowth (second regrowth for one species) was harvested at three different dates. The samples were freeze-dried and the fatty acids were determined by gas chromatography. The nutrient contents were also analysed. In the grasses and the legumes the sum of the fatty acids, and also the different fatty acids, decreased with age, especially in the forage of the first growth. The highest sums of the fatty acids were detected in the legumes and the herb *Taraxacum officinale*. The  $\alpha$ -linolenic acid (C 18:3  $c$ 9 $c$ 12 $c$ 15) was the most dominant fatty acid. In young plants its proportion was over 60%. An exception was found in *T. officinale* of the first growth. Here the total fatty acids decreased from the first to the second cutting date and then increased to the third cutting date, because higher amounts of linoleic acid (C 18:2  $c$ 9 $c$ 12) were produced in the older forage.

### 3.2.15 Seasonal variation in fatty acid contents of cow milk from indoor and pasture-based feeding

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The objective of this study was to compare the fatty acid contents in two systems of milk production. One system was pasture-based (P) with the calving season between February and April and with a restricted concentrate supplementation of 290 kg cow<sup>-1</sup> y<sup>-1</sup>. The second system used indoor feeding (I) with a mixed ration of grass and maize silage as well as a supplementation of concentrates (1135 kg cow<sup>-1</sup> y<sup>-1</sup>). The calving season was mainly between June and September. In 2008 and 2009, every month tank milk samples were taken and the fatty acid composition in the milk fat was analysed. The milk production was 5800 kg cow<sup>-1</sup> y<sup>-1</sup> in system P and 8400 kg cow<sup>-1</sup> y<sup>-1</sup> in system I. The milk of system P had less saturated and more unsaturated fatty acids in comparison to I. The conjugated linoleic acid in fat increased continuously from spring to autumn to 2.5 g (100 g)<sup>-1</sup> in system P while it amounted 0.5 g (100 g)<sup>-1</sup> during the whole year in system I. Differences were also found in the omega-3 acid content. In system P the contents were always higher than in I.

### 3.2.16 PhytoMilk: Effect of silage botanical composition and harvest system on organic milk composition

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The effect of silage botanical composition and harvest system on organic milk composition was studied in a feeding trial. Twenty-four Swedish Red dairy cows in mid lactation were allocated randomly to three treatments in a 3×3 Latin square design with each period of three weeks. The treatments were birdsfoot trefoil (*Lotus corniculatus* L.)/grass silage in two-cut system (B, 16 % birdsfoot trefoil), red clover (*Trifolium pratense* L.)/grass silage in two-cut system (R2, 42 % red clover) and red clover/grass silage in three-cut system (R3, 38 % red clover). Milk samples from the last week in each period were analysed for fat and protein concentration. Milk yield (ECM) was 28.7 ±1.0, 30.3 ±3.2 and 28.6 ±1.4 kg day<sup>-1</sup> (mean and SD) for treatment B, R2 and R3 respectively. Milk fat content was 5.00 ±0.38, 4.75 ±0.01 and 4.98 ±0.25 g (100 g)<sup>-1</sup> and milk protein content was 3.62 ±0.19, 3.54 ±0.08 and 3.57 ±0.09 g (100 g)<sup>-1</sup> for B, R2 and R3 respectively. Harvest system and botanical composition of silage does not seem to affect milk yield or composition.

### 3.2.17 Variation in the profile of fatty acids in ewes' milk in relation to changes in grasslands through the pasture season in meteorologically different years

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Changes in the fatty acids (FA) composition of pasture plant species during the growing season in two meteorologically different years and their changes in ewes' milk were analysed by gas chromatography. In the drier year 2007  $\alpha$ -linolenic acid (ALA), the most abundant FA in pasture, decreased from mid-May to mid-August from 62% to 39% (g (100 g)<sup>-1</sup>) in plant fat ( $P < 0.001$ ) and in mid-September it increased to a similar value as that in May. A similar trend was also found in *cis*-9,*trans*-11 18:2 (CLA) content in milk, which decreased from 2.3% in May to 1.3% ( $P < 0.001$ ) in July and subsequently it increased to 2.3% in September (g (100 g)<sup>-1</sup>) in milk fat. In the year 2008, which was colder and rainier during the pasture season, the highest CLA contents were noted in May (2.3%) and September (2.0%); nevertheless, a minimum in milk CLA content (1.3%) was found in June linked to a higher average temperature and less rainfall compared to July 2008. However, changes in the content of ALA in pasture during the pasture season were significantly smaller than those in 2007 (average ALA content 51.2%). The September milk was similar to the May milk in FA composition of ewes' milk fat, including CLA content. As the seasonal changes in CLA content in milk are determined primarily by ALA content in pasture, oversowing with *Lolium perenne* and *Trifolium repens* was suggested. These plants were characterized by a high ALA content, quick incorporation into the pasture, high ground cover, and durability in growth.

# **Session 4**

## **Grassland ecosystem services**





## **Ecosystem services and functions of biodiversity in grasslands**

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The Millennium Ecosystem Assessment (2005) concluded that the global decline in biological diversity will compromise the delivery of important ecosystem services and thus have an effect on human well-being. Our goal is to test this statement for the biome of temperate grasslands. We seek evidence from experimental studies demonstrating a positive or negative effect of grassland biodiversity on ecosystem functions and services. We find that even though the effect of biodiversity on the four categories of ecosystem services – provisioning, regulating, supporting and cultural – are very differently reflected in scientific literature, there is a large database supporting that biodiversity, and especially functional composition, is an important driver of ecosystem functioning in temperate grassland systems.

## **Balancing trade-offs in ecosystem functions and services in grassland management**

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Managed grasslands are increasingly expected to provide ecosystem services beyond the traditional provision of forage and livestock products. Grassland systems can provide ecosystem services such as soil conservation, water quality protection, biodiversity conservation, medicinal plants, pleasing landscapes, soil carbon storage, and greenhouse gas mitigation. These benefits sometimes are accepted uncritically and the potential trade-offs among ecosystem functions or services are not recognized. For example, greenhouse gas emissions from intensive pasture-based livestock systems can be as large as or larger than losses from confinement systems because of N emissions from dung and urine of grazing animals. Some of the new ecosystem services, such as cellulosic biofuels from forages, may compete with traditional provisioning services. Thus, innovative management is critical to realizing the various ecosystem services from managed grasslands. In this context it is important that management measures are cost-effective to mitigate trade-offs between agricultural production and the provision of other ecosystem services. We illustrate this point by introducing an ecological-economic modelling procedure to design cost-effective payments for species conservation measures in grasslands.

## Session 4.1 Balancing tradeoffs between functions

### Plant functional strategies from 13 co-occurring grass species explain the productivity and abundance in productive grasslands

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How plant functional strategies are translated into species abundance in a community is a key question for the estimation of ecosystem functioning along environmental gradients. We address this question using 13 widespread grass species co-occurring in semi-natural mesic grasslands of central France. Plant functional strategies were identified using a principal component analysis (PCA) on 28 plant traits measured for this species pool. We found that the main functional strategy that explains species productivity in monoculture was linked to a plant stature PCA axis. However, applied to six-species mixtures, the plant stature axis alone did not explain species abundances in these communities. Two additional functional axes were needed, particularly for grass mixtures under strong N limitation and high cutting frequency: the first described a trade-off between the acquisition of  $\text{NO}_3^-$  and  $\text{NH}_4^+$  and the second a trade-off between nitrogen (N) acquisition and conservation strategies.

### Distinct response of two wet grassland communities to different management regimes

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Vegetation characteristics of an Arrhenatherion grassland (Experiment 1) and a Molinion grassland (Experiment 2), both located in the Ljubljana marsh of Slovenia, were evaluated 11 years after exposure to cutting and fertilizer treatments. The responses of both grasslands were compared with respect to shifts in species composition and to changes in species diversity and functional group composition. Each experiment represented a randomized split-plot design with three cutting frequencies as main plots and four fertilizer applications as sub-plots (four replicates). In total 96 vegetation relevés were made in 2009. The cutting treatments affected only plant diversity in Experiment 2 whereas each fertilizer application reduced species richness compared to the unfertilized control in both experiments. These applications also decreased the plant diversity in Experiment 1. The species composition of the Arrhenatherion grassland showed a weaker response to the treatments than that of the Molinion grassland. Shifts of vegetation composition occurred mostly due to fertilizer treatments, but the differences in species composition among PK and two NPK treatments were small. The treatment effects on the functional groups were more pronounced in the Arrhenatherion grassland where a larger increase of legumes was also observed.

## Regulation of meadow saffron (*Colchicum autumnale* L.) in extensively managed grasslands

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During the last years, the toxic grassland species *Colchicum autumnale* has reached critical population densities in extensively managed grasslands of Austria and Germany. As farmers have problems to feed or sell their hay, there is a risk of intensification or abandonment. Extensive management is essential for conserving species-rich grasslands and their ecosystem services. Our objective was to develop management strategies to regulate *C. autumnale* without affecting species richness. In 2008 we established permanent plots (1 m<sup>2</sup>) in seven Austrian and eight German *C. autumnale* populations. In each country, we conducted one of four (five) different mowing treatments per plot and recorded every individual of *C. autumnale*. For data analysis via a matrix population model, plants were categorized into five life stages. First results show that an early cut in April/May had the strongest effect on population growth rate ( $\lambda$ ). The population growth rate of the control treatment was about 1, i.e. population equilibrium, whereas the other treatments reduced  $\lambda$  significantly below 1, indicating population decline. Differences in  $\lambda$  between control and other treatments were mainly the result of growth reduction and increased regression.

## Winter resistance of pasture weeds *Rumex obtusifolius* L. and *R. crispus* L.

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*Rumex obtusifolius* L. is a problematic widespread weed species of permanent grasslands in many European countries. After severe winters, retreat of *R. obtusifolius* from infested grasslands was recorded several times by Czech farmers. The aim of this study was to investigate winter resistance of *R. obtusifolius* L. compared with *R. crispus* L. In spring 2008, a pot experiment with ten fertilizer treatments (combination of N, P and K application) was established and both *Rumex* species were seeded. The plants in pots were exposed to winter conditions without any protection. During the experiment, the lowest measured temperature -13.2 °C was recorded on 3 January 2009. Winter survival over all levels of nutrient availability was 18% and 100% for *R. obtusifolius* and *R. crispus*, respectively. No survival of *R. obtusifolius* was recorded in the K treatment and survival was higher than 30% in NP and NPK treatments. In the case of *R. crispus*, no mortality was recorded. *R. obtusifolius* flowered in all treatments during the first season, while *R. crispus* started to flower in the second season after over-wintering. Retreat of *R. obtusifolius* from infested grasslands after severe winters can be connected with low winter resistance of this species.

## **Evaluation of the agronomical and environmental relevance of the CAP measure ‘flowering grassland’**

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We aimed to evaluate an agri-environment measure called ‘flowering grassland’, devoted to biodiversity preservation in French grasslands. This measure is controlled by a short list of easily identifiable plants (indicators). Flora, agronomical and ecological value of a set of 671 grasslands of four French natural regional parks were studied. The indicators used for the control are mainly linked to the total species richness of the grasslands. Other aspects of the grassland value are less related to these indicators, including ecosystem services like preservation of patrimonial species or contribution to pollinator activity. Agronomical value of grasslands seems poorly linked to the short lists of plants. Finally, the methods used to construct plant lists were analysed. A wide range of lists was found among natural regional parks and it appears as a crucial step for the final result, the preservation of biodiversity.

### **4.1.01 Pyrrolizidine alkaloid level in *Senecio jacobaea* and *Senecio erraticus* – the effect of plant organ and forage conservation**

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Tansy Ragwort (*Senecio jacobaea*, L.) is seriously spreading in the grassland of North Rhine-Westphalia, and in some regions the occurrence of Eastern Marsh Ragwort (*Senecio erraticus*, Bert.) is also increasing. As pyrrolizidine alkaloids (PA), which are the toxic ingredients in *Senecio* species, induce liver diseases it is recommended that *Senecio* species should not be fed to livestock. Our investigations analysed the amount of different PAs in different parts of *Senecio jacobaea* and *Senecio erraticus* during maturity. Moreover, the effects of varying methods of forage conservation such as ensiling or hay production were analysed. The two *Senecio* species differed in the patterns of PA composition but showed similar amounts of overall concentrations of PAs. The PA content was especially high in the blossom. The concentration of PAs in the plants decreased during forage conservation, especially by ensiling in later stages of maturity. The results indicated an interaction between plant age, PA concentration and PA stability. It is concluded that ensiling cannot be recommended as a reliable method to eliminate the risk of intoxication by feeding silage containing Tansy Ragwort or Eastern Marsh Ragwort. Also the decline of PAs by drying for hay is insufficient to use hay from these plants as forage.

#### **4.1.02 Yield evolution from pastures on the Po Valley plain during the growing season**

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In investigation on the development of herbage yield and herbage quality during the 2006 growing season of two non-irrigated pastures on the plain of the Po Valley in NE Italy is reported. The pastures differed in sward composition: one was composed almost exclusively of grasses and the other of a balanced mixture of grasses and legumes. Both pastures gave an uninterrupted yield for approximately 200 days. The pasture with the mixture of grasses and legumes provided a higher annual DM yield (8.1 vs. 6.7 Mg ha<sup>-1</sup>), which, in addition, was more evenly distributed over the growing season and had a higher forage quality.

#### **4.1.03 Pasture characteristics on a Venetian prealps *malga* where the animals' diet is supplemented by concentrates**

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The botanical composition and soil characteristics were surveyed on *malga* pastures at the Asiago Plateau (NE Italy) where the animals' diet is supplemented by concentrates. In areas far away from the farm buildings, pastures are re-colonized by *Brachypodium rupestre* ssp. *coespitosum* and the adjacent woodland. Elsewhere the pasture has become rich in species with a high forage value, even if there are phenomena of degradation in the areas immediately surrounding the farmstead due to an excess of nitrophilous species. The content of the major soil nutrients increases progressively along a gradient from the higher elevated areas to the lower-lying areas where the cattle tend to linger.

#### **4.1.04 Speed of reduction of the specific biodiversity in abandoned meadows when they are re-colonized by woodland**

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During the three-year period 2006-2008, the botanical composition and crown area projection of the woody component were surveyed on five meadows on the southern slopes of the Treviso pre-Alps that had been abandoned for different lengths of time (3-25 years). The results demonstrated that every 10 m<sup>2</sup> increase of the trees crown area projection corresponds to a loss of 8.1 species from the plant community, and that the crown area projection increases on average by 1.18 times of its initial value over a two-year period. On the basis of these

results it has been estimated that, during the first 12 years after being abandoned, the reduction in the number of species forming the community remains limited, while it subsequently markedly increases, so that at 16 years after being abandoned the overall reduction is more than 38% of the initial value of the biodiversity of the meadow.

#### **4.1.05 Effects of the management techniques on the specific and coenotic biodiversity in three meadows of the Venetian plain (NE Italy)**

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Results are presented from a botanical survey conducted in 2007, in plot trials on three irrigated permanent meadows of the northern Veneto plain, in order to study the effect of fertilization level and mowing frequency on the plant community and specific biodiversity. Neither of the two studied variables showed any consistent effect in modifying the number of plants of the meadow sward over a period three years differentiated management. However, the increase in mowing frequency produced marked variations in plant community composition, while there was no change with fertilization level.

#### **4.1.06 Evaluation of the productivity and specific composition of the Šyša floodplain of the Lower Nemunas**

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Since 1990 in Lithuania there have been some changes observed in floodplain management (change of land ownership, production of grass forage has ceased, and a decrease in the areas of properly fertilized and grazed pastures). The changes are due to Lithuania's transition from the Soviet system to independent state status and they have led to a process of landscape renaturalization and changes in pasture productivity and species composition. Two sites differing in GWL were selected for evaluation of productivity and species composition in the Nemunas river lower floodplain, Šyša summer polder. Pasture DM yield at the Šyša-1 site with a lower GWL was similar in 1999-2002 and in 2009 (5.12 and 5.49 Mg ha<sup>-1</sup> respectively). However, DM yields at the Šyša-2 site, with a higher GWL, differed and were 7.40-7.87 Mg ha<sup>-1</sup> and 9.14 Mg ha<sup>-1</sup> respectively, in 1999-2002 and 2009. The grasses and other herbs dominated; however, changes in species composition were observed. The present situation leads to the search for new means of management (grass for horse litter, meeting bioenergy needs and agro-tourism services) of the floodplain of the Lower Nemunas.

#### **4.1.07 Construction of a simplified method based on the functional composition of the vegetation for characterizing the agricultural services provided by species-rich grasslands**

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Functional composition of species-rich grasslands, weighted leaf dry matter content-based (LDMCw), was previously successfully used for evaluating agricultural services they provided: plant productivity (P), dynamic of herbage production (T), and flexibility for management (F). However, these results were only based on measurements of plant traits for grass species because dicot species are usually numerous and tedious to recognize. Thus we wonder how to assess as simple as possible the three agricultural services, i.e. avoiding recognizing individually the dicots species, and only considering the LDMC for grass species. Based on the study of 24 grassland communities, we found that there were significant differences between the grass and dicotyledonous components co-existing within a plant community for T (earlier for dicots), but no significant effect for P. The presence of dicots species increased F. We concluded that recording the list and abundance of grass species and the abundance of dicots species as a whole allows assessing agricultural services provided by species-rich grasslands.

#### **4.1.08 Survival of *Rumex* seedlings under different management in upland grassland**

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Survival of seedlings of *Rumex obtusifolius* and *R. crispus* was studied on upland grassland in the Jizera Mts. in the north of the Czech Republic from 2008 to 2009. The following treatments were applied: intensive grazing, extensive grazing, abandonment and cutting. Pre-cultivated seedlings were implanted into the sward in a factorial design with different micro-site conditions (gap – no gap, cowpat – no cowpat) in each treatment. The following variables of *Rumex* plants were measured: number of surviving plants, height of plants, number of leaves and size of plant base. Measurements were made three times per year (spring, summer and autumn). Due to the trampling effect the seedlings were more damaged on the intensively grazed plots than on extensively grazed ones. Seedlings of *R. crispus* were more susceptible to applied management than were *Rumex* seedlings. For the success of *Rumex* seedlings soil disturbance and nutrient availability but also grassland management are important.



#### **4.1.09 Increasing the milk quality with grazing feeding in humid Spain grassland**

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The aim was to study the effect on milk fatty acids (FA) composition of three groups of cows with different proportion of grazing (zero, 12 hr and 24 hr) having silage and concentrate (6.5 kg cow<sup>-1</sup>) on the ration during the grazing season of sixty-one autumn-calving Holstein-Friesian dairy cows. Milk yield and quality, including the FA profile, were determined. Grazing 24-hr caused a significant decrease ( $P < 0.05$ ) in the saturated (SFA) and a significant increase in the unsaturated (UFA) fatty acids. The conjugated linoleic acid (CLA) showed a significantly increase ( $P < 0.05$ ) with grazing time, from 4.8, 8.4 and 11.7 g kg<sup>-1</sup> of FA in milk fat for the silage feeding, 12-hr or 24-hr grazing, respectively during the spring. Farmers from the humid part of Spain, producing milk from grazed grass, might get a benefit in milk price if FA composition of milk is taken into account in the dairy industry. We found that milk from grazing dairy cows had a higher proportion of unsaturated FA, and more polyunsaturated FA and CLA than milk from silage-fed cows, in the sustainable dairy systems proposed to reduce the intensiveness of milk production.

#### **4.1.10 Grassland in Pays de Caux (France): balancing trade-off between livestock feeding and decreasing runoff**

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In mixed cropping-livestock farms, grassland fits both productive and environmental functions. Thus, in the Pays de Caux (Haute-Normandie, France), runoff might be mitigated by the presence of permanent or rotational grassland. The aim of our study was to assess how mixed crop-livestock farms, specifically breeding dairy or suckler cows, integrate grassland into their global functioning and to know the farmers' position about grass management. Livestock farms were surveyed and the collected data were analysed by multidimensional statistical analysis. Even though maize silage is the main fodder resource in this region now, we observed a large diversity of types in the more or less intensive uses of grassland. We identified two main strategies of grassland management. In the first type, farms combine grazed grassland and maize silage considered as forage security. In the second type, the farmers' choice of including cultivated grassland in crop rotations has both advantageous objectives: improving forage self-sufficiency (intensive use of grass for grazing or hay making) and decreasing the risk of runoff. Considering trade-offs between farm production and environmental benefit, the possibility to develop these sown pastures was assessed with quantitative indicators showing their impact on runoff level and providing economic results at farm scale.

#### **4.1.11 Secondary dry grassland management by frequent mowing in the Western-Cserhát, Hungary**

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The effect of long-term mowing on the composition of secondary dry grasslands was studied in the Western Cserhát hills in Hungary. Our main aim was to develop an effective method which can facilitate the regeneration of grasslands. Here we report the results of a long-term mowing experiment designed to suppress the spread of *Calamagrostis epigeios*. In May 2001 we established permanent plots in the study area to understand if the dominant grass species of abandoned grassland fields can be suppressed by mowing. It was found that mowing was a useful management technique for modifying the botanical composition of the grassland to a composition that was better suited for agricultural use, in particular for grazing which could replace the costly and time-consuming hand-cutting. Mowing twice a year significantly affected the palatability of the herbage. Plant species richness and diversity increased continuously during the eight-year-long study.

#### **4.1.12 Agronomic characteristics of a lowland and a mountain hay meadow under different cutting regimes**

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In this study, typical lowland hay meadows and mountain meadows are managed under agri-environmental scheme agreements according the time of the first cut and the cutting frequency as well as the nutrient management. Yield and forage quality under different agri-environmental schemes are compared to agronomic potential without management restrictions in these species-rich grasslands. Annual yields of dry matter obtained from species-rich grasslands managed under the restrictions to agri-environment schemes ranged from 51% to about 94% of the production that can be achieved under conventional management of these grasslands. Annual net energy lactation yields were 10-55% below those under conventional management for these grasslands, particularly in the very late first-cut treatment. These semi-natural grasslands, with low net energy content of the late-cut forage, will be difficult to integrate into livestock feeding systems.

#### **4.1.13 The effect of different grazing systems on botanical composition, diversity and productivity of permanent pasture**

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Two types of grazing systems are common in the Czech Republic: continuous grazing and rotational grazing with 2 – 4 grazing cycles from May to October. The effect of the two grazing systems on botanical composition, sward type, plant species diversity and production of a *Festuceto-Trisetetum* (*Cynosurion* alliance) pasture sward was examined at an altitude of 650 m a.s.l. from 2000 – 2008 in South Bohemia. A differentiation of *Festuceto-Trisetetum* to *Festuceto-Dactylidetum*, *Dactylideto-Agrostidetum* and *Poaetum* swards was observed for rotational and continuous grazing. Rotational grazing with a lower frequency (2 grazing cycles) increased the dominance of grasses, while the higher grazing frequency (4 grazing cycles) as well as continuous grazing increased the dominance of herbs. The highest species diversity (Simpson's index – D) was observed under rotational grazing with three grazing cycles ( $D > 12.80$ ). Higher biomass production ( $P < 0.01$ ) was recorded for rotational than for continuous grazing.

#### **4.1.14 The impact of *Deschampsia caespitosa* (L.) P. Beauv (tufted hairgrass) on the floristic composition of meadow communities**

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The impact of *Deschampsia caespitosa* (tufted hairgrass) on the floristic composition of meadow communities was investigated. Based on a phytosociological survey with some 2500 samples the relationship of the occurrence of tufted hairgrass with (1) the proportion of synanthropic species, including annuals (therophytes), (2) the number of plant species, and (3) the floristic diversity was analysed. Increased proportions of tufted hairgrass in meadow swards were negatively related to the nature value (sward botanical composition, diversity) of the plant communities of the *Phragmitetea* class and *Molinietalia* order.

#### **4.1.15 Effect of cutting frequency of a meadow sward on the bulk density of a peat-muck soil**

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In recent years, grassland in Poland has been increasingly abandoned from agricultural use. This has been connected with a decrease in Poland's livestock density which, in consequence,

has decreased the demand for forage from grasslands. Abandonment of meadows, in post-boggy habitats in particular, results in changes of plant species composition and in the physicochemical characteristics of the soil. Studies were carried out in 2006-2009 in a peatland complex in Sosnowica (the Wieprz-Krzna Canal area in eastern Poland). In 1964-1966, the fen had been drained and the reclaimed land was put to agricultural use. At present, the soils of this grassland complex belong to the muck soil type and peat-muck soil subtype (Mt II). The soil of utilized meadows was characterized by a lower bulk density in comparison with abandoned ones. The largest changes in the bulk density of soil were observed on abandoned grassland. Maintaining the utilization of meadows is an appropriate method of preventing the degradation of this ecosystem.

#### **4.1.16 Protecting Aquatic Warblers (*Acrocephalus paludicola*) through a landscape-scale solution for the management of fen peat meadows in Poland**

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The fen peatlands of the Biebrza Valley in Northeast-Poland hold 2500 singing males of Aquatic Warblers (*Acrocephalus paludicola*), equalling almost 20% of the world population of this globally threatened bird species. After traditional land use by hand-scything for hay ceased around 1970, successional overgrowth has become the main threat to this habitat, with over 15000 ha affected by 1999. A project funded by the EU LIFE Programme has now catalysed the implementation of a landscape-scale solution for the restoration and sustainable management of these fen peatlands, with almost 2300 ha under regular management by spring 2010. Purpose-built prototype mowing machinery with very low ground pressure and fast working speed is now used across the site. The national park has made 12500 ha of public land available for management under lease agreements that guarantee the benefit for biodiversity. A targeted Aquatic Warbler agri-environment package provides a financial incentive for local farmers and enterprises to take up the lease and implement the management measures. It is expected and there are clear indications that this management approach is benefiting the Aquatic Warbler population, but any final conclusions require additional years of monitoring and further analysis of existing data.

#### **4.1.17 Practices and motivations of farmers who sign contracts to preserve grassland biodiversity**

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The agri-environment measure 'Flowering meadows' aims to preserve the biodiversity of permanent grasslands. The measure is based on a list of specific plants that have to be maintained. It is an innovative measure as it is performance-indexed to ecological results,

while farmers are left free to decide how to implement the measure. We aimed to identify and understand farmers' practices on contract-scheme grasslands, the roles these grasslands play in the forage system, and the reasons that prompted the farmers to sign the contract. We surveyed 21 farmers in two Regional Natural Parks in French mountain areas. Farmers establish a relationship between on-grassland biodiversity and organic manure management. The role of contract-scheme grasslands in the forage system varies greatly due to different farmers' strategies. Subsidies were a motivation, but the main driver is that farmers see the contract as a social recognition of their practices and skills.

#### **4.1.18 Phenolic compounds in sustainable grassland production: availability of nitrogen to plants**

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The establishment of productive pastures with a low input of nitrogen fertilization is a primary focus in sustainable grassland production. *Lolium* spp. encompasses a genus of valuable forage grasses. Several species of *Lolium* contain phenolic compounds, which may have a role on the allelopathic potential of the species. We undertook a field trial to ascertain 1) whether phenols present in *Lolium* were able to depress the activity of soil nitrifying populations, thus decreasing the availability of nitrate to plants, and 2) whether the addition of other easily usable sugar was able to modulate this effect. Twenty-four hours after substrate additions (phenols and/or glucose at different concentrations) N microbial biomass remained constant, whereas nitrifying activity decreased significantly with high glucose addition, suggesting ammonium starvation, and eclipsing the tendency of phenols to restrain populations of nitrifiers.

#### **4.1.19 Could the grassland production costs be an argument for biodiversity?**

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In order to find economic arguments in favour of maintaining species-rich grasslands a study was carried out on grassland production costs. The aim was to test whether these costs were decreasing with higher biodiversity, as agricultural practices were supposed to be more extensive. A set of 29 permanent grasslands (14 mown, 15 grazed only) located in Auvergne (central France) were analysed using information on grassland management, yield and floristic diversity. The production costs were estimated through agricultural practices and divided into mechanisation and input costs. Results showed globally no obvious link between production costs per hectare and biodiversity level for grazed or mown grasslands. However, when considering the intensification degree of the practices, we noticed that the most extensive grazed pastures had a higher biodiversity level than the intensive one and the lowest cost per hectare and per tonne of dry matter.

#### **4.1.20 Multidimensional scaling for describing the risks for grasslands ecosystems located in the Polish Landscape Parks**

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The identification of factors that might be harmful for grasslands is important concerning the protection of their nature values. Based on questionnaires that were sent to all landscape parks in Poland, the most dangerous factors for grasslands were listed. Some of the threats occurred together. Multidimensional scaling was used to describe similarities among landscape parks in terms of the perceived threats. Parks located close to each other on the multidimensional scaling graph were grouped into five blocks. Based on this chart, we have found a few distinctive threats to the groups of parks: cessation of grassland management, secondary succession, problems with the enforcement of regulations and development of infrastructure.

#### **4.1.21 Changes in plant C-S-R strategy after 10 years of different management of a mountain hay meadow**

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The aim of this study was to identify changes in plant C-S-R strategy in a mountain hay meadow (*Polygono-Trisetion*) when management ceases. Five permanent paired plots in a once-yearly mown (M) and an abandoned (U) meadow were established in 1999. The changes in C-S-R strategy were calculated by means of C, S, R values (ranged from 0 to 1) weighted with cover of each species and the sum of calculated C-S-R strategies was 1 for each plot. C strategy was the most successful strategy with means of 0.64 and 0.67 for M and U treatment respectively. In contrast, R strategists had the lowest values with means of 0.14 and 0.11 for M and U treatment respectively. S strategy was indifferent to management with a value of 0.22. The proportion of herbs with C and S strategy was significantly higher on U than on M treatment, whereas the proportion of graminoids with C-S-R strategy was higher in M treatment than in U. Detailed evaluation of plant C-S-R strategy according to the main botanical groups can give different results when all plants are analysed together. No matter how infertile, mountain hay meadows are fairly stable systems and despite long term different management the changes of botanical composition and C-S-R were slight and they are still in process.

#### **4.1.22 Incidence of *Epichloë festucae* in *Festuca rubra* plants of natural grasslands and presence of double-stranded RNA fungal viruses**

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In natural grasslands of western Spain, *Festuca rubra* is frequently infected by *Epichloë festucae* and this association is considered as a mutualistic symbiosis. Viruses appear to be common in fungi and are often associated with symptomless infections. This study focused on three objectives: i) to examine the infection frequency of *E. festucae* in populations of *F. rubra*, ii) to identify the presence of two known viruses, EfV1 and EfV2, in *E. festucae* strains, and iii) to determine if there are differences in the chemical composition of *E. festucae* strains infected and non infected by viruses. A total of 161 plants of *F. rubra* were collected in natural grasslands at six locations. The infection frequency by *E. festucae* in these populations of *F. rubra* ranged from 24% to 87% (average 59%); 57% of the endophytic isolates were infected by viruses. EfV2 infections and coinfections by EfV1 and EfV2 were common in isolates from the different locations and only one isolate of the 93 analysed was infected only by EfV1. No significant differences were found among virus-infected and virus-free *E. festucae* isolates with respect to their chemical composition.

#### **4.1.23 e-FLORA-sys, a website tool to evaluate the agronomical and environmental value of grasslands**

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e-FLORA-sys is a free website tool (<http://eflorasys.inpl-nancy.fr/>), designed by Nancy University and INRA, in order to provide a research and decision-making tool. The system is based on databases describing features of most European grassland species (ecological indices, plant traits, productivity, and forage quality), floristic composition, agricultural practices, soil and climate characteristics, and vegetation associations. From this information, the system calculates numerous indices to evaluate the agronomical and ecological value and management of grasslands. For instance, indices of forage productivity or grassland value for pollinator insects are provided by e-Floras-sys. Users can freely record their own observations (botanical relevés, agricultural practices, etc.), which are protected by a login device. One of the key goals of e-FLORA-sys is to produce real time and useful information to decision makers and scientists concerned with the management or the understanding of grasslands.

#### 4.1.24 Effects of extensive year-round grazing on breeding bird communities in Northern Germany

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The effects of extensive year-round grazing on breeding bird communities have rarely been investigated so far. For this purpose, territory mapping of birds was carried out on ten sites in the federal state of Schleswig-Holstein in Northern Germany in 2009. Grazing areas were characterised by low stocking rates (0.3 to 0.6 livestock units per hectare) as well as by abandonment of fertilisation, herbicides and tillage operations. For every grazing area, a similar conventionally used agricultural site was selected as reference (paired sampling design: resemblance to area size, landscape structure and former agricultural management of the grazing sites). 43 breeding bird species were registered, 38 of them on the grazing areas and 23 on the reference sites. Total abundance of breeding pairs and diversity (species density, Shannon index) were significantly higher on the grazing sites compared to the reference areas. Species density and total abundance of threatened bird species also achieved higher values in the year-round grazing sites. Both, species and breeding bird density of ground nesting species, were significantly higher in the grazing areas. Significant effects on the abundance of single species could be detected for Tree Pipit (*Anthus trivialis*) and Skylark (*Alauda arvensis*), which both reached higher abundances in the grazing sites. Results indicate that establishment of extensive year-round grazing systems can contribute to the protection of (threatened) bird species.

#### 4.1.25 Multiple uses of rangelands in Alborz mountain (Iran)

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The most precious ecological functions of rangelands are the conservation of soil and water as well as supplying forage for domestic and wild animals. However, rangelands have been subject to disorders for a variety of reasons for many years. Floods, hungry animals and desertification are the consequences of such disorders. Therefore, rangeland managers have suggested the multiple usages of rangelands based on their existing resources and efficiency, which is called “rangeland suitability”. In this research, based on biodiversity potentials of the region, the recognition and functions of plants of the Alborz mountain rangelands have been considered as rangeland management tools. The sampling was carried out in work units (combination of traditional systems in plant types) randomly-systematically by setting ten 50 m transects and putting down a metal bar. In this way the relative frequency of medicinal and nectarous rangeland plants in work units has been evaluated. Planning for multiple use of rangelands was performed based on two criteria of suitability of medicinal and nectarous plants, 1991 FAO method, and using a Geographical Information Systems at the scale of



1:50000. The best-growing habitat of the plants was selected based on the modeling. By proving the existence of environmental gradient, one can recommend the above methods to study the environmental factors as complementary to incarnation models theories.

#### **4.1.26 Assessing the influence of *Amorpha fruticosa* L. invasive shrub species on grassland vegetation types in western Romania**

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Indigo bush (*Amorpha fruticosa* L.) is an invasive shrub native to North America and having great ecologic plasticity, being found in different ecological conditions. This species is very aggressive and is fast replacing the native vegetation. It occurs in western Romania, being spread along all the waterways (Mureș River, Danube River, Crișul Alb, Crișul Negru, Timiș, Bega, Bârzava) and their tributaries, and along the transport routes, but it has started to be found in grasslands also. The data analysed in this work were recorded during the 2005-2009 period from four grazed grasslands from Timis County (Voiteg, Moravița, Albina and Sacoșu Turcesc). The purpose of the research is to assess the influence of indigo bush on grasslands and its invasive potential on grassland vegetation in western Romania. The evolution of the index of coverage and the dynamics of biodiversity were determined. The results obtained show that indigo bush has increased its invasive potential in grasslands, with negative effects on the native vegetation.

#### **4.1.27 Plant communities and plant species of the permanent grasslands in 'The Bug Ravine Landscape Park' and the methods of their protection**

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We can still find a vast number of environmentally invaluable phytocenoses in Poland. Based on the phytosociological studies carried out in 2004-2006 in the area of 'The Bug Ravine Landscape Park' it was possible to describe 40 plant communities connected with the permanent meadows and pastures. Five of developed phytocenoses are considered as rare and should be protected in the Nature 2000 Network. The plant communities described consisted of 340 vascular plant and lichen species from 60 botanical families. There were 72 rare species among them. Moreover, it was precise in what kinds of grassland protection are used in the borders of 'The Bug Ravine Landscape Park'.

#### 4.1.28 Mechanical weeding of *Rumex obtusifolius* in grasslands

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In Europe, *Rumex obtusifolius* L. is a serious grassland weed, especially under the conditions of organic agriculture. The aims of this study were (1) to test the effectiveness of repeated mechanical weeding of *R. obtusifolius* plants from a permanent sward in the Czech Republic, where the plants were cut twice per year and dug out from 5 cm below the ground, and (2) to test the effect of nutrient availability on the effectiveness of mechanical weeding. In 2007, the manipulative experiment was established on permanent grassland infested by *R. obtusifolius* with the following fertiliser treatments: control, P, N, NP and NPK. Plants of *R. obtusifolius* were removed eight times during three vegetation seasons. No significant decrease in plant density of *R. obtusifolius* was recorded after the three vegetation seasons and the density was not significantly affected by fertiliser treatment. Mechanical weeding – digging the plants out from 5 cm below the ground – was not a sufficient method for the control of *R. obtusifolius* in infested fertilised grasslands, even when applied eight times during three vegetation seasons.

#### 4.1.29 Effect of different management on the yields, forage quality and botanical composition of permanent grassland

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We investigated the effects of cutting frequency and fertilisation on the dry matter (DM) yield, forage quality and plant species composition of permanent grassland. A plot trial was set up in 2003 at Rapotín. Four levels of cutting frequency (4 cuts per year; 3 cuts per year; 2 cuts per year; 1 or 2 cuts per year) and four levels of fertilisation (no fertilisation, P<sub>30</sub>K<sub>60</sub>, N<sub>90</sub>P<sub>30</sub>K<sub>60</sub>, N<sub>180</sub>P<sub>30</sub>K<sub>60</sub>; pure nutrients) were applied from 2003-2008. The results showed that DM yield was significantly influenced by fertilisation and by intensity of use; the lowest DM yield was found with the 4-cut regime (6.10 t ha<sup>-1</sup>). Decreasing the cutting frequency reduced the energy value (NEL) to 4.64 MJ kg<sup>-1</sup> DM. The redundancy analyses showed that species composition was significantly influenced by intensity of use (9.5%) and time (8.5%).

#### **4.1.30 Effects of mowing and grazing with Hungarian grey cattle on species composition of Pannon grasslands**

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Phytosociological samples were collected from grassland stands with low intensity grazing (under-grazed pasture), overgrazed pastures, hayfield meadows and from stands where animals drink. The areas were suitable for follow-up recording of changes of vegetation and production in every grazing season of a year. Five areas of 2×2 m phytosociological samples were examined on each sample area in April, May, June, August and September 2008.

In the case of undergrazed pastures a low number of species was detected in the control area. The overgrazed pasture carries grass of low forage value and contains a high number of weed species, despite the spectacularly high total number of plant species; consequently, grazing pressure has to be decreased. Although the number of species is lower in the hayfields, species composition and ability of the sward to supply forage was better.

#### **4.1.31 Fertilization as a factor of plant community change, higher productivity and water percolation on a mountain meadow**

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Mountain grasslands serve multiple functions. They are not only the main source of forage in mountainous areas but also play an important environmental role. This study aimed at analysing the effects of fertilization on floristic changes, utilization value and rainwater retention in a mountain meadow. An experiment was performed from 2005-2007 comprising three fertilizer treatments (farmyard manure, mineral fertilizers, or combination of both) and a control treatment. On each plot lysimeters were dug into the soil. Mineral fertilization showed considerable effects on the floristic composition of the sward. It reduced the number of species in comparison to the control treatment, but provided the highest dry matter production. However, manure and combined fertilization reduced the amount of percolating water due to increased water consumption and higher density of the sward.

#### **4.1.32 Minimum management intensity for maintaining and improving biodiversity of a mesotrophic semi-natural grassland**

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Species-rich semi-natural grasslands traditionally used as hay meadows are threatened by both intensification and abandonment in many European regions. A minimum management is necessary to maintain or restore the biodiversity of grasslands that are no longer part of agricultural production systems. For economic reasons, it might be interesting to substitute cutting by mulching, and to reduce cutting or mulching frequency from two or three operations to just one operation per year. This may, however, have negative effects on plant biodiversity. An experiment was set up on a mesotrophic grassland in 1999 comparing cutting and mulching regimes at three management frequencies (one to three operations per year). Highest species numbers, and lowest dominance of most abundant species, were achieved by a management regime with two or three cuts, or by three mulching operations. The treatment with just one mulching operation in the middle of July yielded the least favourable results in these terms. The negative effects on vegetation appear to be related to a more intense covering with mulched biomass material. It therefore seems possible to maintain mesotrophic grassland sites by mulching, provided that more than just one operation per year takes place.

#### **4.1.33 Sward composition of natural grasslands in relation to the different grade of pig slurry pollution on Hungarian arid solonetz steppe**

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Results of pig slurry pollution on the sward composition and biodiversity in Puszta Hortobágy grassland areas are presented. Slightly polluted grassland had remarkably higher diversity (26-28 species) compared with strongly polluted areas (1-7 species) in the spring. In the strongly polluted areas some open spaces in the sward were found, while on the slightly polluted areas completely closed swards were observed. Representation of herbs was greater in every sample area than that of grasses. In the early autumn sward-composition survey, an intensive transformation of vegetation-structure can be found in the strongly polluted sample areas with better hydrological conditions. The total ground cover of strongly polluted areas was increased from 2 and 65% to 30 and 85%. The number of species also increased there from 2-7 to 12-14 species. The species that appeared are disturbance tolerating, nitrophyta, high seed-producing weed species. This can be explained by the excess of nutrients (e.g. ammonium and nitrate) in the soil and groundwater environment.

#### **4.1.34 Concepts for nutrient management in nature conservation areas on organic soils**

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Concepts of nutrient management that rely on actual nutrient fluxes are rarely available for the practice of nature conservation management. Especially protected grassland sites on low peat soils show different trophic levels depending on soil status and management, which in turn has an effect not only on botanical composition and feed quality, but also on the abundance of soil fauna as a feed source for meadow birds. Although nitrogen is not a limiting factor on low moor soils, levels of available potassium can decrease drastically within a short period of time under a cutting regime. Based on these considerations and experimental data, we propose a concept for nutrient management that takes into account nutrient offtake rather than soil nutrient status alone. This would imply that controlled nutrient input should be allowed if required, and, generally, that concepts should be allowed to take precedence over inflexible restrictions.

#### **4.1.35 Do management strategies of dairy farming clash with floristic diversity of dairy production?**

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Owing to economic constraints, organic dairy production has been intensified resulting in a loss of floristic diversity of permanent grassland. In order to increase milk yield, different feeding strategies are discussed: (1) maximizing milk yield per cow based on a high input of concentrates and other farm resources, and (2) maximizing the roughage performance with lower resource requirements and making intensive use of grazing on permanent pastures. We hypothesize that such contrasting strategies differ in their impact not only on productivity but also on grassland botanical diversity at the farm scale and we investigated feeding management, roughage production, and animal husbandry of 100 organic dairy farms in Germany. Data on milk and forage quality were collected. Botanical relevés were obtained on 850 permanent pastures and meadows, and the corresponding herbage mass was estimated by the method of Klapp and Stählin (1936). We differentiated encountered strategies of organic dairy farming using a cluster analysis and PCA. The impact of these management strategies on floristic diversity will be presented and discussed.

#### 4.1.36 Relationship between a soil reaction and floristic diversity of grass communities from the *Molinio-Arrhenatheretea* class

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The studies were conducted on the grasslands of the Nadwieprzański Landscape Park (Poland) in the years 2005-2007. The aim was to determine the relationship between the species richness of grass communities from *Molinio-Arrhenatheretea* class and soil reaction. The floristic composition of grassland in the middle course of the Wieprz River was assessed according to Braun-Blanquet. Soil sampling was carried out to measure soil reaction at each phytosociological releve site. Floristic diversity of the plant associations was evaluated using Shannon-Wiener diversity index ( $H'$ ). The highest diversity occurred in the associations from the order of *Molinietalia* ( $H' = 2.6-3.4$ ) and *Arrhenatheretalia* ( $H' = 2.7-3.3$ ), and the lowest in the associations from the *Plantaginietalia majoris* order ( $H' = 1.5-2.4$ ). Species diversity was influenced by the impact of both, habitat conditions and anthropogenic factor. The number of species in the sward correlated significantly ( $R^2 = 0.5681$ ) with soil reaction. Communities occurring in light acidic habitats had substantially higher diversity than communities in habitats with a soil reaction approaching neutral.

## Session 4.2 Functions of biodiversity

### Paths of nitrogen transfer from *Trifolium repens* to non-legume plants in unfertilised pastures

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Biological N fixation (BNF) is the main N input in unfertilised pastures and can provide transfer N to non-legume plants. This transfer can be coupled spatially or temporally to different degrees. In principle, three mechanisms are conceivable: (i) a direct transfer between living plants, (ii) a local but delayed transfer when non-legumes colonise a patch with decaying legume biomass, and (iii) a spatially diffuse transfer via the excreta of grazing animals. We analysed these mechanisms on 10 pastures grazed by suckler cows and offspring where BNF input was quantified over nine years. Modelled annual BNF yield varied between 1 and 225 kg ha<sup>-1</sup> yr<sup>-1</sup> (mean 30) between paddocks and years. Comparison of <sup>15</sup>N in non-legume plants growing in the immediate vicinity of white clover (*Trifolium repens*) and at large distance indicated negligible direct BNF-N transfer. <sup>15</sup>N analyses of non-legumes growing on legume patches of the previous year also indicated no significant delayed local transfer. Conversely, the <sup>15</sup>N of cattle correlated closely with the BNF input of the previous year. We conclude that BNF-N transfer occurred mainly via the excreta and was independent of the spatial distribution of legumes on the paddock.

## **Effect of mono- and mixed grazing of cattle and sheep on grassland diversity patterns**

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Plant diversity is linked to a multitude of important ecosystem functions such as productivity. Intensive agricultural management results in a decrease of grassland diversity. In this study, the effect of different grazer species on the vegetation composition and diversity patterns of an extensively managed semi-natural grassland sward was investigated. The hypothesis was that grazing cattle and sheep affect vegetation composition and diversity patterns in different ways because of differences in forage selectivity. Mixed grazing should, therefore, lead to a greater evenness of the vegetation, which might be beneficial for the maintenance and enhancement of diverse grassland. The experimental site is a moderately species-rich *Lolio-Cynosuretum* in the Solling Uplands, Germany. The initial diversity of the grass sward was manipulated by the use of a herbicide, resulting in a low diversity sward compared to the untreated sward (control). Both diversity treatments were either grazed by sheep, by cattle or by both. The six combinations of plant diversity and grazing treatment were replicated three times in blocks that were grazed rotationally. Data on plant species diversity and botanical composition of three years were analysed. Grazing with cattle led to a significantly different vegetation composition than mono-grazing by sheep, which seemed to be related to differences in forage selectivity.

## **Anecic earthworms and associated ecosystem services under pressure in a ley-arable crop rotation**

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Earthworms in general, and anecic earthworms in particular, play a key role in the ecosystem service of water regulation. Earthworms were sampled over three years in a 36-year-old experiment. Permanent arable land was compared with permanent grassland and with a ley-arable crop rotation. In the first year of arable cropping in the rotation, the number of earthworms was already low and not different from continuous cropping. In the three-year grass ley, the abundance of earthworms returned to the level of permanent grassland in the second year. The restoration of earthworm biomass took a minimum of three years. However, the anecic species did not recover in the three-years of grass ley to the dominance they had in permanent grassland. The number of earthworm burrows was related to earthworm biomass and was highest in permanent grassland. Our data suggest that anecic earthworms are under pressure in a ley-arable crop rotation, which may have a negative impact on the ecosystem service of water regulation.

## **Agronomically improved grass-legume mixtures: higher dry matter yields and more persistent legume proportions**

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Since 1955, ‘Swiss Standard Mixtures’ (SSMIX) of grasses and legumes have been continuously improved, based on extensive experimentation in small plots and under practical conditions. These mixtures are labelled with a quality label of the Swiss Grassland Society (AGFF) and are highly accepted by Swiss seed companies and farmers. A multi-site grassland experiment across 33 European sites (COST852) with two grass and two legume species (one variety of each species) demonstrated strong yield benefits of four-species mixtures containing 30-70% legumes. The proportion of legumes in these mixtures, however, strongly decreased below the optimal range in the third year of the experiment. In a three-year field experiment, we compared the yield and the persistence of legume proportions in four different SSMIX with those of COST852 mixtures. The SSMIX surpassed the COST852 mixtures in yield and in persistence of legume proportion. We suggest that the higher number of species and/or varieties (2 legume species with 2 varieties of white clover and 4 to 5 grass species), as well as the partially different species and cultivars may be the main reasons for the observed differences. The long-term experience and knowledge gained from decades of mixture development have yielded an effective product.

## **Grass root turn-over for improved soil hydrology to combat flooding**

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A *Lolium perenne* x *Festuca pratensis* cultivar demonstrates rapid and extensive root growth, in excess of either its parent species. Root turn-over at depth in the soil has a major effect on soil structure and porosity and thereby aids water retention and flood control improving water quality by mitigating against run-off of diffuse sediment and nutrients. Improved soil water retention together with increased root development at depth also improves access to scarce water resources and reduces impacts from drought stress when the water supply may be limited. We demonstrate heterosis between *Lolium* and *Festuca* gene sequences capable of providing grasslands with new multifunctional capabilities providing safeguards against flooding and improved food security with increased crop resilience to climate change. We identify QTL in *Festulolium* relevant to root growth and turn-over.



#### **4.2.01 Habitat improvements with agronomic treatments for ungulates in an area of central Italy**

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Research was conducted to evaluate the effectiveness of different environmental improvements in order to recover areas encroached by *Pteridium aquilinum* for wildlife in Tuscany. The habitat improvements were represented by a simple cutting and a harrowing, followed by the sowing of a mixture of forage species. The two agronomical interventions were also compared with the surrounding natural areas that received no treatments. The results show a greater presence of forage species in the areas restored with agronomic managements, compared to the natural surfaces. Improved areas also presented a marked improvement in floristic richness and in biodiversity, as testified by the Shannon index.

#### **4.2.02 Plant communities and soil groups in mountain pastures of the Central Pyrenees**

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The type of ecosystem ‘mountain pastures’ in the Central Pyrenees is located at an altitude between 1400 and 2400 m a.s.l., and characterised by a distinct physiognomy, phytosociology and use as extensive pastures during summer time. To establish a sustainable use of these pasture areas, it is necessary to obtain a profound knowledge of these phytocoenoses and of the biotic and abiotic factors that govern them. The aim of this project was to determine the relationship between the vegetation units and the soils. The investigation was carried out in the Benasque Valley (Spanish Central Pyrenees). Five toposequences representing different lithological substrates and geomorphological characteristics of the area were selected. A total of 60 soil profiles was studied. Inventories of vegetation were done in the corresponding pastures and the vegetation units were established. The results indicate a great variability of plant communities (14 alliances, 24 associations) related to 12 soil groups. The abundance of well-developed soils (mostly eutric and dystic Cambisols) with high vegetation cover suggests that the use of these pastures has not led to significant ecosystem degradation.

### 4.2.03 Quality of food products from species-rich alpine pastures

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Alpine pastures have been created by extensive and long term farming practices, and their maintenance and biodiversity is dependent on livestock grazing. In an interdisciplinary project in the Norwegian mountains, we focus on local food production and 'added values' such as beautiful landscapes, biodiversity, special food quality and flavour. Possible connections between species-rich alpine pastures and food quality are documented by several methods, including product analysis, fodder analysis and by recording landscape patterns and vegetation types. Three local products (sour cream, brown whey goat's cheese and lamb chops) were analysed for fatty acids and antioxidants. Industrially produced milk products and meat from animals fed on different types of pastures, mostly less species-rich, or silage and supplementary concentrates were used as references. The results show that local products based on species-rich alpine pastures contain more  $\alpha$ -linolenic acid, conjugated linolenic acid (CLA), carotenoids and polyphenols than the reference products. Milk products and lamb produced on species-rich alpine pastures are in other words of special quality. Maintenance of beautiful landscapes and biodiversity by grazing as well as special food quality and flavour may be defined as 'added values' to local food production.

### 4.2.04 Halting the loss of biodiversity: Endemic vascular plants in grasslands of Europe

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About 6200 vascular plant taxa are confined to Europe. As underlined in the Convention on Biological Diversity or in subsequent regional strategies, Europe has a particular responsibility to protect those species that are restricted to its boundaries. However, little is known about the distribution patterns of European endemics. Which habitats are rich in endemics and should therefore be given conservation priority? And are there endemic plants associated with European grassland ecosystems?

We evaluated European floras to obtain data on ecological affinities and habitat preferences. We assigned endemic taxa to one or more of eight predefined habitat categories, e.g. habitats of rocks and screes, forest ecosystems, grasslands, and others. At least 1320 endemic plants inhabit grasslands. Of these, 352 taxa are restricted entirely to natural or semi-natural grasslands. Although grassland covers only a small portion of Europe, this habitat type contains the second largest number of endemics and exceeds e.g. woodland ecosystems by far. Our analysis confirms the particular importance of grassland in species conservation but, nevertheless, this habitat type is strongly endangered by a creeping loss of quantity and quality. Therefore, it is imperative that action be taken in the area of grassland management and conservation.

#### 4.2.05 Diversity of weed spectrum in grasses grown for seed in the Czech Republic

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Growing grasses for seed has almost a 100-year tradition in the Czech Republic and the area, an integral part of grasslands, now occupies 18 000 ha. In the years 1999-2008, the occurrence of weeds was monitored for 19 different grass species during the growing season on an area of 2000 – 4500 ha at several locations in the country. The continuously occurring weed species can be divided into three groups: (1) species whose occurrence was recorded in 15-70% of the areas under study (*Elytrigia repens*, undesirable cultivated grasses, *Rumex* spp., *Matricaria* spp., *Tripleurospermum* spp., *Cirsium arvense*, *Apera spica venti*, wild *Poa* species); (2) species occurring in 5-15% of areas (*Viola tricolor*, *Avena fatua*, *Myosotis arvensis*, *Chenopodium* spp., *Echinochloa crus-galli*); and (3) species occurring in less than 5% of the localities under study (*Galeopsis* spp., *Capsella bursa-pastoris*, *Lamium* spp. etc.). A stable trend in occurrence was evident in *Elytrigia repens*, whereas a downward trend was recorded in *Matricaria* spp. and *Tripleurospermum* spp. A further increasing tendency in occurrence is expected in *Echinochloa crus-galli* and *Viola tricolor*.

#### 4.2.06 Multi-species mixtures - new perspectives on models and mechanisms

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The delivery of essential ecosystem functions (primary productivity, maintenance of soil fertility, resistance to weed invasion etc.) may be compromised by global declines in biodiversity. There is still controversy about the description of, and mechanisms behind, Biodiversity-Ecosystem Function (BEF) relationships. The Diversity-Interactions model quantified BEF relationships in terms of all the pairwise interactions between the species in a community. The model gives the contribution of two species (*i* and *j*) to the functional response in a community as  $\delta_{ij}P_iP_j$ , where  $\delta_{ij}$  reflects the potential of the two species to contribute to the response and its actual contribution depends also on  $P_i$  and  $P_j$ , the initial relative abundance of the two species in the community. This model and variants fitted well to a wide range of functional responses (biomass production, respiration) from several, but not all, experiments that examined a wide range of organisms (plants, microorganisms) and levels of species richness (1 to 72 species). A modified version introduces a more complex effect of pairwise interaction. The properties of this more flexible model and its implications for BEF relationships are discussed, particularly in the context of grass-clover contributions to sward functions.

#### **4.2.07 Study of the earthworm population (*Lumbricus terrestris*) in grassland differing in management**

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This study summarises the occurrence of the earthworm *Lumbricus terrestris* in differently managed grassland. Experiments were conducted in four sward management systems: long-term sward of seven years of use, perennial grasses in the crop rotation kept for five, three and two years. The ploughed soil layer ( $13.5 \text{ m}^{-2}$ ) had the lowest number of earthworms. The number of earthworms ranged from 0 to  $28.8 \text{ m}^{-2}$  in the long-term sward,  $5.0\text{--}20.0 \text{ m}^{-2}$  in the sward used 5 years,  $0\text{--}36.2 \text{ m}^{-2}$  in the sward used three years and  $5.0\text{--}12.5 \text{ m}^{-2}$  in the sward used two years. The occurrence of earthworms was most markedly affected by the moisture content of freshly ploughed soil. A lesser effect was exerted by the soil undisturbed for three years. The effect of moisture in soil undisturbed for five years on the occurrence of earthworms was weak, and no effects were identified in the soil undisturbed for 18–24 years. Legumes had a positive effect on the occurrence of earthworms when the swards were used for three years (*Trifolium pratense*) and five years (*Trifolium repens*). It should be noted that in the sward of five years of use, *Lolium perenne* accounted for the largest share of grasses (34.9%).

#### **4.2.08 The comparison of qualitative assessment of soil surface potential attributes in two regions of Ghareghir and Maravetappe in Golestan province**

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Awareness of type of soil surface attributes is very important and assessment of important attributes of soil and vegetation can help develop awareness of rangeland potential. The goal of this research is to determine some plant and soil indicators of hilly winter rangelands of Ghareghir and Maravetappe in Golestan province. By considering plant cover and soil surface attributes we used the soil surface classification (SSCC) method to assess soil surface attributes. The length and width of ecological patches were measured in terms of lichen, lichen-grass, forbs, shrub, and bare soil inter patches with litter. We also measured the 11 soil surface parameters. These parameters belong to 3 main soil attributes: stability, infiltration and nutrient cycles. These three indicators in east and west aspects of Ghareghir and Maravetappe showed significant differences ( $P < 0.05$ ) in shrub, forbs and lichen-grass. In Maravetappe and especially in the west aspect, these indicators in shrub were greater than at Ghareghir, but in the hill of Ghareghir, lichen-grass patches were more significant. The most important ecological indicators of the east landscapes of this region are forbs and lichen-grass.

#### **4.2.09 A method to assess the management of permanent grasslands at farm level**

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In less-favoured areas, even if there are supports for conserving permanent grasslands, little is known about the agricultural services they can provide, especially at farm level. To assess such services, we propose a method based upon plant functional types (PFT). It was evaluated on eight beef and dairy farms in the Central Massif, 169 vegetation samplings in total. At land use type level (cutting area, area grazed by cow or heifer), we found that within- and between-field PFT diversity was highest for grassland vegetations mixing PFT having acquisitive (PFT<sub>acq</sub>) and conservative strategies for resource capture and use, respectively. At land use type level, a significant positive correlation was established between stocking rate and the percentage of PFT<sub>acq</sub> in the grasslands. In dairy farms during spring, similar milk production and turnout dates were observed whatever the proportion of PFT<sub>acq</sub>, but farms having the lowest proportion of PFT<sub>acq</sub> proceeded to topping on the meadows to compensate for later grass growth. The approach may be a relevant support for discussing management options.

#### **4.2.10 Influence of management and environmental factors on species composition and species richness in semi-arid rangeland in western Iran**

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A large proportion of rangeland in western Iran is in either fair or poor condition. The objective of this study was to analyse the main drivers of rangeland degradation and the vegetational changes that come along with it, and thereby identify mitigation options. A number of 43 main plots were sampled in four grazing areas using a stratified double sampling method. Soil and topographic variables, plant species richness and the distribution of species composition were determined. A measure of grazing intensity was obtained from livestock census data of the different grazing areas. For data analysis, parametric and non-parametric statistics as well as multivariate data analysis techniques were used. Of the measured environmental variables, altitude was the single one that showed a significant linear correlation with species richness. Furthermore, only the amount of K, the percentage cover of stones, and north-facing aspect were related with species composition. Grazing intensity as a management variable was negatively associated with species richness. The results indicated that past and present grazing intensity may have been an important factor influencing species richness and distribution of species composition in semi-arid rangeland in western Iran.

#### 4.2.11 Grazing exclusion effects on species composition and primary productivity in a pasture, Tenerife (Canary Islands)

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We analysed how grazing exclusion affects the species composition and primary production of herbaceous species in a protected pasture on Tenerife (Canary Islands). The botanical composition was evaluated by the point-quadrat method in permanent transects, excluded and open to goat grazing. The production of the herbaceous species was obtained from means of random harvests of 1 m<sup>2</sup> size. Sampling was carried out in spring, after one (2008) and two (2009) years of grazing exclusion. Species composition and productivity did not respond significantly to grazing exclusion. This can be explained by the low grazing pressure of the rotational management system, the dominance of the climate over the effects of grazing on this non-equilibrium ecosystem, the dominance of species evolved under herbivore pressure and the lack of potential vegetation propagule sources. Since the studied variables require more time to reveal significant differences, and due to the important cultural and socioeconomic values of this pasture, we suggest monitoring the study area to guarantee an adequate management for the maintenance and conservation of this ecosystem.

#### 4.2.12 Richness of unsown plant species in a sown ley crop

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A field trial was established in Svalöv, Sweden in June 2007. The experimental layout consisted of 48 communities following a simplex design, and the species used were timothy (*Phleum pratense* L.), perennial ryegrass (*Lolium perenne* L.), red clover (*Trifolium pratense* L.) and a deep-rooted forb: either chicory (*Cichorium intybus* L.) or lucerne (*Medicago sativa* L.). No harvest was taken in 2007, and no herbicide was applied. The plots were harvested regularly in 2008 and 2009. Emerging unsown species identity was identified in each plot four times each harvest year. They were classified into grasses, legumes, annual + biennial forbs and perennial forbs. At the end of the trial, a total of 54 unsown species had been recorded. Fewer unsown species emerged in mixtures of the species sown than in the pure stands of the species. However, pure stands of perennial ryegrass contained significantly fewer unsown species than the other pure stands.

#### **4.2.13 Carbon isotope composition ( $\delta^{13}\text{C}$ ) in *Dactylis glomerata* and its relationship with water use efficiency at plant and leaf level**

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The objective of the present work was to analyse the relationship between leaf carbon isotopic composition ( $\delta^{13}\text{C}$ ) and the water use efficiency (WUE) measured at plant and leaf level in three cultivars of *Dactylis glomerata*. Two irrigation treatments were applied: a) 100% of field capacity and b) progressive drought. Plant water use efficiency (produced biomass/consumed water), intrinsic water use efficiency (A/g, net photosynthesis/stomatal conductance) and carbon isotopic composition of different parts of the leaf blade were determined. The younger section of the leaves presented a slightly higher  $\delta^{13}\text{C}$  than the older section, probably as a consequence of the higher  $\text{CO}_2$  demand of the former. However, both the younger and the older section of the leaves showed similar regression coefficient between  $\delta^{13}\text{C}$  and intrinsic WUE. There were no differences in WUE estimation with respect to the sampled aerial biomass for  $\delta^{13}\text{C}$  analysis. The main conclusion was that  $\delta^{13}\text{C}$  did not appear to be a clear parameter to estimate either WUE or intrinsic WUE.

#### **4.2.14 Management strategies to increase botanical diversity at grassland with a history of intensive agricultural management**

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To increase biodiversity on grassland after years of intensive agricultural management, different management strategies were established in 1997: continuous summer grazing with cattle, combinations of cutting and grazing, early and late cutting with two cuts, addition of potassium fertiliser and abandonment. Changes in biodiversity after 6 and 10 years with different management regimes are given as well as the effect on selected single species. Botanical biodiversity increased more under early cutting and two cuts than under extensive summer grazing. Abandonment for a few years resulted in establishment of some new species, and it was evaluated that small steppingstone areas of short time abandonment could be beneficial. The results indicate that a phased management with initial biomass/nutrient removal can facilitate an increase in botanical biodiversity.

#### **4.2.15 How can *Trifolium repens* patches simultaneously expand and persist?**

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Simultaneously expanding and persistent *Trifolium repens* patches were studied in a nutrient-poor lawn that was frequently cut. *Trifolium repens* primary stolon growth strategies were analysed in relation to their location inside the patch, and according to patch size. It was hypothesised that different growth strategies inside a patch can explain a both persistent and expanding patch of *Trifolium repens*, and that growth strategies were different between patch sizes. The results indicated different growth strategies inside and at the border of patches. *Trifolium repens* stolons at the border were long, grew fast, had few lateral stolons and grew out of the patch, whereas stolons inside the patch were smaller, grew slowly, and had more lateral stolons and a wide range of growth directions. Growth strategies were not different between patch sizes. The directional growth and the high growth rate at the border will increase the patch size with time, whereas the growth strategy near the centre consolidates the patch in space and time, by placing ramets inside the patch. These growth strategies together in a patch result in *Trifolium repens* patches that are simultaneously persistent and on the increase. The results also indicate a division of labour among primary *Trifolium repens* stolons in a patch.

#### **4.2.16 Restoration of species-rich grasslands: reduction in nutrient availability slightly improved forb species' establishment**

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Restoring plant diversity of previously intensively used meadows has proven difficult even long after cessation of fertiliser application. Despite extensive management, forb species typical of semi-natural grasslands often fail to re-colonise such meadows. This may be due to the persistence of high nutrient availability in the soil or to seed limitation. In this experiment, the effects of nitrogen-, phosphorus-, and potassium-availability on the success of forb species' establishment in an existing sward was examined. We spread seeds of 27 different forb species and planted seedlings of *Leucanthemum vulgare* Lam. and *Salvia pratensis* L. in a long-term fertiliser experiment with large between-treatment differences in P- and/or K-availability in the soil and consequently, biomass production of the sward. The results support the hypothesis that low biomass productivity due to lower nutrient availability is favourable to the establishment of forb species typical of semi-natural meadows. Three years after sowing, only a small percentage of the sown species had more than a few individuals present and the number of surviving seedlings strongly decreased within three years after planting, even in the nutrient-poor treatments. These results show that restoration of plant diversity remains difficult even if nutrient availability has been successfully reduced.



#### 4.2.17 Differences in plant species diversity between managed and abandoned semi-natural meadows

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Differences in species diversity between abandoned and managed *Molinion* meadows were studied using 228 samples randomly collected from 60 meadows in southwestern Poland. The meadows were either currently managed, or had been abandoned for at least five years. Ecological diversity indices, Ellenberg indicators and the Disturbance Index (Z) were estimated. Differences between abandoned and managed meadows were identified, as were differences between the typical and atypical forms of *Molinion* meadows distinguished based on Z. The meadows differed in plant cover, total number of species, selected groups of species, and environmental condition as reflected by the Ellenberg indicators. Managed meadows had higher diversity and more species. Abandoned meadows and atypical forms had lower diversity, lower cover of species tolerant to mowing, and higher cover of woody plants, tall herbaceous plants and grasses.

#### 4.2.18 Restoration of rangelands with grass-legume mixtures

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The aim of this study was the restoration of livestock grazing lands by ploughing and then seeding mixtures of perennial grass and legume species. Six types of rangelands were selected in central Greece: an abandoned field, a grassland, a shrubland, a scrubland and open woodlands. Three different grass-legume seed mixtures were established by hand broadcasting at a seed rate of 30 kg ha<sup>-1</sup>. The best establishment of all mixtures was shown at the 'abandoned field' rangeland. Mixture 1 had the best establishment at the majority of the rangelands. Perennial grass-legume species should be used in restoration programmes because they provide stable vegetation cover with a low establishment cost.

#### 4.2.19 Diversity–ecosystem function relationship in mixed forage crops

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Monocultures and three species mixtures containing a grass (*Festuca arundinacea*), a legume (*Medicago sativa*) and a forb (*Cichorium intybus*) were sown in order to test the effects of diversity on forage swards. Yield, LAI (Leaf Area Index), leaching and stability indicators

were determined as a function of sown species identity and diversity effects. Yield and LAI were higher in mixed swards than in monocultures. A diversity effect was found for both variables, with values in mixtures above that expected from the proportions of the sown species. There was a seasonal substitution of species dominance, thus maintaining overall total yield. As a result, mixtures showed higher stability than monocultures. On the other hand, we found a negative effect of total biomass on leaching, but this trend was not consistent across the 6 studied harvests.

#### 4.2.20 Plant strategies in relation to different grazing intensities

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The effect of grazing intensity on plant strategies (C-S-R signature) was studied on an experimental pasture in the Jizera Mts. (Czech Republic). The data collection took place during the vegetation seasons of 2003 - 2007 for two treatments: intensive grazing (IG) and extensive grazing (EG). Sward height was the main attribute for the analysis and the two following categories of sward patches were distinguished: i) heavily grazed (*H*): 0 - 5 cm and ii) rarely grazed (*R*): more than 10.5 cm. The *S* strategy occurred in all types of patches with the lowest value. The defoliation intensity had no effect on its abundance. In the *H* patches with higher disturbances, the *R*-components predominated, whereas the *C* strategy had the lowest value. For example, ruderals, like *Polygonum aviculare* or *Poa annua*, were present in those patches only. The *C* strategy had a higher proportion in the *R* patches. Although it has been shown that the IG treatment favours ruderal (*R*) strategy and EG treatment competitive (*C*) strategy, the results were affected by the abundance of different sward patches in treatments. Therefore, the rate of each C-S-R strategy was more dependent on the rate of different sward patches in treatments than by the grazing intensity itself.

#### 4.2.21 Grass-legume mixtures can fix more N<sub>2</sub> from the atmosphere than legume pure stands

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A multi-site grassland experiment across 33 European sites (COST 852) demonstrated transgressive overyielding of grass-legume mixtures (biomass yield of the mixture was higher than that of the best monoculture) under agronomic management. To get insight into mechanisms driving such mixing effects, we studied N-resource use of grass-legume mixtures over a wide range of legume percentages in the sward (0-100%). We found interspecific interactions stimulating acquisition of N from symbiotic sources to be most important. Interspecific interactions stimulating acquisition of N from non-symbiotic sources were also evident. Furthermore, transformation of acquired N into biomass was more efficient in well

balanced mixtures as compared to legume pure stands. We conclude that the largest benefit of mixing grasses and legumes in terms of biomass and N-yield are achieved with about 40-60% legumes in the sward.

#### **4.2.22 The effect of manipulated plant species diversity of semi-natural permanent grassland on forage production and quality**

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So far, most experiments investigating environmental as well as agricultural benefits of plant diversity in grassland have dealt with sown grassland, whereas permanent grassland has been poorly examined. In the Grassland Management Project (GRASSMAN) in the Solling Uplands (Germany), the biodiversity of permanent grassland has been manipulated by herbicides to obtain either pure grass swards or swards with relatively high amounts of forbs and legumes, on top of untreated control swards. These swards were subjected to different management intensities, regulated by both the cutting regime and the nutrient supply. The aim of this study was to compare the forage quality in terms of crude protein and fibre content as well as the yield of the different swards. Furthermore, the role of species richness as well as that of functional biodiversity, that is to say the distribution of the functional groups, for yield formation was examined. Neither the species composition of the sward nor its functional diversity influenced the yield in this experiment. The swards rich in legumes and forbs tended to have a better quality than the control and grass-rich swards.

#### **4.2.23 Manipulating species richness of permanent grasslands - a new approach to biodiversity experiments**

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The relationship between biodiversity and ecosystem services of grasslands has received increasing attention in recent years. While most of the research has so far been focussing on artificial grasslands, only few studies have examined semi-natural systems such as managed permanent grasslands. The Grassland Management Project (GRASSMAN) in Silberborn (Solling Uplands, Germany), implemented in 2008, tries to fill this gap of knowledge. Instead of sowing new grassland with different levels of species richness, permanent grassland has been manipulated by application of herbicides against a) dicots and b) monocots to alter the species richness and to obtain a new distribution of the functional groups. The resulting swards were subjected to different management intensities in terms of cutting regime and fertilisation. The combination of treatments, especially the herbicide application, led to a broad variety of grass swards. They differed significantly in species numbers, evenness and composition of functional groups.

#### 4.2.24 Diversity and stability in experimental grassland communities

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The relationship between diversity and stability in grasslands is an historical issue of debate in ecology. Here we build on plant breeding concepts of crop yield stability to test the hypotheses that multi-species grasslands were more stable across environments than monocultures, and that stability increased linearly with species richness. We assembled eight perennial grassland species in fifty different experimental communities ('entries') ranging from monocultures to six-species mixtures, in a randomised complete block design with three replications per entry, at two locations in Iowa, USA. We split the plots into two harvest management systems, and collected total biomass yield data over three years. Each of the twelve combinations of location, harvest management, and year was defined as a unique 'environment'. The mean yield of all entries in each environment was defined as the environment mean. For each entry, the means of the three replications in each environment were regressed against the environment means. Entries with four and six species were more stable across environments than the highest yielding monoculture measured as deviations of the regression. Consistency (yields parallel to the environment potential) and reliability (deviation from the expected yield) increased linearly with species richness.

#### 4.2.25 <sup>15</sup>Nitrogen uptake from shallow- versus deep-rooted plants in multi-species and monoculture grassland

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Only a few studies have explored the importance of functional diversity in temperate agricultural grasslands in relation to nitrogen (N) uptake. This study investigates the consequence of growing deep-rooted plants together with grass-clover mixtures in terms of N uptake efficiency from deep soil layers. The objective was to compare the N uptake of the shallow-rooted grassland species *Lolium perenne* and *Trifolium repens*; and the deep-rooted species *Cichorium intybus* and *Medicago sativa* in monocultures and mixtures. We hypothesized that growing deep-rooted plant species in mixture with shallow-rooted species increases the N uptake from deep soil layers partly through competition. A <sup>15</sup>N tracer study was carried out with <sup>15</sup>N enriched ammonium sulphate placed at three different soil depths (40, 80 and 120 cm). To recover <sup>15</sup>N, above-ground plant biomass was harvested after 10 days. We described the decline of <sup>15</sup>N uptake with depth by using an exponential decay function. The studied plant communities showed the same relative decline in <sup>15</sup>N uptake by

increasing soil depths, but different capacities in total  $^{15}\text{N}$  uptake. Monoculture *L. perenne* foraged less  $^{15}\text{N}$  at all depths compared to the other four plant communities. The relative  $^{15}\text{N}$  uptake of individual plant species grown in mixture decreased more strongly with depth than in monoculture. Thus, both findings rejected our hypothesis.

#### **4.2.26 Use of species number, Shannon index and Sorensen index for the evaluation of biodiversity in different types of pasture**

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Many of the indices that are normally used to analyse biodiversity are based only on the number of species present in the plant communities. However, they are very often not useful for studying how the community as a whole evolves. In this paper, two of these indices (species number and Shannon index) are compared with a qualitative analysis obtained with the matrix of the Sorensen index. The evaluation was conducted on two pastures in different stages of succession. The first type showed three levels of vegetation change, from pasture to complete re-colonisation by the adjacent woodland; the second was characterised by a gradual evolution of *Nardus stricta* grassland. During 2009, a floral survey was done on twenty-six plots, in both locations. The results of these surveys were used to calculate the number of species present, the Shannon index and Sorensen index. Because of the high plant community complexity, the species number and Shannon index were inadequate for a full understanding of the pasture ecosystem. At the first location, the qualitative analysis confirmed the discontinuity of the succession. In the second, the percentage of degradation with the biodiversity was highlighted, which pointed out qualitative variations in the composition.

#### **4.2.27 Influence of afforestation on forage value and plant diversity in the Mediterranean**

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We examined the influence of afforestation on diversity and forage value of herbal layer in comparison with neighbouring grassland sites. Nine woods differing in plantation year (1992, 2000 and 2004, respectively) were studied in Caorle, NE Italy, to evaluate the temporal development of the herbaceous component. Botanical surveys of herbaceous species were performed both inside each wood and in neighbouring grassland areas that were cut regularly 2-3 times per year. The results indicated a general decrease in species numbers passing from recently established (1 to 3 years old) to older woods, that were characterised by 60-70% and 30-40% of arboreal and shrubby cover, respectively; at the same time, the forage value remained relatively constant. In contrast, on the grassland sites the total number of species was maintained or increased, at the same time improving the grassland forage value. The forage quality results showed that in the first years after wood constitution, the qualitative characteristics of herbaceous components were almost similar in both situations; in the

following years, however, the phytomass from grassland was characterised by higher quality compared to the herb layer of the woods.

#### **4.2.28 Temporal evolution of the herbaceous component inside and outside newly planted woods. II. Forage quality**

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During the winter and summer seasons of 2005 and 2007, the main characteristics of the herbaceous component detectable inside and outside some hydrophilic woods that had been established in 1992, 2000 and 2004, were evaluated. The analysis highlighted a reduction of phytomass production during winter, both inside the wooded areas and in external herbaceous strips. In contrast, during summer time, the biomass production in the grassland strips was progressively higher compared with the wooded sites, so that after 15 years from transplanting it was almost double than in the arboreal groups. The results of forage quality showed that in the first years after woodland establishment the qualitative characteristics of herbaceous component were almost similar in both situations; in the following years, however, the phytomass taken from grassland strips was characterized by higher quality than in the herb layer under the wooded areas.

#### **4.2.29 Changes in biodiversity composition and soil nutrient content with management in a Pyrenean grassland community**

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We investigated the influence of livestock type on vegetation and biogeochemical cycling in grasslands experiencing different managements from a trophic perspective. We sampled plots in the Pyrenees of which four were grazed by sheep and four by cattle. We defined three patch types, based on the specific and functional plant composition: legume-dominated (mostly by *Lotus corniculatus*); grass-dominated (mainly by either *Festuca nigrescens* or *Nardus stricta*); and forb-diverse (with *Myosotis sylvatica* and a diversity of other species). We sampled both above- and below-ground to obtain information about vegetation, roots (including mycorrhiza colonization) and soil nutrients. The above- and belowground plant biomass depended upon functional components of the patch and on grazing management. Plant allocation to green and dead matter changed with management. Further, differences in vegetation composition between cattle- and sheep-grazed areas found in previous studies were confirmed. Higher P and NO<sub>3</sub> concentrations in cattle-grazed areas suggest eutrophication under this management, linked with lower mycorrhizal colonisation. Our results therefore confirm patterns in previous studies and provide a deeper insight into the mechanisms of biotic differentiation and biogeochemical processes associated with differences in grazing management.

#### 4.2.30 Species richness and natural amenities of selected grassland communities in Western Pomerania

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In 2002-2004 and 2007-2008, studies were carried out in the Western Pomeranian Province referring to floristic evaluation of selected grassland pratocenoses situated by the Szczecin Lagoon and the Dąbie Lake (Czarna Łąka – 1, Krępsko – 2, Stepnica – 3) as well as in the Ina River valley (Stawno – 4, Sowno – 5). They consisted of phytosociological evaluation of grassland communities and compilation of detailed lists of vascular plants. Vascular plants were represented most numerous in meadows of the Ina River valley (areas 4 and 5) and constituted almost 50% of the recorded species. The evaluation of the natural environment showed little or moderate natural value of the examined grasslands. In the vegetation of objects that were monitored, the presence of melliferous, protected and medicinal species was recorded (14.0, 1.0 and 9.0%, respectively). In the second study period (2007-2008), an increase in species richness was observed, in particular in the monitored areas 1, 4 and 5.

#### 4.2.31 The influence of the land-use system upon *Arnica montana* L. grasslands

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In the Gârda de Sus commune there is ongoing research concerning the influence of the system of land use upon *Arnica montana* L. grasslands; more precisely, the manner in which the fertilisation actions are performed and how they influence the sward composition. The existence of *A. montana* meadows is the result of an extensive type of traditional management carried out over a long period. These oligotrophic grasslands are only fertilised organically, mainly using stable manure. Most landowners fertilise the *Arnica* grasslands in a regular cycle; in most cases annually, and rarely only once in two or three years. Exploitation only through grazing produces a strong presence of some species such as: *Vaccinium myrtillus* L., *Vaccinium vitis-idaea* L., *Luzula luzuloides* Lam., *Deschampsia flexuosa* L. etc. The application of maintenance works and utilisation through mowing favours the spread of some species with forage value: *Agrostis capillaris* L., *Festuca rubra* L., *Trisetum flavescens* L., *Trifolium pratense* L., etc., as well as some without forage value: *Centaurea pseudophrygia* C.A. Meyer, *Euphrasia officinalis* L., *Gymnadenia conopsea* L., *Hieracium aurantiacum* L. etc. The populations of *Arnica montana* L., in terms of numbers of individuals, are poorly influenced by these two systems of management practice, being present in both cases with considerable cover.

#### **4.2.32 Effects of arbuscular mycorrhizal symbiosis on growth and N<sub>2</sub> fixation of *Trifolium alexandrinum* under late drought stress conditions**

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Several experiments, mostly carried out under controlled conditions, have shown that arbuscular mycorrhizal (AM) symbiosis enhances nutrient uptake and improves drought tolerance of host plants. The present research, carried out in a typical Mediterranean environment, evaluated the effect of AM symbiosis on berseem clover (*Trifolium alexandrinum* L.) grown in the field under both late drought stress and well-watered conditions. The crop was subjected to repeated defoliation. N<sub>2</sub> fixation was estimated using the <sup>15</sup>N dilution method and using ryegrass (*Lolium multiflorum* var. Westervoldicum) as the reference crop. In late drought conditions, AM symbiosis resulted in a significant increase in biomass yield, total N uptake, total amount of N fixed, and proportion of N derived from the atmosphere. The results suggest that AM symbiosis could play a key role in alleviating the stress effects of late drought on berseem forage production in the field.

#### **4.2.33 Plant functional trait expression in the Rengen Grassland Experiment**

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Plant functional trait expression was investigated in the Rengen Grassland Experiment (RGE). Six fertiliser treatments have been present in the RGE since 1941: unfertilised control, Ca, CaN, CaNP and CaNPK with K in two forms. Categorical traits of communities were determined throughout four consecutive years. Cluster analysis identified distinct clusters: (i) control, (ii) Ca, (iii) CaN and (vi) the remaining treatments with CaNP or CaNPK application. Redundancy analysis (RDA) revealed high similarity of categorical traits in treatments with CaNP and CaNPK application, but a distinct differentiation to CaN, Ca and control. Categorical traits varied such that one can identify trait-based plant strategy of adaptation in response to soil nutrient content.



#### **4.2.34 Long-term effects of large-scale, moderate grazing on the vegetation of a river valley**

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In this study we present results of large-scale, moderate cattle grazing. We are concerned with long-term (1999-2009) effects on the structure and dynamics of vegetation in three pastures with distinct land use histories. Our investigations were carried out in a typical northern German river valley. The results showed that species richness depends on livestock unit, forage quality of the vegetation, and on previous land use. Both in fen areas and on mineral slopes, species richness increased in cases where the previous land use was termed either 'abandoned' or 'high-density grazing'. In fen areas with previously moderately used, species-diverse grasslands, species richness decreased when adjacent mineral slopes provided good forage quality for grazing, and when livestock unit was less than 0.75 cattle ha<sup>-1</sup> a<sup>-1</sup>. We conclude that large-scale grazing is an appropriate alternative to more costly nature conservation measures in grasslands. However, in order to avoid pasture abandonment in isolated species-rich wet grasslands, additional measures, such as mowing or temporary fencing, should be considered.

#### **4.2.35 Assessing the environmental qualities of permanent grassland**

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A current issue is whether it is possible to evaluate the environmental qualities of individual meadows and pastures based solely on information about some of their attributes. The question is: would biologists make concordant evaluations and, if so, which attributes would be relevant. The aim of this study was to investigate the possibility of developing a model that can classify grassland by environmental values based on survey data. The reason is the policy demand to prioritise measures for preserving the environmental qualities of grassland cost-effectively. A questionnaire was used in which 40 grassland-biology experts classified 50 semi-natural grassland objects into value deciles based on survey data. The grassland objects were randomly spread across Sweden, and described by eight attributes. The study indicates that: (i) domestic experts in biodiversity conservation are quite concordant in assessing semi-natural grasslands; (ii) it is possible to quantitatively assess the general environmental quality of a grassland object by means of a simple, linear prediction model, and less than 10 carefully selected variables suffice to characterise a grassland object in a condensed but balanced way; and (iii) 'number of positive indicator species' is the variable the experts most heavily relied upon in their assessments of grassland environmental qualities.

#### 4.2.36 Survey of permanent grasslands in Sweden

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Since the 19<sup>th</sup> century, the permanent grassland area in Sweden has declined from several million ha to half a million ha. The Swedish Board of Agriculture and the County Administrative Boards have carried out a national field survey on 300000 ha of the ecologically and culturally most valuable grasslands. The survey concerns environmental qualities, as type of habitat, flora signal species, water or cultural heritage (e.g. historic elements). About 230000 ha have been identified as semi-natural pastures and about 7000 ha as meadows. Since the previous survey (1987-92), 30000 ha have become overgrown and are no longer considered as valuable. The survey results are freely and publicly available on the Internet, and will be supplemented and updated continuously.

#### 4.2.37 Grassland associations in Serbia on Stara Planina Mountain conditions

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Production of organic, biologically valuable food is a trend in today's World, and in Serbia it can be successfully realized in meat and milk production from small ruminants in mountainous regions. Grasslands in these regions have not been affected by mineral fertilizers and chemical plant-protection products; therefore production of healthy food is still possible with minimum investments. For this purpose, the dominating five plant associations at eight locations on the Stara Planina Mountain (at altitude of 750-1000 m) were analysed. These associations were: *Medicago falcata-Festucetum rubrae*, *Trifolium campestre-Agrostietum vulgaris*, *Agrostietum vulgaris* Z. Pavl. 1955. sensu lato, *Festucetum vallesiaceae* Borisavljević 1956, and *Festucovallesiaceae-Agrostietum vulgaris* Danon et Blaž. 1978. Number of species was 34 to 77. In addition to recording the number of species, their share was also described in categories of: quality grasses, quality legumes and useful species from other families, and harmful species (i.e. weed species). Main quality parameters were established in samples from all associations. The objective of analysis of natural grasslands was to establish the share of high quality species, which is reflected directly through production and quality for food to small ruminants.

#### **4.2.38 Roots and earthworms under grass, clover and a grass-clover mixture**

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We investigated the root biomass, the abundance of earthworms and a selection of soil physical parameters in white clover, grass-clover and grass. The treatment with clover-only had a lower root biomass, a lower C/N ratio of the roots, a higher abundance of earthworms, a higher number of earthworm burrows, a lower penetration resistance at the 20-30 cm soil layer and a lower proportion of crumbs in the soil, than the other treatments. This confirms evidence in the literature that pure clover stimulates the ecosystem services of water regulation, but is less conducive to soil structure maintenance. However, the grass-clover mixture did not differ significantly from the grass treatments, but differed from clover-only in a higher percentage of soil crumbs. We infer that when clover is introduced in grassland to reduce the reliance on inorganic fertiliser, the mixture of grass and clover maintains the positive impact of grass roots on soil structure. However, it only may show a positive effect of clover-only on water regulation with a higher clover percentage in the dry matter.

#### **4.2.39 <sup>13</sup>C Carbon allocated to the leaf growth zone of *Poa pratensis* reflects soil water and vapour pressure deficit**

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Leaf expansion is extremely sensitive to water stress caused by a shortage of soil water content or a high vapour pressure deficit. Both parameters also influence stomatal opening, which affects the discrimination of the heavier carbon isotope (<sup>13</sup>C) during photosynthesis. Thus, photosynthates reflect the water status of the leaf by their <sup>13</sup>C content and this signal is incorporated in the leaf growth zone. This mechanism was elaborated by analysing the <sup>13</sup>C content of the leaf growth zone of *Poa pratensis* sampled at eleven sites with different soil organic carbon and at three different times (early spring to mid summer) during the growing period to cover wide ranges in soil water content (15-500 mm for 1 m depth) and vapour pressure deficit (0.5-2 kPa). Discrimination varied by about 5‰. This variation and hence stomatal opening of *P. pratensis* was mainly determined by vapour pressure deficit and less by the soil water content. A large vapour pressure deficit, however, only occurred during times of low soil water content. The combined effect of both influences was described best by the ratio of vapour pressure deficit and the logarithm of soil water content. Analysis of <sup>13</sup>C in the leaf growth zone offers an elegant way to record stomatal opening as influenced by water stress with high temporal resolution.

#### 4.2.40 Influence of drought stress and fertilisation on carbon isotopes as indicators of water use of grassland differing in diversity

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Plant diversity in grassland may influence the water use of a sward due to complementary use of the rooting zone. An indicator of the water use of C<sub>3</sub> plants is their natural abundance of the carbon isotope <sup>13</sup>C. Without water stress, plants may fractionate more against <sup>13</sup>C than with water stress, leading to a stronger depletion of <sup>13</sup>C in plant material. We have used this principle to investigate the water use of grassland differing in diversity. In old grassland, diversity was altered three years before this experiment by applying a herbicide against dicots in half of the plots. On sub-plots, different combinations of rainout shelters (yes-no) and N fertilisation (0 or 90 kg ha<sup>-1</sup>) were established. Differences between drought treatments were clearly reflected in <sup>13</sup>C values. N fertilisation led to a further enrichment in <sup>13</sup>C, especially in unsheltered conditions. This could be explained by increased biomass production, which might have led to higher water use, and enhanced CO<sub>2</sub> fixation capacity. Unexpectedly, plant diversity did not have a significant influence on the isotopic composition. This was perhaps due to the occurrence of the deep-rooted *Taraxacum* sp. on all plots and the similar species numbers in herbicide-treated and -untreated plots.

#### 4.2.41 Grasslands in Strandja Mountain

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We studied the main pasture type in the region of Strandja Mountain in Bulgaria - their status, botanical composition and use. Our studies showed that most of the grasslands in Strandja are xerothermal – belonging mainly to the *Chrysopogon gryllus* and *Andropogon ischaemum* type. The meadows along the river valleys are mesothermal (*Poa silvicola*) and the more moist ones on the slopes belong to the *Agrostis vulgaris* and *Cynodon dactylon* - *Lolium perenne* type. The Mediterranean influence on the phytocaeenological peculiarities of the natural grasslands in the area is expressed in the constant, abundant presence of the annual clovers - *Trifolium subterraneum*, *Tr. setiferum* and some typical representatives of the grasses - *Hordeum bulbosum*, *Phleum graecum*, *Hordeum crinitum*. The rational use of the grasslands and the implementation of ecological measures for their preservation and improvement create a possibility for conserving the species diversity and providing forage for livestock breeding for a long period of time.

#### **4.2.42 Perturbed ecosystems are the most affected by goat grazing: A study of floristic composition (La Palma, Canary Island)**

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In the Canary Islands more than 40% of territory is protected, consequently goat grazing is restricted or prohibited in almost all natural protected areas. The exclusion of grazing in these areas is based on the general idea that goats modify vegetation therefore ecosystems could become threatened. The aim of this study is to know if goat grazing is affecting floristic composition. The study was carried out in three main ecosystems of La Palma (Canary Islands) characterized by different disturbance levels of previous human activities (pine forest, shrublands and abandoned fields). Relative frequency of plant species was measured in grazed and ungrazed areas in each vegetal community from 2005 to 2007. Our results showed that grazing modified floristic composition of the most perturbed ecosystems (shrublands and abandoned fields) but did not affect the most natural ecosystem (pine forest).

#### **4.2.43 Investigation of environmental factors that affect species diversity in mountainous grasslands (case study: Zagros, Iran)**

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Species diversity is an index for sustainability of rangeland ecosystems. We studied the effect of environmental factors (soil properties and aspects) on species diversity in Zagros mountainous rangelands (vegetation type: grass-shrub). For this purpose, four aspects were defined in the study area. Flora and vegetation type were studied by a physiognomic-floristic method in the field. Vegetation factors were measured on transects, using a systematic randomized method. Five transects (100 m) and five plots along each transect were used. One soil sample (depth: 0-40 cm) in each plot was collected by a randomized method and assessments made in the laboratory of pH, OM, N, EC, P, K and texture. To investigate the relationship among species diversity (dependent variable) and soil and topographical factors (independent variables) multiple regression was used. Statistical analysis of data showed that diversity has significant linear regression with soil characteristics and aspects. North, east and west aspects, and the soil factors of OM, N, EC and clay, had the most significant effect on the diversity model.

#### **4.2.44 Following plant community assembly and plant phenotypic plasticity in different grassland habitats using traditional ecological and non-invasive high resolution census methods**

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Priority effects in community assembly, whereby the species that arrive first at a disturbed site play a key role in the further development of the community, are known to be important in many types of ecosystem. A grassland ecosystem developing on ex-arable land has been found to develop with a high species turnover and increasing dissimilarity of species over time but the traits of species in the system became more similar. Thus, we aim to investigate community assembly and dynamics in two different grassland habitats (dry vs. mesic grassland). We investigated effects of species composition and richness (priority effects) over time within a field-experiment. We aim to correlate traditional ecological with non-invasive high resolution census methods (FieldScreen: Mobile Field Positioning System) - with the objective to improve field phenotyping of plant species under natural conditions. Here we provide information on the design, procedures and first results of our assembly field-experiment.

#### **4.2.45 Does biodiversity promote stability against prolonged summer drought?**

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It is of growing interest whether biodiversity promotes the stability of grasslands against the effects of climatic changes, such as prolonged summer drought. Published studies show inconsistent results. Furthermore, it is not clear how different management practices of grasslands additionally affect the response to drought. We established an experiment to analyse the effects of biodiversity, management practice and drought. We ask: (1) whether species diversity increases the resistance of grasslands to drought, and (2) whether the relationship between species diversity and drought effects change with increasing management intensity. Our experimental setup contains several grassland communities of the Jena Experiment, differing in species richness and functional group richness. We varied annual mowing regime and the amount of fertilization in all communities so as to create different management intensities. The generated subplots were again divided in a control with ambient precipitation and a plot simulating extended summer drought using transparent roofs. With this experimental design we investigated the effects of drought, management intensity and biodiversity on ecosystem properties separately, as well as to study their interaction. This approach should help us to better understand the mechanisms of grassland stability.



# **Session 5**

## **Pastoral/grazing systems**





## Environmental impacts of grazed pastures

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Large nitrogen (N) surplus and return of excreta-N in localised patches at high N rates in intensively grazed pasture systems markedly increases the risk of N losses to waterways and the atmosphere. Here are described the main routes of N input to grazed pastures, losses via N leaching, methane (CH<sub>4</sub>) and nitrous oxide (N<sub>2</sub>O) emissions. Furthermore, farm N budgets and N-use efficiency in relation to management strategies that can be applied to reduce N losses are discussed. Nitrate leaching increases exponentially with increased inputs and is closely related to urine patches, which also influence the leaching of dissolved organic N. High N<sub>2</sub>O emission rates in grazed pastures are related to fertiliser-N or N in excreta combined with compaction by animal treading. Grazing may considerably reduce CH<sub>4</sub> emissions compared to indoor housing of cows. Pastures are occasionally cultivated due to sward deterioration followed by a rapid and extended period of N mineralization, contributing to an increased potential for losses. Good management of the pasture (e.g. reduced fertiliser input and reduced length of grazing) and of the mixed crop rotation during both the grassland and the arable phase (e.g. delayed ploughing time and a catch-crop strategy) can considerably reduce the negative environmental impact of grazing. It is important to consider the whole farm system when evaluating environmental impact, in particular for greenhouse gases since the pasture may serve as a source of N<sub>2</sub>O and indirectly of CH<sub>4</sub>, but also as a sink of CO<sub>2</sub> influenced by management practices on the farm.

## Producing milk from grazing to reconcile economic and environmental performances

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Several reports, directives, regulations and initiatives challenge high-input dairy systems at the environmental level. At the same time the dairy sector has to adapt to a greater volatility of prices and to the projected increase in energy and fertiliser prices. In this new context, it should be considered whether the model of development based on intensification, often in connection with the reduction in the use of grazing, is always well adapted. Dairy systems that maximise grass utilisation appear to be highly competitive and the various roles of grassland in providing regulating and supporting services are now widely recognized. Thus grassland should form the basis of more sustainable dairy systems in the future, provided technical innovations are produced to improve the efficiency of grassland-based dairy systems. Innovations in forage production, innovations in characteristics of the cows and management of lactations, as well as innovations in the management of the system have

potential for increasing economic and environmental performances of grassland-based systems. The more systematic use of legume forages in multi-species swards makes it possible to reduce the consumption of mineral N, to reduce the carbon footprint of the dairy system, to regularize the forage production over the year and to increase the nutritional quality of the forages. It clearly appears that intensive selection for milk based on high concentrate diets has generally resulted in genotypes that are not well suited for systems maximising forage utilisation. In these systems there needs to be a special focus to address fertility, survival and other functional traits such as mastitis resistance, although high genetic merit for milk should be maintained to produce efficient responses to concentrate supply. Finally, extending the grazing season with early turnout or late grazing, and tactical use of grazing in association with conserved forages in large herds, offers many opportunities to reduce the requirement of expensive conserved forage and to reduce the utilisation of purchased feeds. All these potential sources of progress are discussed.

## **Session 5.1 Pasture management and production**

### **Utilisation of cut and grazed fields is linked to their geographical characteristics in mountainous bovine systems**

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The impact of geographical characteristics on the utilization of cut and grazed fields was investigated on 72 farms in Massif Central (France) managing milked cows with their calves. Principal component and hierarchical cluster analyses were performed on 679 cut and grazed fields. Relationships between the classes obtained and the slope, area, distance to farmstead and elevation of the field were established through linear mixed models. The population was separated into six utilisation classes characterized by different types of sequences: one grazing before cutting, early cutting before grazing, late cutting before grazing, grazing cutting and grazing sequence, two cuttings before grazing, and one unspecialised sequence of cutting and grazing. The fields grazed before cutting are larger and closer to the farmstead than the fields cut before grazing. Elevation is involved in the orientation between early and late cutting. The fields grazed twice have a low distance to farmstead that is consistent with two periods of grazing. Although field utilisation is strongly driven by its geography, farmers have the possibility to adapt their conducting on fields with characteristics suitable for several utilisations. These results will help to model the forage system functioning and to adapt on-farm advice to the fields' characteristics.

## Grazing behaviour and intake of two Holstein cow types in a pasture-based production system

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Cow types adapted to forage-based production systems are of particular interest for organic milk production. The objective of the present study was to compare grass intake and grazing behaviour of New Zealand genetics Holstein cows ( $H_{NZ}$ ) ( $n = 11$ ) with farm-bred 'Swiss' Holstein cows ( $H_{CH}$ ) ( $n = 11$ ). The comparison was realised in a pasture-based production system with a short late winter/early spring calving season, under organic conditions. Intake of cows was estimated individually 4 times during 2 grazing seasons using the n-alkane marker technique. Simultaneously, selected cows were equipped with behaviour recorders to collect grazing behaviour data. Motion sensors monitored activity and position status. Grass dry matter intake (GDMI) and total DM intake (TDMI) of  $H_{NZ}$  were significantly lower than  $H_{CH}$ , but per unit of metabolic body weight no differences were found. Energy-corrected milk yield per unit of TDMI shows no significant differences between the two cow types. The  $H_{NZ}$  spent more time ruminating, had a higher number of mastications during rumination, but no differences occurred related to eating and idling time. Fewer bites and more mastications during eating were found for  $H_{NZ}$ . The latter tended to stand less and lie more.

## Comparison of methods to quantify bite rate in calves grazing winter oats with different structures

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To compare methods for the identification of bites: acoustic recorder (AR) and IGER behaviour recorder (IBR), 5-minute grazing sessions were registered for 9 Holstein-Friesian calves on winter oats (*Avena sativa*) with 3 different structures (surface height): tall (T;  $50.4 \pm 9.9$  cm), medium (M;  $25.3 \pm 4.9$  cm) and short (S;  $13.9 \pm 3.4$  cm). The experiment lasted for 3 days, and each day 3 animals grazed on the 3 structures in a randomised sequence. Sound files were analysed aurally and IGER recordings by Graze 8.0. Data (bites per minute of eating time) were analysed as a completely randomised design by ANOVA. Bite rates were 40, 40 and 32 (RMSE = 6,  $P < 0.0001$ ) for O, AR and IBR, respectively. Within the structures, bite rates were T = 37, 37, 29 (RMSE = 8,  $P = 0.03$ ); M = 44, 43, 33 (RMSE = 5.1,  $P = 0.0002$ ) and S = 37, 38, 32 (RMSE = 4.7,  $P = 0.02$ ) for O, AR and IBR, respectively. The AR method provided accurate information of bite rate.

## **Increasing concentrate levels during the grazing season – effects on yield and behaviour of dairy cows**

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In a six-week grazing trial, 27 lactating dairy cows (Swedish Red Breed) were randomly assigned to five treatments with different concentrate levels in their diet: 20, 30, 40, 50 and 60% of each cow's energy requirement at the start of the study. The cows were fed their treatments twice daily together with 4 kg dry matter (DM) silage in the barn in connection with milking. The cows grazed together on 10.5 ha in a rotational grazing system with 6 paddocks. The average energy content and daily allowance of pasture was 10.8 MJ metabolisable energy per kg DM and 20 kg DM per cow. A 10% increase in the proportion of concentrates in the diet reduced grazing and rumination time by 4.1% ( $P < 0.001$ ) and 2.1% ( $P < 0.01$ ), respectively. With a 10% increase of the proportion of concentrate in the diet, milk yield increased by 1.5 kg ( $P < 0.001$ ). An increase in concentrates of 1 kg gave an average response in milk yield with 0.8 kg milk. The results indicate that feeding concentrates up to 60% of energy requirements during the pasture season is profitable when concentrate prices are below 0.8 of the payment for milk.

## **The effect of sward *Lolium perenne* content and defoliation method on seasonal and total dry matter production**

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Quantifying the production loss, as sward perennial ryegrass (*Lolium perenne* L.; PRG) content decreases is an important issue for grassland farmers. The evaluation of grass varieties in Ireland incorporates mechanical defoliation or simulated grazing (SG) methods and visual ground score (GS) estimates of the proportion of PRG in a sward. The objective of this study was to quantify the effect of i) sward PRG content and ii) defoliation method on seasonal and total dry matter (DM) production, as well as the effectiveness of GS estimates in predicting sward PRG content and DM production under an actual grazing management (AG). Plots were established in autumn 2007 incorporating three varieties of PRG, at five different seeding rates 5, 7.5, 12, 20 and 30 kg ha<sup>-1</sup> to establish swards with a PRG content of approximately 15%, 25%, 40%, 65% and 100%, under 2 defoliation managements SG and AG, replicated 3 times. Sward PRG proportion and defoliation method had a significant effect ( $P < 0.001$ ) on spring, summer and total DM production, increasing as sward PRG proportion increased, with the AG defoliation method having higher yields. GS was a useful indicator of sward PRG content and production potential. It can be concluded that swards with less than 65% PRG content are close to the reseeding threshold.

## **The effect of organic management strategies on dairy production in clover-based grassland**

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In Ireland, there is a price premium for supplying 50% of annual organic milk production during the winter. However, profitability will only be realised through active cost reducing strategies by producers. In 2008/2009, this study examined the viability of supplying a large proportion (>50%) of the diet from grazed grass-clover (*Trifolium repens* L.) swards during the autumn and winter in order to substantially lower the cost of feed for organic winter milk production. Three systems of production compared had: (i) a mean calving date of 17 February, stocking density of 2.15 cows per ha, receiving 90 kg/ha of annual fertilizer N input (Control); (ii) a mean calving date of 17 February, stocking density of 1.6 cows/ha, receiving no fertilizer N input (S-NFN) and (iii) a mean calving date of 16 April, stocking density of 1.6 cows/ha between calving and 1 September and stocking density of 1.2 cows/ha between 1 September and 18 February, receiving no fertilizer N input (W-NFN). There were 18 cows per system. There were no ( $P > 0.05$ ) differences between systems in production of milk yields and milk composition or live-weight and BCS during or at the end of lactation. The W-NFN system produced 48% of milk between 1 September and 18 February, suggesting a later calving date than 16 April is necessary to produce 50% of annual milk between September and March.

## **Feeding behaviour of sheep on shrubs (*Cytisus scoparius* L.) in response to contrasting herbaceous cover**

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Understanding the feeding behaviour of livestock faced with high plant diversity is a powerful tool available to managers to modify plant-herbivore interactions and achieve targeted shrub grazing levels. We addressed this issue by evaluating the role of herbaceous feed item diversity on browsing intensity of a targeted dominant shrub (broom, *Cytisus scoparius*). The effect of three herbaceous covers, which varied greatly in terms of green and dead material and of species phenological stages, on broom consumption, was compared by investigating the feeding behaviour of a flock of ewes over time and by monitoring the evolution of feed item availability and quality. We observed that different herbaceous covers influence the feeding choices of ewes, modifying their rate of consumption of broom. This confirms that factors other than the intrinsic properties of the dominant shrub (toxic contents, phenological stage, nutritive value, etc.) influence foraging choices. Therefore, managers can influence ewes' diet selection by modifying the herbaceous cover in order to stimulate the use of broom, amplifying the impact of browsing on the demography of this shrub population.

### 5.1.01 Modelling the dynamics of biomass production and herbage quality of grasslands according to functional groups composition

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A model predicting the dynamics of herbage biomass, structure and digestibility in managed permanent grasslands (Jouven *et al.*, 2006a) was tested on data obtained over three successive vegetation cycles and two years from three contrasting grasslands: based on the classification given in Cruz *et al.* (2002), plot one (86% grasses) was dominated by functional group A species (*Lolium perenne*), plot two (68% grasses) was dominated by group B (*Dactylis glomerata*) and group b species (*Holcus mollis*), and plot three (only 39% grasses) was dominated by group b (*Agrostis capillaris*) and group C species (*Festuca rubra*). For the three types of grasslands, the precision of the simulation of biomass production was good for the first vegetation cycle but lower for the second and the third cycles. Digestibility was precisely simulated during the first cycle for grasslands one and two but was overestimated for plot three. It is concluded that model could be improved by better taking into account the seasonal modulation of growth, and by better knowledge of the herbage quality of species from functional groups b and C.

### 5.1.02 The quest for persistent green in outdoor chicken runs – an investigation on fourteen grassland species

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In free-range chicken husbandry systems, the vegetation cover of the hen run is exposed to particularly high levels of stress. Sward deterioration is common, which entails environmental and animal health risks. Thus, specific agronomic strategies ensuring the preservation of an intact vegetation cover need to be developed for outdoor chicken runs.

Within the present field experiment, we investigated fourteen species of native grassland plants with regard to their suitability for greening chicken free-range areas. To this end, monocultures and a mixture of all species were grazed with chicken at three different stocking rates. The following parameters were analysed for each species: a) reduction of aboveground biomass caused by grazing and b) growth rates of aboveground biomass during rest periods. We identified significant ( $P < 0.001$ ) inter-specific differences in biomass removal by grazing with relative removal of original biomass ranging from 17 to 100% at the highest stocking rate. Stocking rate significantly ( $P < 0.001$ ) influenced post-grazing growth rates. Our results indicate that *Festuca arundinacea* potentially is the most eligible species for greening chicken outdoor runs, as in this species relative biomass removal by chickens is low and growth rates during recovery periods are largely unaffected by the previous grazing event.

### **5.1.03 Dietary selection of heifers in natural grasslands: effect of time of day and phenological stage**

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This study was conducted on a natural mosaic grassland of tall tussocks comprised mainly of *Eragrostis plana* Nees, and shorter inter-tussock areas comprised of prostrate grasses. The experimental paddocks were grazed by beef heifers and contained equal proportions of tussock and inter-tussock areas. Measurements were made at two times of day (during the first and the last grazing meals) replicated four times: twice spatially on paddocks and twice in time. The complete set of replicate measurements was conducted during two different tussock phenological stages: green reproductive (GR) and senescent reproductive (SR). Time of day had no effect on the proportions of grazing activity spent on the inter-tussock areas and tussocks. However, during GR stage the heifers spent more time grazing the reproductive tissues than the inter-tussock areas (66% vs. 34% of grazing activity, respectively). During SR stage virtually all grazing activity was concentrated on the inter-tussock areas (2% vs. 98% of grazing activity, respectively) and the heifers were able to increase mean bite mass and short-term intake rate.

### **5.1.04 Intake choices of cattle and sheep grazing alone or together on grass swards differing in plant species diversity**

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The objective of this study was to evaluate the effect of either mono grazing of sheep and cattle or co-grazing, as well as the influence of sward botanical composition (either diverse swards or grass dominated swards) on intake choices of six forage species. The hypothesis was tested that intake choices of sheep and cattle are modified by the sward composition and the type of grazing. Jacobs' selection index was employed to quantify the proportion of a single target species preference in relation to its proportion to the sward composition. Results revealed distinct intake preferences of sheep and cattle; especially, sheep were more selective than cattle. To a lesser extent, the sward composition had an effect on intake preferences. Co-grazing facilitated a more homogeneous consumption of the main forage species. Co-grazing might have the potential to better maintain grassland biodiversity.



### **5.1.05 Relationship between herbaceous productivity and species richness in grazed areas on La Palma (Canary Islands)**

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Goat grazing in the Canary Islands is increasingly related to environmental policies, because it has to coexist with the natural protection of the territory. In order to correctly manage goat grazing and ensure its sustainability it is crucial to study its effect on the environment. After three years of monitoring in grazed areas of La Palma we try to observe whether the relationship between species richness and productivity shows different patterns due to the effect of grazing on vegetation. Biomass and richness of herbaceous plants were measured in grazed and non-grazed areas in the main ecosystems on the island. These communities differ in mean productivity and species richness ( $P < 0.01$ ). Three responses were detected, a) communities with no significant relationship between species richness and productivity in both grazed and non-grazed areas, b) communities with a significant and positive linear relationship only in non-grazed areas, and c) communities in which the relationship is significant in both areas but showing different patterns, linear and positive in grazed areas and unimodal in non-grazed areas ( $P < 0.01$ ). Managers should take into account the differences in the response of species richness to goat grazing depending on the type of vegetal community, as their productivity values are influencing the type of answer.

### **5.1.06 Are high genetic merit dairy cows compatible with low input grazing systems?**

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High genetic merit (HGM) dairy cows are often described as poorly adapted to low input grazing systems. To evaluate the ability of HGM cows to support varying levels of feed supply during lactation, a 5-year experiment comparing 4 feeding strategies took place at the INRA experimental farm based in Normandy. Cows received high and low levels of concentrate in early lactation during winter feeding time and 0 and 4 kg of concentrate per day during the grazing period resulting in four strategies : High-high, High-low, Low-high and Low-low levels of concentrate (i.e. 355, 736, 938 and 1300 kg per lactation). The dataset comprised 325 lactations of Holstein and Normande cows with milk genetic index varying between +396 and +3026 kg and +187 and +2149 kg, respectively. Within each breed, milk yield increased with increased supplementation. Within each breed, and irrespective of feeding strategy, the higher milk index animals achieved a higher level of milk, fat and protein production. While reproductive performance was significantly better for the Normande breed, within each breed, milk genetic index and feeding strategy had no effect on

reproductive performance. It is concluded that HGM cows can be managed in low input grazing systems.

### 5.1.07 Daily pattern of feeding activities of dairy cows in an 8-d rotational grazing system

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The behavioural adaptation of dairy cows during the grazing down process was examined in an 8-d rotational grazing system. Eight cows were grazed in four 8-d paddocks of perennial ryegrass pasture without any supplements, at an average low pasture dry matter (DM) allowance of 25 kg cow<sup>-1</sup> d<sup>-1</sup> at ground level. On average, sward height measured with a platometer declined from 14.4 to 5.7 cm, extended height of free leaf lamina from 20.3 to 2.0 cm, 4%-corrected milk production from 22.6 to 17.2 kg, and herbage intake from 21.4 to 14.9 kg DM from d1 to d7-d8. Grazing and rumination times were lowest on d1, d2 and d8, and were slightly higher and stable from d3 to d7 (+41 and 25 min, respectively). Average pasture DM intake rate decreased from 37 g min<sup>-1</sup> on d1 to 26 g min<sup>-1</sup> on d7. Cows still maintained a high level of grazing activity until the end of the last day despite clear lower motivation to graze in the morning of d8. It is concluded that, despite the rapid and strong changes in sward canopy structure during the grazing down process, there was no 'rupture' in the behavioural strategy of the cows but rather a regular and continuous adaptation.

### 5.1.08 Tillering dynamics in *Brachiaria decumbens* pastures under continuous stocking

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Two strategies for managing *Brachiaria decumbens* under continuous stocking in the State of Minas Gerais, Brazil were evaluated. In one, the pasture was managed to maintain an average height of 15 cm in winter and 25 cm in both spring and summer. In the other, pasture height was kept at an average of 25 cm during all the experiment. All pastures were managed at varying stocking rates with crossbred cattle weighing about 200 kg. A randomized block design and subdivided plots were used. Tiller emergence rate (TER) and tiller mortality rate (TMR) were lower in winter and higher in spring and summer. These results indicate a higher *B. decumbens* tiller turnover in spring and summer, resulting in more young tillers in the pasture. Lowering the pasture height to 15 cm in winter increased the TER by 35% compared to 25 cm. On the other hand, the management strategies did not influence the TMR. Hence, to optimize the turnover of tillers in the pasture, *B. decumbens* should be managed, under continuous stocking, to have 15 cm in height in winter and 25 cm in spring and summer.

### 5.1.09 Selective grazing, patch stability and vegetation dynamics in a rotationally-grazed pasture

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The lack of data on interactions between grazing intensity and livestock species makes it difficult to propose recommendations for the management of biodiversity and production in grassland ecosystems. A productive grassland area was therefore divided into 12 plots that were rotationally grazed by heifers at a high or a low stocking rate or by ewes at the same low stocking rate. Stocking rate appeared more important than grazer species in affecting the initial direction of community changes. Both heifers and ewes preferentially selected for bites containing legumes and forbs, and avoided reproductive grass. In lightly grazed plots, no significant effect of grazer species on sward botanical composition could be detected after four years of treatment application, though legumes were on average three-fold more abundant in plots grazed by heifers than plots grazed by ewes. Selective grazing on legumes and forbs, and avoidance of reproductive grass, can partly explain the stability of fine-scale grazing patterns in plots that were used by heifers. Cattle grazing would thus favour the creation of relatively stable open patches enabling prostrate forbs and legumes to compete with tall grasses. This could result in divergent vegetation dynamics within plots.

### 5.1.10 Balance between production and biodiversity in two upland dairy grazing systems

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More stringent requirements for PDO (protected designation of origin) cheese products and societal demands are encouraging farmers to promote grazing and favour biodiversity. Trials were conducted for two years in an upland region to compare animal performance, grass productivity and biodiversity in two dairy grazing systems: DIV–, managed with rotational grazing on former temporary grassland at a ‘high’ stocking rate (1.8 LU ha<sup>-1</sup>); and DIV+, managed with continuous grazing on diversified permanent grassland at a ‘low’ stocking rate (1.0 LU ha<sup>-1</sup>). Twelve cows per system were compared, with no concentrate supplementation. At the beginning of the grazing season, DIV+ showed higher milk production than DIV– (+ 2.1 kg d<sup>-1</sup> per cow), due to a greater herbage allowance and better quality of grass selected by cows. Two months later an inversion of the milk production curves was observed, following the fall in grass nutritional value. From July to September, DIV– allowed a similar milk

production to that of DIV+ in 2008, and a higher production per cow in 2009 (+ 1.5 kg d<sup>-1</sup>). Animals' weight was not affected by the systems. Insect and flora biodiversity was greater in DIV+. This study supports that the two upland dairy systems have both advantages and limitations in the context of PDO cheese production.

#### **5.1.11 Long term performance of an artificial pasture vegetation under Mediterranean conditions in Turkey**

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A study on artificial pasture was conducted during 2002-09 in the experimental field of a private farm at Aydin, Turkey, which was under typical Mediterranean climatic conditions. Some promising legumes in this environment (*Medicago sativa*, *Lotus corniculatus*, *Trifolium resupinatum*) and some grasses (*Bromus inermis*, *Dactylis glomerata*, *Festuca arundinacea*, *Arrhenatherum elatius*) as well as *Sanguisorba minor* were sown as a mixture. Stand yield characteristics and crop performances of sward were tested for 7 yrs under cattle grazing. The results indicated the adverse effects of Mediterranean climate and to some extent of grazing on the yield and cover characteristics of some mixture crop material, particularly *T. resupinatum*, *B. inermis* and *D. glomerata*. In contrast, *F. arundinacea*, *M. sativa*, *A. elatius* and *L. corniculatus* displayed higher contributions to total yield.

#### **5.1.12 The effect of nitrogen on yield and composition of grass clover swards at three sites in Ireland: a comparison of six commonly grown species**

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With the trend to reduce nitrogen (N) use in grassland systems it is apt to reappraise the performance of different forage grasses. Here, we compare the performance of the most widely grown species, perennial ryegrass, to that of four alternative species at three different N levels. Over three years, cocksfoot, meadow fescue, tall fescue, Timothy, diploid and tetraploid perennial ryegrass, were grown along with a companion white clover at three sites across Ireland. Plants were grown at three N levels: high (420 kg ha<sup>-1</sup> N), medium (210 kg ha<sup>-1</sup> N) and low (105 kg ha<sup>-1</sup> N), in a randomised block design. Differences between sites were significant, with the two more northerly sites showing a large increase in clover in low N plots, such that clover typically accounted for more than 50% of the yield by year three. Timothy and tall fescue showed potential to out yield perennial ryegrass, particularly at low and medium N. Although the results are strictly limited to the cultivars tested, the consistently high yields from Timothy and tall fescue at low and medium N suggest they are worthy of further investigation. However, care must be taken in marginal sites where the combination of limited N and poor growing conditions can result in the over abundance of clover.

### 5.1.13 Evaluation of leaf tensile strength of selected grass genotypes

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The objective of this work was to evaluate leaf tensile strength of selected pasture grass species and cultivars. The investigations were carried out in 2008-2009 on plant material obtained from two cultivar testing experiments, in which *Dactylis glomerata* (10 cultivars), *Festuca arundinacea* (10 cvs), *Festuca pratensis* (15 cvs), *Lolium perenne* (16 2x and 15 4x cvs) and *Phleum pratense* (10 cvs) were analysed. Leaf tensile strength was estimated on fully developed leaf blades using a prototype testing stand for measuring tensile strength of biological material designed on the basis of a sub-assemblies of the Höttinger Baldwin Messtechnik (HBM) Company. The dry matter weight and size of leaves were also determined. Leaf tensile strength of investigated species ranged from 3.64 N (*Lolium perenne* 2x) to 22.16 N (*Dactylis glomerata*). The differentiation of cultivars within species was also high and statistically significant. The obtained results help to better understand the impact of plant functional traits on forage intake.

### 5.1.14 Performance of *Lolium perenne* with *Trifolium repens*, and spontaneous grasses with *Trifolium repens*, in Azores

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A three-year experiment was conducted in the interior of Terceira Island, Azores, at 400 meters of altitude, to evaluate yield and quality of the herbage of a seeded pasture of *Lolium perenne* and *Trifolium repens* (LPxTR) and of a pasture of spontaneous species and introduced *Trifolium repens* (SPxTR), both harvested at four-week intervals. The average LPxTR pasture dry matter (DM) productions were 6368, 6671, 7340, 7960 kg ha<sup>-1</sup> y<sup>-1</sup> and the average SPxTR DM productions were 5176, 5266, 6887, 7038 kg ha<sup>-1</sup> y<sup>-1</sup> for respectively 0, 100, 200 and 300 kg ha<sup>-1</sup> y<sup>-1</sup> N. Increasing nitrogen fertilisation increased yield in either pasture only in the first two years of the study but not in the third. Nitrogen fertilization never significantly increased yields in summer, increased yields in two springs and increased yields in only one winter (the driest). The two pastures had a similar pattern of dry matter production. For both pastures the highest fibre concentrations were in summer and the lowest crude protein concentrations were in the spring. In the management of a *L. perenne* x *T. repens* pasture care should be taken to avoid infestation by spontaneous grasses as this decreases pasture yield, especially under summer drought and low N rates.

### 5.1.15 Livestock production and restoration of degraded steppes in Ukraine

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Steppes are natural grasslands with a typical continental climate, on average 400 mm annual rainfall, situated from Hungary to Mongolia. Over the past century the extent of steppe areas has declined dramatically as a result of their transformation to arable land. Large areas show signs of serious degradation and soil erosion, resulting in loss of productivity. Opportunities for restoration of degraded steppe areas around Luhansk Oblast in eastern Ukraine have been studied. Grazing and livestock production can be an important management tool to conserve and restore the steppes and their biodiversity. Based on the feeding values of steppe grasses and nutritional requirements and intake of cattle, we observed that steppe grasses were not sufficient for ruminant nutrition in some seasons. The conclusion was that livestock production and grazing on steppes can be profitable when integrated in a mixed farming system with fodder production on arable land situated near steppes.

### 5.1.16 Comparison of methods for estimating forage mass in grazing systems of the south Brazilian Pampas

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We evaluated two different methods of indirect forage mass estimate on two large-scale grazing experiments in the south Brazilian Pampas. HFRO Sward stick (SW) and Rising Plate meter (RPM) forage mass estimates were compared to the forage mass obtained with representative cutting samples in two experiments varying in grazing intensity and fertilization level. The investigations indicated a clear linearity between SW, RPM and the forage mass. However, there was a high variation between measurements. The sward structure was influenced by the presence of tall grasses, which belongs to the less frequently grazed areas in the paddock. Although the SW performed marginally better than the RPM, the latter had a limited application in swards or sward areas with taller species (> 25 cm). In conclusion, with  $R^2 = 0.92$  (CV = 27.1; RMSE = 840) for SW and  $R^2 = 0.88$  (CV = 32.9; RMSE = 1017) for RPM, both methods were applicable for different grazing intensities of the complex natural grassland in the subtropics.

### 5.1.17 Post-grazing height and productivity of white clover-based systems of dairy production

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The objective was to examine the impact of post-grazing height (PGH) on annual herbage production and milk production by spring-calving dairy cows grazing grass-clover (*Trifolium repens* L.) swards under rotational grazing management throughout three consecutive grazing seasons (2007 to 2009) at Solohead Research Farm (52° 51' N, 08° 21' W). There were three treatments involving PGH of 6, 5 and 4 cm, each maintained throughout the grazing season (mid-February to mid-November). Each treatment was stocked at 2.1 cows per ha, with an average of 21 cows per treatment each year. Herbage dry matter (DM) yields [mean (s.e.) Mg ha<sup>-1</sup>] increased ( $P < 0.05$ ) with lower PGH from 9.92 to 11.22 (0.255). There were no differences in the clover content of herbage DM; 195 (14.8) g kg<sup>-1</sup> or in clover stolon DM mass; 542 (40.6) kg ha<sup>-1</sup>. There were no differences in yields (kg cow<sup>-1</sup>) of milk; 6177 (94.2), fat; 263 (4.5), protein; 222 (3.3) or lactose; 287 (4.5) between the PGH treatments. There were no differences in cow live-weight or body condition score. A PGH of 4 cm substantially increased herbage DM yields with no significant impact on dairy cow performance.

### 5.1.18 Growth and quality of multispecies pastures harvested at a fixed sward height

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Two multispecies swards in Central Norway were repeatedly cut as soon as they reached 15 cm sward height in order to simulate rotational grazing. From early May to early September swards were cut nine (2007) or seven (2008, 2009) times at a stubble height of 7 cm. Despite challenging overwintering conditions, 'Ryegrass' (*Lolium perenne* and *Trifolium repens*) yielded no less than 'Winterhardy' in which *Festuca pratensis*, *Phleum pratense* and *Poa pratense* were the dominating grass species in mixture with *Trifolium repens*. The quality of 'Ryegrass' as analysed by NIRS was higher than that of 'Winterhardy'. However, differences between mixtures were less than those between cuts. Early spring growths were low in NDF and high in water soluble carbohydrates (WSC) and digestible dry matter. Cuts later in the growing season were lower in WSC and less digestible, whereas from July to September, higher in crude protein due to high contents of *Trifolium repens*.

### **5.1.19 The use of grazing in intensive dairy production and assessment of farmers' attitude towards grazing**

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The intensification and specialization of dairy farming in Western Europe has decreased the use of grazing. This paper looks at the development based on information from a questionnaire which was sent to 800 Danish dairy farmers with more than 100 cows. Completed questionnaires were obtained for 396 farms, of which 347 were conventional and 49 organic certified. Of the conventional farms only 25% ( $n = 87$ ) had grazing cows, while 62% ( $n = 215$ ) of the farms had grazing heifers. The non-grazing - defined as farm without access to pasture for the cows - conventional farms had more cows and land than the grazing farms, and were also characterized by having a larger percentage using robot milking and change of ownership since year 2000, which, together with the largest increase in herd size since year 2000, illustrates that the trend from grazing to non-grazing indeed seems to be part of the ongoing intensification. Stocking rate was identical in the two groups, but in the non-grazing group fewer farms had the theoretical possibility of access to at least 0.3 ha per cow of arable land for grazing, and at these farms the cows had to cross more roads and walk further to get to the far end of the pasture.

### **5.1.20 Herbage productivity and quality of mountain grassland under different forage management systems**

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Our objective was to evaluate the effects of 4 defoliation practices on productivity and quality of grassland. Treatments were cattle grazing followed by sheep grazing (CS); cattle grazing (2 rotations) followed by one hay cut, and then cattle grazing for the rest of season (CHC); two hay cuts (spring and autumn) and cattle rotational grazing between hay cuts (HCH); one hay cut (spring) followed by cattle rotational grazing at the rest of growing season (HC). Available herbage mass was similar between the treatments (mean  $9.75 \text{ t ha}^{-1}$ ,  $P > 0.05$ ). The greatest rejected herbage mass was under CHC ( $2.37 \text{ t ha}^{-1}$ ), and the lowest under HCH ( $0.71 \text{ t ha}^{-1}$ ). The highest crude protein content (CP) was under CHC and CS (mean  $202.2 \text{ g kg}^{-1}$ ), and the lowest under HCH ( $164.8 \text{ g kg}^{-1}$ ). A significant treatment  $\times$  year interaction for CP was found ( $P < 0.01$ ). Only HC had the similar CP in all investigated years (mean  $183.9 \text{ g kg}^{-1}$ ,  $P > 0.05$ ). Acid detergent fibre content was similar at all treatments and years (mean  $311.6 \text{ g kg}^{-1}$ ). There were no significant differences between treatments in neutral detergent fibre content (NDF) (mean  $487.78 \text{ g kg}^{-1}$ ), but there were differences between years ( $P < 0.01$ ).



### 5.1.21 The effect of pasture herbage mass on dairy cow ruminal pH

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The objective of this study was to investigate the effects of different herbage mass treatments on dairy cow ruminal pH. A systems study with three separate farmlets was established. The three treatments were i) low herbage dry matter (DM) mass [LM] (1000 kg ha<sup>-1</sup>), ii) medium herbage DM mass [MM] (1600 kg ha<sup>-1</sup>), iii) high herbage DM mass [HM] (2200 kg ha<sup>-1</sup>). Six lactating rumen-cannulated dairy cows were arranged into two 3 x 3 Latin squares. Each period lasted two weeks. Ruminal pH was measured on days 10 and 11 of each period by means of an indwelling rumen pH probe connected to a datalogger, which recorded ruminal pH every 60 seconds. There was no difference in the average ruminal pH of dairy cows grazing grass of three different herbage masses (LM = 5.90, MM = 6.09, HM = 5.98) or on the amount of time during which ruminal pH was less than pH 5.5 (LM = 187, MM = 43, HM = 216 min d<sup>-1</sup>). Further work is needed to expand the limited data available on ruminal pH in grazing dairy cows and to explore the mechanisms by which the low ruminal pH values seen in grazing systems are attained without the expected problems of lameness and reduced milk fat concentration.

### 5.1.22 Patterns of sward height reduction in a tropical pasture grazed by dairy cows

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The aim was to study the changes on sward height and herbage intake measured during grazing of dairy cows on a pearl millet (*Pennisetum glaucum* (L.) R. Br.) pasture under a rotational grazing system. The treatments (60-20; 60-10; 40-20; 40-10) consisted of the combination of two pre-grazing (60 and 40 cm) and two post-grazing (20 and 10 cm) sward heights. Measurements of sward height were made every 10 minutes along the grazing periods with 60 minutes duration. For the sward height reduction, treatment 60-10 seems to be the management strategy that most constrains the animals' grazing. Bite rate did not differ among treatments. The highest intake rate was observed in the treatment 60-20, which indicates that this management strategy is the best for dairy cows in a pearl millet pasture.

### 5.1.23 Beef fattening on grazed leys: interest of tall fescue

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Experiments were conducted at four sites from 2007 to 2009 comparing two grass-clover mixtures (dominant grass: M1 perennial ryegrass; M2 tall fescue) grazed by young cattle. During the first two years, annual DM yield exceeded 12 t y<sup>-1</sup>. Under dryer conditions, in 2009, M2 grew better than M1. Sward height and organic matter digestibility of both mixtures were similar, resulting in comparable animal performance. Tall fescue was shown to be a promising component for creation of pastures in dry conditions.

### 5.1.24 The effects of the nitrification inhibitor dicyandiamide (DCD) on herbage production when applied at different times and rates in the autumn and spring

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Nitrification inhibitors have been proposed as management tools to reduce nitrate (NO<sub>3</sub><sup>-</sup>) leaching and denitrification, as well as increasing the availability of nitrogen (N) for the growing sward (Serna *et al.*, 1995). The objective of this experiment was to observe the effects, if any, of DCD on herbage production when applied at different times and rates in the autumn and winter. A randomised block design experiment with three replicates of each treatment was conducted at two sites - Moorepark (MPK) and Ballydague (BD). The soils were: (1) a free-draining acid brown earth of sandy loam to loam in texture at MPK, and (2) a moderate to heavy brown earth of sandy loam texture with evidence of an iron pan at BD. Swards were predominantly perennial ryegrass. Annual precipitation was 1052 mm in 2008 and 1293 mm in 2009. The factors that were tested in this experiment were as follows: urine application, fertiliser application, DCD rate and time application. Annual herbage production was significantly increased at both sites when fertiliser was applied ( $P < 0.001$ ). There was a significant effect ( $P < 0.01$ ) of urine application on annual herbage production at MPK and for the November treatment only at BD. There was no significant effect of DCD rate or application time on annual herbage production at either site.

### 5.1.25 Substitution rate and milk response to maize silage supplementation of dairy cows grazing low-mass pastures

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When extending the grazing season into autumn, the grazing of low-mass pastures is almost inevitable, potentially limiting pasture availability and animal performance. An experiment was carried out to determine the substitution rate and the milk response to maize silage (zero vs. 8 kg d<sup>-1</sup> of dry matter (DM) of a mixture of 7/1 of maize silage and soyabean meal) of dairy cows grazing low-mass swards at two pasture allowances (low = 18 vs. high = 30 kg cow<sup>-1</sup> d<sup>-1</sup> DM above 2.5 cm). Twelve multiparous Holstein cows in late lactation, producing 18 kg FCM at the beginning of the experiment, were used in a 4 × 4 Latin square design during four 14-d periods. Pregrazing pasture DM mass, platometer height and OMD of the pasture were 1780 kg ha<sup>-1</sup>, 6.3 cm and 0.62, respectively. Maize silage supplementation decreased pasture DM intake by 4.0 and 5.8 kg d<sup>-1</sup> at low and high pasture allowance, respectively (substitution rate: 0.51 vs. 0.75). Milk response averaged + 0.67 kg of milk per kg of supplement, whatever the pasture allowance was. The low substitution rate combined with the high milk response suggests that energy intake from pasture was restricted. This restriction seems more related to the low quality than to the low mass of the pasture.

### 5.1.26 Impacts of autumn cutting height and interval on annual productivity of a white clover-grass sward.

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This experiment measured the effects of autumn cutting interval and cutting height on annual herbage production and persistence of a white clover (*Trifolium repens* L.) and predominantly perennial ryegrass (*Lolium perenne* L.) sward in Ireland. The experiment involved four cutting intervals (21, 42, 56 or 84 days) and four cutting heights (approximately 2.7, 3.6, 5.4 or 6.0 cm above ground level). Plots were laid out in a randomized complete block design with five replications. Treatments were imposed from July to December 2008. From March to June 2009 all plots were harvested at an interval of 28 days and a cutting height of 4.5 cm. Grass yield, clover yield and clover stolon mass were measured using standard protocols. There was no ( $P > 0.05$ ) interaction between cutting interval and cutting height for any of the variables measured. Highest ( $P < 0.001$ ) herbage and clover yields were associated with the 42-day interval and with the two lower cutting heights. Lowest grass yield and lowest stolon mass were associated with the 21-day interval ( $P < 0.001$ ). A 42-day interval with a low cutting height (2.7 to 3.6 cm) in autumn gave the most desirable results in terms of herbage yield and stolon mass in the following spring and summer.

### **5.1.27 Nutritive value of meadows in the Northeast of Portugal**

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Meadows continue to be the most important source of pasture and hay for beef cattle production in the mountain regions of the Northeast of Portugal. To evaluate the nutritive value, crude protein (CP) and *in vitro* organic matter digestibility (IVOMD), seven hay meadows were studied. The results obtained showed that the lowest values of CP and IVOMD occurred at the hay-cutting period and were similar to those obtained at the end of autumn. The highest values occurred at the beginning of spring when meadows are in active growth. The nutritive value of meadows is in line with the type of plant communities and the agroecological potential of the environments where they are located.

### **5.1.28 Productivity and floristic diversity of a continuous grazing system on short swards in mountainous regions of Austria**

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Austrian farmers cast major doubts on a successful implementation of a continuous grazing system on short swards due to the assumption it may cause high ecological and mechanical stress on grassland. Productivity, forage quality and botanical composition of a continuous grazing system have therefore been investigated for a period of six years on a mountainous site in Central Austria. Growth rate, digestibility of organic matter, energy concentration and content of crude nutrients were analysed, as well as the botanical development of the swards. Even under unfavourable climatic conditions, in mountainous areas continuous grazing on short swards resulted in high yields and excellent forage quality without any negative botanical impact on the grassland ecosystem during the observation period. The results suggest that this grazing system can be recommended for practice in Austria.

### 5.1.29 Voluntary intake of forages from permanent grasslands with different quality in suckler cows

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Objectively determined voluntary intake of forage from permanent grasslands is necessary for ensuring both the required intake of nutrients by different cattle categories and for appropriate grassland management. This paper presents the results on voluntary intake of high dry matter-content silages made from the second cuts of permanent grasslands. Grasslands were managed as follows: fertilised treatments (N<sub>90</sub>P<sub>30</sub>K<sub>60</sub>; pure nutrients), intensive utilisation (4 cuts per year), medium intensive utilisation (3 cuts per year), low intensive utilisation (2 cuts per year); and unfertilised treatment, extensive utilisation (2 cuts per year). The experiment was conducted on 6 suckler cows at the Research Institute for Cattle Breeding, Ltd. using feeding troughs (Comp. Insentec). Voluntary dry matter (DM) intake was influenced by intensity of grassland management increasing intensity of use increased the voluntary dry matter intake. The average DM intake for the particular treatments ranged from 15.2 to 23.9 g kg<sup>-1</sup> live weight (LW). A significant decrease in DM intake in connection with increasing content of crude fibre in forage was also found. It is important to continue studies with different cattle categories fed on permanent grassland.

### 5.1.30 Effect of two pre-grazing herbage masses and daily herbage allowances on perennial ryegrass sward characteristics

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The aim of this study was to investigate the effect of two pre-grazing herbage masses (HM) and daily herbage allowances (DHA) on perennial ryegrass sward structure in the upper and lower sward horizon (> and < 4 cm). Sixty-four spring-calving Holstein Friesian dairy cows (24 primiparous and 40 multiparous) were balanced on calving date, lactation number, milk yield, body weight and body condition score, and randomly assigned to one of four grazing treatments (n = 16) in a 2 x 2 factorial design. Animals were offered two levels of pre-grazing dry matter HM, low (L – 1600 kg ha<sup>-1</sup>) or high (H – 2400 kg ha<sup>-1</sup>) and two levels of dry matter DHA, low (L – 15 kg cow<sup>-1</sup> d<sup>-1</sup>) or high (H – 20 kg cow<sup>-1</sup> d<sup>-1</sup>). Thus the four treatments were LL, LH, HL and HH. The experiment was carried out from April to October. Pre- and post-grazing heights were measured and herbage utilization was calculated. Leaf, stem and dead proportions were determined. The results indicate that by maintaining 1600 kg ha<sup>-1</sup> and offering cows 15 kg cow<sup>-1</sup> d<sup>-1</sup> it is possible to achieve high herbage utilization and this will improve sward quality. These swards showed an increased leaf:stem ratio and lower dead proportion which is linked to higher nutritive value in the swards.

### 5.1.31 Wood-pastures of Hungary, a disappearing agrosilvopastoral system

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There are still numerous wood-pastures hidden among the hills of Hungary. This land use type has played a significant role in the pristine grass-based and extensive livestock keeping husbandry of Hungary. Wood-pastures are forest-grass habitat complexes, a kind of silvopastoral systems created by anthropogenic influences. Agriculture and forestry have changed a lot during the past 150-200 years, and have been intensified since the 1950s. Livestock feeding shifted towards the increased use of grain-based feed, while the importance of pastures started to decrease. The old wood-pastures being used until the 1950s or 1980s started to reforest when grazing and pasture cleaning ceased. Today, the characteristic pasture shrub species grow over the open grasses among the dispersed veteran trees and seedlings of the evolving forests. Consequently, a land use type that had evolved during centuries, and which had been used until recently, falls into oblivion. Due to their diversity, landscape, natural and conservation values, wood-pastures play a role in landscape protection and conservation management nowadays. There are several opportunities to sustain these habitats within the confines of extensive livestock keeping (again), such as adaptation to climate change, tourism or recreation.

### 5.1.32 Effect of entry time to a daily strip on daily weight gain and nitrogen balance

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Twenty-four Holstein-Friesian male calves ( $132.9 \pm 6.3$  kg BW) divided in 3 blocks (8 animals block<sup>-1</sup>) grazing *Avena sativa*, were used to assess the effect of entry time to a daily strip on daily weight gain (DWG; 54 d). Nitrogen balance was estimated in animals from block 1 (n = 8). Animals had access to an individual daily grazing strip either at 8:30 (M) or at 14:30 (A). Herbage allowance on a dry matter basis was 4.5% of BW. Individual dry matter intake (DMI) and faecal output were estimated by the *n*-alkane technique. Pasture nitrogen content was lower and non-structural carbohydrates content was higher in A compared with M. Animals were weighed on days 1, 18 and 54 after a 48-hour fast. Data were analysed by ANOVA according to a complete block design. DMI and DWG were not affected by treatments ( $P > 0.05$ ). However, DWG was 21% higher in treatment A compared to M in blocks 2 and 3 ( $P < 0.03$ , n = 16) (0.790 vs. 0.650 kg d<sup>-1</sup>). Nitrogen intake, N retention, N faecal excretion and N excreted in urine were not affected by treatments.

### 5.1.33 Suitability of grass species on equine pasture: water soluble carbohydrates and grass preferences by horses

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Suitability of timothy (T; *Phleum pratense* L.), meadow fescue (MF; *Festuca pratensis* L.) and tall fescue (TF; *F. arundinacea* Schreb.) and of T-MF, T-TF and TF-Kentucky bluegrass (KB; *Poa pratensis* L.) mixtures for equine pasture was studied. Total area of 240 m x 240 m was divided into three equal paddocks. Each had the six treatments randomized in four blocks. Paddocks were grazed rotationally for 10 – 14 days with ten Finnhorse mares in May-August 2008. Water soluble carbohydrates (WSC) content of grass was measured and behaviour observations of grass preferences were made. WSC content in dry matter averaged 238 g kg<sup>-1</sup> on 14 May and 74 g kg<sup>-1</sup> on 26 August. In spring, T had significantly higher ( $P < 0.001$ ) and TF had lower ( $P < 0.05$ ) WSC content compared to other grasses. Based on grazing behaviour, the mares preferred TF-KB over other grasses ( $P < 0.001$ ). T, TF and T-TF were preferred secondly and were not statistically different. MF was the least preferred. Low WSC content and good preference by horses makes TF an interesting option for horse pastures.

### 5.1.34 Potassium effect on pasture yield and its composition in management of an old permanent pasture

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In pastures, potassium (K) can be one of the essential elements. An experiment was conducted over two periods (1961-1964 and 2005-2008) on a loamy *Endocalcari-Epihypogleyic Cambisol* cultivated soil, following the same experimental design. The focus was to estimate dry matter (DM) yield and botanical composition of the pasture in relation to different K rates. K rates influenced *botanical composition* in pastures and white clover (*Trifolium repens* L.) content decreased without the use of potassium. The annual DM yield was significantly affected by PK applications compared with the treatments without fertilizers. A regular application of PK in a long-term pasture sward makes it possible to maintain a good sward with a sufficient amount of legumes and a rather stable DM yield. In an older sward, the higher potassium rate exhibited a significant advantage over the lower rates.

### 5.1.35 Morphological characteristics and tiller population density of aruana guineagrass subjected to frequencies and severities of grazing by sheep

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The objective of the experiment was to evaluate morphological characteristics and tiller population density of *Panicum maximum* cv Aruana subjected to frequencies and severities of grazing by sheep. Frequencies of grazing corresponded to interruption of regrowth at 95 and 98% of light interception (LI) by sward canopy, and severities corresponded to post-grazing heights of 10 and 15 cm. Treatments were assigned to experimental units (200 m<sup>2</sup> plots) according to a 2 x 2 factorial arrangement in a completely randomised design, with three replications. Measurements of morphological characteristics were performed on 20 randomly chosen tillers per plot. Grazing after the 95% LI condition resulted in significant stem elongation, particularly during autumn, causing difficulties to maintain the post-grazing target of 10 cm. The results indicate the importance of controlling sward conditions during regrowth, highlighting the importance of controlling grazing frequency as a means of minimising stem elongation and consequent reduction in nutritive value of the produced herbage. In this context, sward height is an effective and efficient field indicator to monitor the process.

### 5.1.36 Continuous grazing in comparison to cutting management on an organic meadow in the eastern Alps

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Continuous grazing is an appropriate pasture system for dairy cows in low input milk production systems like organic farming. Grazing increases for economic reasons and is also caused by regulations in organic farming. If a dairy farm converts a pasture-based system, cows will start grazing on a cutting-managed meadow. Due to the utilisation changing from cutting to grazing, a conversion of the botanical composition and the quantity and quality yield is expected. To document and assess such conversions, a three-year field trial was carried out on the organic grassland and dairy farm of the AREC Raumberg-Gumpenstein between 2007 and 2009. In this study, changes in the botanical composition were found. In contrast to botanical composition, no significant differences between below-ground biomass and quality yield (CP and NEL) could be detected, although the harvest sward yields of the grazing sward were significantly less than in the cutting variant in the years 2007 and 2008.



### **5.1.37 Changing towards a seasonal low-input pastoral dairy production system in mountainous regions of Austria – results from pilot farms during reorganisation**

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In order to obtain novel management and economic information on pastoral milk production in mountainous regions a research project with six pilot dairy farms (5 organic, 1 low input) was carried out in Austria. The farms were supervised during the reorganisation period aiming at a seasonal milk production system with a calving period in the winter-spring season. Within the observation period of three years a strict annual cycle in milk production and reproduction was only realised on two farms. An average pasture proportion of 42% (range 26 to 61%) of the total DM intake per year was realized. On four farms, which fed little supplementary feed during the grazing period, a pasture proportion of 50% of the total DM intake per year was realized in the last project year. With an input of only 470 kg cow<sup>-1</sup> y<sup>-1</sup> DM concentrate (8% of DM intake) a milk performance of 5542 kg with 4.02% fat and 3.34 % protein was achieved on those four farms. The results indicate that the full grazing strategy with seasonal calving is feasible for animal health reasons in Austria. Despite lower milk yield per cow, lower marginal costs per unit milk are possible under well managed grazing systems.

### **5.1.38 Impact of grazing intensity on performance of sheep in the Inner Mongolian steppe, China**

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In Inner Mongolia, China, grassland degradation due to overgrazing reduces grassland and animal productivity and leads to desertification with severe ecological and economical consequences. In 2005, 2006, and 2007, a grazing experiment was conducted in the Inner Mongolian steppe to analyse the effects of six different grazing intensities (GI) on quality of ingested herbage, feed intake and animal performance. Sheep were continuously kept on the plots throughout the grazing season (July – September). GI strongly influenced herbage mass

and quality. However, digestibility of organic matter, feed intake, and live weight gain were not different between GIs. Feed intake as well as live weight gain per hectare increased with increasing GI. Hence, intensive grazing does not reduce performance of individual animals but increases productivity per area and therefore, income for farmers. However, in dry years a lack of herbage mass on offer on heavily grazed pastures may require the purchase of additional forage for animals at the end of the vegetation period or the untimely sale of animals. Long-term negative effects of high GIs on grassland productivity are likely.

### **5.1.39 Efficiency of Swiss and New Zealand dairy breeds under grazing conditions on Swiss dairy farms**

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The objective of the study was to investigate over three years (2007 – 2009) the attributes of cows adapted to a pasture-based seasonal milk production system (New Zealand Holstein Friesian) under Swiss conditions and to compare them with Swiss breeds. For this purpose, pairs of Swiss (CH) and New Zealand (NZHF) cows were established (100 cows in total) with similar age and calving date on 15 commercial farms. Body weight (BW) in the first and second lactations were higher in CH cows than in NZHF cows (in 2007, 544 vs. 477 kg,  $P < 0.001$ ; in 2008, 578 vs. 517 kg,  $P < 0.001$ ). Milk yield was similar in CH and NZ cows for the initial two years but the milk of NZ cows had higher fat and protein content. The NZ cows produced more energy corrected milk (ECM) in the second lactation than the CH cows (6017 vs. 5470 kg,  $P < 0.001$ ). As a consequence, the efficiency (ECM per metabolic BW, kg kg<sup>-1</sup>) was higher in NZ than in CH cows in both years (2007, 49.7 vs. 44.2,  $P < 0.001$ ; 2008, 55.6 vs. 46.6,  $P < 0.001$ ). It is therefore concluded that New Zealand Holstein Friesians are more efficient in a pasture-based milk production system than Swiss breeds.

### **5.1.40 Dry matter production of perennial ryegrass swards following poaching damage on a free-draining brown earth soil**

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Poaching affects pasture production. This study investigated the effects of poaching on herbage production and tiller density of a perennial ryegrass sward on a free-draining brown earth soil. Twenty-four plots were established in a two-year-old perennial ryegrass (*Lolium perenne* L.) sward at Teagasc Moorepark Dairy Production Centre, Ireland. Four treatments were applied: i) Control (C), ii) Barely damaged (BR), iii) Intermediately damaged (ID), and

iv) Badly damaged (BD). Forty-five cows were used to create the desired level of damage. Half of each plot was rolled four weeks after the treatments had been applied (12 March 2009). Once preceding, and five times subsequent to treatments being applied, herbage mass was estimated on each treatment plot. Tiller density was assessed once before and twice after the poaching event. Plots were fertilised with 30 kg nitrogen (N) per ha in the form of calcium ammonium nitrate (CAN) after each grazing. After poaching, the BD plots produced 691 kg dry matter (DM) per ha (30%) less than C plots. However, cumulative DM yields were not different between treatments (10383 kg ha<sup>-1</sup>) and tiller density was not affected by poaching or rolling. This study suggests that perennial ryegrass swards on a free-draining earth soil may overcome a single event of substantial treading damage in spring.

#### **5.1.41 The grazing selectivity of Konik horses on grasslands located in Biebrza National Park**

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The aim of the study was to evaluate grazing preferences of Polish primitive horses (Koniks) grazing on peatlands in Biebrza National Park in Northeastern Poland. The studies were carried out in three periods (spring, early and late summer) for which the selectivity ratio was calculated on the basis of grazing time and percentage of grazing horses on the specific grassland area. During the vegetative season the highest percent of grazing horses was observed in sedge community with *Carex nigra*. Communities *Molinia caerulea* and willow-birch thicket were grazed mostly in spring. In June, Koniks grazed on swards dominated by *Agrostis canina* and swards dominated by *C. nigra*, *M. caerulea* and *Potentilla erecta*. In August thicket and sedges were used more. The changing values of selectivity ratio, representing different levels of palatability of communities during the vegetative season, show that communities of *P. anserina* and *M. caerulea* are mostly exploited in spring, whereas during summer Koniks choose *C. nigra*, *M. caerulea* and *P. erecta*. A positive effect of horse grazing on grassland stability was also observed during the study.

#### **5.1.42 The impact of white clover-lucerne interactions in the swards on pasture seasonal productivity**

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White clover tolerates intensive grazing and is the most beneficial pasture legume in many regions of Europe. However, white clover has some drawbacks such as insufficient tolerance of unfavourable abiotic conditions. The use of two or more legume species in mixtures could mitigate some disadvantages. Different swards consisting of *Trifolium repens* L., *Medicago sativa* L., *Lolium perenne* L., *Poa pratensis* L. were investigated under grazing management on a gleyic loamy *Cambisol*. The proportion of legumes in the legume/grass mixtures fluctuated both from year to year and within individual growth periods, and was very strongly influenced by environmental stress. As a result, legume yields affected the sward composition

and total yield. The yield of legumes in the swards consisting of lucerne after ten years of grazing accounted for nearly half and even more than half of the total sward yield. The white clover-lucerne-grass sward outyielded white clover-grass sward. The content of white clover decreased more rapidly than that of lucerne. A positive effect of lucerne was obtained on yield and its distribution over the grazing season. The results of white clover persistence and yields confirm that some attributes are limited and still need to be improved.

#### **5.1.43 Establishment of a structure of cultures in Transylvanian Plain conditions to adapt forage production to drought**

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In recent years the intensification of drought phenomena during the vegetation period of plants has resulted in serious problems for Romanian farmers, and lead to partial or total loss of crops. This is also a common problem for fodder producing farmers in Transylvania. Introducing an assortment of some drought-resistant fodder plant species, like C<sub>4</sub> species, could represent a long-term solution for these farmers.

#### **5.1.44 Bite frequency as indicator for grass intake during grazing**

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The objective of this experiment was to explore the correlation between bite frequency of high yielding dairy cows, stocking density, milk yield and grass height. Bite frequency, in combination with grazing time and pre-grazing mass of grass, could be a valuable indicator for computing grass intake while grazing. Bite frequency was measured manually and by using accelerometers attached to the cows' heads. In this paper the results of the manually measured bite frequency related to initial milk yield per cow, grass length and pre-grazing mass of grass are presented. Individual cows were found to have large differences in bite frequencies. Bite frequency was not influenced by grass height, pre-grazing mass of grass or initial milk yield. Grass height differences were not large in the experiment.

## Session 5.2 Environmental benefits and risks

### The contribution of grass and clover root turnover to N leaching

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Sources of inorganic and organic N leaching from grass-clover mixtures at field sites in Denmark, Germany and Iceland were investigated. Grass or clover was labelled with <sup>15</sup>N-urea four times (autumn 2007, spring, summer and autumn 2008) prior to the leaching season in autumn and winter 2008. Soil water was sampled at 30 cm depth and analysed for <sup>15</sup>N-enrichment of dissolved inorganic N (DIN) and dissolved organic N (DON). Most <sup>15</sup>N was recovered in DON for both labelled grass and clover at all sites. At the Danish site, grass and clover contributed more to the DON pool than the DIN, whereas the opposite was observed at the German and Icelandic sites. The results show that both clover and grass contribute directly to N leaching from the root zone in mixtures, and that clover contribution is higher than grass. Furthermore, the present study indicates that roots active in the growth season prior to the drainage period contribute more to N leaching than roots active in the growth season the previous year, which is consistent with estimates of root longevity at the three sites.

### Winter grazing of grass-clover swards grown as green manure under the maritime climatic conditions of Northern Germany

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The aim of the study was to investigate if winter grazing is an alternative to mulching or harvesting grass-clover grown as green manure in organic farming, taking into account both N-leaching and pre-crop value to following arable crop. Against this background, yield and forage quality of three different legume species (*Trifolium repens*, *Trifolium pratense*, *Medicago sativa*), grown in binary mixtures with two grass species (*Lolium perenne*, *Festuca arundinacea*) on a loamy sand under the maritime climatic conditions of Northern Germany, respectively, had been examined before grazing the third growth in autumn or winter. Nitrate leaching losses during winter and yield of the following spring wheat have been recorded. Yield and forage quality of the sward were not significantly influenced by grass species while the interaction of legume species and grazing date had a high impact. Mulching the last growth and autumn grazing led to higher N-leaching than late winter grazing.

Winter grazing promises to be an interesting alternative to mulching or autumn grazing of grass-clover, because of a decreased risk of N leaching and the absence of negative effects on the following spring wheat.

### **Nitrogen excretions in dairy cows on a rotational grazing system: effects of fertilization type, days in the paddock and time period.**

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The present study aims to quantify nitrogen (N) excretions in dairy cows on a rotational grazing system with different types of fertilization (mineral N, slurry and compost) after 3 or 5 days in the paddock and during two different periods in June and September. Individual samples of faeces and urine were collected to assess N excretions from cows in the paddocks. The urea content in milk from the tank or from the individual cows was also measured. N intake was higher on day 3 compared to day 5 (465 vs. 425 g d<sup>-1</sup>,  $P < 0.001$ ) and in September as compared to June (488 vs. 400 g d<sup>-1</sup>,  $P < 0.001$ ) but was not influenced by the fertilization type. The amount of excreted urinary N was significantly higher in the mineral N group than in the two other groups (272 vs. 226 g d<sup>-1</sup>;  $P < 0.001$ ). The N excretion in faeces and urine decreased with days (92 vs. 84 g d<sup>-1</sup>,  $P < 0.01$ ; 256 vs. 228 g d<sup>-1</sup>,  $P < 0.001$  respectively for days 3 and 5). Urinary N excretion was lower in June than in September (181 vs. 302 g d<sup>-1</sup>,  $P < 0.001$ ) while the N excretion in the faeces was higher (96 vs. 80 g d<sup>-1</sup>,  $P < 0.01$ ).

#### **5.2.01 Water quality and the environmental use of livestock ponds**

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Many pastoral systems in Europe are included in protected areas. Management decisions in these ecosystems prioritize environmental concerns over stockbreeding objectives. The design and management of livestock ponds for wildlife is an example. This issue was examined in the Urbasa-Andia Natural Park, a 16100 ha mountain rangeland grazed by over 11700 livestock units. The effect of constructive traits of different ponds on the physicochemical and bacteriological quality of the water during the grazing period was evaluated, the amphibian populations living there were identified, and the interaction between wildlife conservation purposes and livestock production requirements was evaluated.

### 5.2.02 Residual effects of cutting and grazing on grass-clover growth

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The residual effect of cutting and grazing during the growing season was investigated in the spring and summer growth in an organic crop rotation with 1-4 year-old grass-clover mixtures of white clover (*Trifolium repens* L.) and perennial ryegrass (*Lolium perenne* L.) either with or without red clover (*Trifolium pratense* L.) and with and without slurry. The white clover mixtures had significantly higher yields in spring and summer in swards that were previously grazed compared to previously cut swards, when slurry was applied. The percentage of white clover in spring was considerably reduced by previous grazing and this caused the yield response of slurry application to be highest following grazing. A similar effect on the clover content was not found in the summer growth. With the inclusion of red clover in the sward the effect of previous management on spring yield disappeared. Red clover was very abundant under the cutting regime, while the contents were declining under grazing.

### 5.2.03 How does stocking rate influence biodiversity in a hill-range pasture continuously grazed by horses?

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Reduction of grazing intensity is assumed to favour biodiversity as a result of increased pasture heterogeneity, but there is a clear lack of data on the impact of grazing horses at different stocking rates. Over a 4-year study, we therefore recorded the species richness and abundance of vascular plants (25 fixed 50 cm × 50 cm quadrats per plot), ground beetles (18 pitfall traps per plot) and grasshoppers (three fixed 50 m long transects per plot) in a mesophile grassland that was continuously grazed by horses at either 1.8 or 1.1 LU ha<sup>-1</sup>. Average number of plant species per plot (n = 28) was not affected by stocking rate, but the creation of relatively stable short patches by horses enabled legumes to compete with tall grasses. Consequently, legume abundance increased from an average of 0.042 to 0.157 of plot area at the high stocking rate, while remaining stable around 0.082 in moderately grazed plots (SR×year: *P* = 0.024). Higher structural heterogeneity in these last plots led to favour ground-beetle and grasshopper populations, especially those species associated with tall swards. Reduction in stocking rate did not affect horse performance per ha.

#### **5.2.04 Silage maize in crop rotations with different grass mixtures – N balances and N leaching**

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The cultivation of maize in Germany is expanding due to its use as fodder or corn and increases in biogas production based on renewables. The biogas boom helped to make maize the most cultivated crop in the federal state of Lower Saxony in 2007. A further increase in maize production is, however, viewed with criticism, because it affects the landscape and its biodiversity and might pose a risk to groundwater protection. For future developments maize needs to be integrated in economically and ecologically sound crop rotations.

We tested the effect of different grass mixtures, with and without clover, reduced or moderate N supply, on yield and N leaching of corn as a follower crop in a 3-year field experiment on sandy soils. The yield of silage maize is an important factor in evaluating the suitability of such crops within a rotation, as is the amount of N leaching for the environmental impact of the whole system. We found that integrating maize in crop rotations with a reduced N input has the potential to achieve satisfying DM yields of 160 dt ha<sup>-1</sup> combined with lower risks of N leaching losses (60 kg ha<sup>-1</sup> versus 123 kg ha<sup>-1</sup> with high N input).

#### **5.2.05 Soil nitrogen, phosphorus and potassium contents on a dairy cattle pasture**

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On a pasture for dairy cattle (mean annual milk yield of approximately 9000 kg), that has been utilised continuously for over 50 years, the sward utilisation intensity, the date of sampling and the depth of sample collection significantly affected the soil nutrient status. From spring to autumn, the soil mineral nitrogen increased, predominantly in the form of nitrate. In summer and autumn, the highest quantities of mineral nitrogen (111 to 174 kg ha<sup>-1</sup>), predominantly as ammonium, were determined at 31–60 cm depth in the grazed paddocks. Phosphorus and potassium contents were low and not subjected to clear fluctuations in relation to the method of utilisation and the date or depth of soil sample collection. Mean contents of phosphorus ranged from 113 to 171 mg kg<sup>-1</sup> of soil and the highest quantities were found to occur on grazed plots.



### **5.2.06 Shortcut strategies to improve plant species richness after years of intensive management in moist grassland**

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In Denmark new wetland areas are established with the aim of reducing the nutrient load to the aquatic environment, and at some sites former lakes are re-established. They will attract people to enjoy the local amenity values. However, the grasslands around the lakes may need careful management to improve plant species richness after years of intensive agriculture. Therefore we imposed different shortcut restoration treatments to examine if improvement in the species richness could be optimised by initial nutrient removal or immobilisation. The three restoration treatments were: de-turfing, deep ploughing, and rough sawdust mulched into the topsoil, and these were compared with more usual grassland management strategies: two cuts and three cuts per year. The most efficient treatment in terms of nutrient reduction was topsoil removal, as assessed in the lowest Ellenberg-N index of the vegetation after this treatment. Sawdust mulch had only a very short-time effect, and in the following years it showed a faster increase in available nutrients than expected, resulting in the highest Ellenberg-N index. Removal of nutrients by cutting-only treatments gave intermediate responses, slower than the de-turfing treatment.

### **5.2.07 Cattle grazing on Swedish semi-natural pastures – how behaviour effects nutrient transport in the grazing area**

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The objective of this study was to examine the grazing behaviour of cattle on semi-natural pastures and how cattle behaviour relates to their urination and defaecation patterns. The research was carried out in nine semi-natural pastures, grazed by cattle of different breeds. On each site, different vegetation types were identified and mapped: dry, mesic, wet, shaded and previously fertilised. Three adult female cattle were followed for 24 hours. Every five minutes, an observer noted the behaviour of the animals (grazing/lying down/other) and which vegetation type the animal grazed. Continuous recordings were also taken of the time and location of defaecation and urination, using a hand-held GPS device.

Location preference for urination and defaecation followed cattle preferences for grazing and rest location. The vegetation types differed significantly with regard to all nutrient-content measurements except crude protein. Previously fertilised areas had vegetation with the highest nutritive content and were also grazed most often by the cattle. No evidence could be seen that cattle chose to defaecate or urinate in locations other than where they were grazing.

### 5.2.08 Nitrogen and potassium leaching from grassland soil depending on applied fertilizer type and rate and sward botanical composition

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In Estonia annual precipitation exceeds evaporation so there is a need to implement fertilization practices that minimize nutrient leaching. The objective of the present research was to study nitrogen (N) and potassium (K) leaching from three grassland swards in relation to fertilizer type and application rate. The experiment was 3x3x6 factorial design with three replicates, conducted in plastic mini-lysimeters (0.01 m<sup>3</sup>) filled with loamy sand soil. We tested effects of (1) sward type (three-species grass mixture, grass mixture with white clover, grass mixture with lucerne); (2) fertilizer type (mineral fertilizer, cattle slurry and sewage sludge); and (3) mineral fertilizer at six application rates (N<sub>0</sub>P<sub>0</sub>K<sub>0</sub>, N<sub>0</sub>P<sub>30</sub>K<sub>60</sub>, N<sub>0</sub>P<sub>60</sub>K<sub>120</sub>, N<sub>60</sub>P<sub>30</sub>K<sub>60</sub>, N<sub>120</sub>P<sub>60</sub>K<sub>120</sub>, N<sub>180</sub>P<sub>60</sub>K<sub>120</sub> kg ha<sup>-1</sup>). Organic manures were applied in quantities corresponding to nitrogen rates equivalent to 60, 120 and 180 kg ha<sup>-1</sup>.

Initial results indicate that the lowest leaching losses during the growing season (May to end of October) were from a grass-white clover mixture, while the highest were recorded under a grass-only sward. Amounts of N and K leached depended on water drainage and sward yield. Effects of type of fertilizer and the applied N rate on nutrient leaching were weak.

### 5.2.09 Behaviour of two cow genotypes within a low input grazing system and a high input total confinement system

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Forty Holstein-Friesian dairy cows (H) and 40 Jersey x Holstein-Friesian crossbred dairy cows (Jx) were randomly allocated to one of two milk production systems (a low input grazing system or a high input total confinement system) in a 2 x 2 factorial design experiment. On three occasions during a six-week period, each group was observed at 20-min intervals, between 16:00-22:00 h and 07:00-14:00 h. The 'behaviour' of each cow was recorded, as follows: feeding/grazing, lying, or standing (including walking and drinking, but not feeding/grazing) and, in addition, ruminating or non-ruminating. Average milk yields (kg day<sup>-1</sup>) over the six-week period were 14.8 (H) and 14.8 (Jx) for the grazing system, and 28.0 (H) and 23.3 (Jx) for the confinement system. There were significant differences between the three observation periods for time spent lying ( $P < 0.001$ ), feeding ( $P < 0.05$ ) and ruminating ( $P < 0.001$ ), while time spent standing did not differ between observation periods. Breed had no significant effect on any of the behaviours recorded ( $P > 0.05$ ). Cows on the grazing system spent significantly ( $P < 0.001$ ) more time grazing, than those on the confinement system spent eating. Cows on the confinement system spent significantly more time lying, standing and ruminating ( $P < 0.001$ ) than did those on the grazing system.

### **5.2.10 Effect of Scottish Highland cattle grazing on plant communities with *Phalaris arundinacea***

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Reed canary grass (*Phalaris arundinacea* L.) communities constitute a substantial percentage of grasslands by the Szczecin Lagoon. These multi-hectare meadows situated on organic soils have been partly included under protective actions related to the Habitat and Bird Directives. To protect these habitats, one method is to carry out extensive grazing. This was performed in 2005-2009 and results of its effects are presented in this paper. Within singled-out study areas dominated by *Phalaris arundinacea* up to 75% (A) and 50% (B) a year-round grazing of Scottish Highland cattle was carried out with a livestock density equal to 0.3 LU ha<sup>-1</sup>. A strong reduction in the percentage of reed canary grass was observed in both areas affected by grazing, with 30% in A and 18% in B after 2 and 4 years respectively. It was first replaced by other grasses as well as herbs and weeds. The percentage of legumes, amounting initially to 1%, increased to 8-9% after 5 years of pasture use. There was a clear improvement in plant species richness during the study period. Grazing showed a favourable effect in natural amenities of these meadows and such a system can be a useful method of active protection on moist grassland habitats.

### **5.2.11 Nitrogen balances for three strains of dairy cows and contrasting intensive grassland systems**

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In recent years nitrogen (N) use efficiency has become increasingly important because of economical and environmental concerns, combined with EU policy such as the Water Framework Directive. A Nitrogen balance model, at the cow level, has been developed to assess N use efficiency, N surpluses and N losses from spring-calving grass-based dairy production systems. The model was linked with the Moorepark Dairy Systems Model (MDSM; Shalloo *et al.*, 2005). Data from a 5-year study undertaken at Moorepark were used to evaluate the N-use efficiency of contrasting spring-calving dairy systems. The study consisted of 3 divergent strains of Holstein-Friesian cows: high-production North American (HP), high-durability North American (HD) and New Zealand (NZ), managed across a variety of Irish pasture-based production systems. As replacement rate increased, the total N input per cow increased – 170 kg cow<sup>-1</sup> for NZ strain (0.18 replacement rate), 184 kg cow<sup>-1</sup> for HD strain (0.25 replacement rate) and 200 kg cow<sup>-1</sup> for HP strain (0.37 replacement rate). The N surplus per cow was greater for the HD and HP strains (141 and 157 kg cow<sup>-1</sup>, respectively) than for the NZ strain (129 kg cow<sup>-1</sup>).

### **5.2.12 Flows of nitrogen and phosphorus on large dairy farms with different grazing systems – a model study**

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This study describes and calculates flows of nitrogen (N) and phosphorus (P) on theoretical 300-cow dairy farms with four different grazing systems and investigates potential risks for negative environmental impacts regarding N and P losses. The systems were: 1) Indoor - cows indoors all year around; 2) Pasture for exercise - cows have access to permanent pasture just outside the house 6 hours a day for 3 months; 3 and 4) Pasture-based milk production - cows graze for 4 months and have access to pasture for 8 hours during the day (3) or for 18 hours during the day and night (4). Point loads of N and P were highest on cattle walkways to grazing areas. Total ammonia (NH<sub>3</sub>) losses at farm level decreased from 10.1 t y<sup>-1</sup> in system 1 to 7.4 t y<sup>-1</sup> in system 4. The N surplus at field level was larger in systems 3 and 4 (18 and 33 kg ha<sup>-1</sup> respectively) than in systems 1 and 2 (9 kg ha<sup>-1</sup>). By hypothetically including the fertiliser effect of urine-N on herbage production, it was possible to reduce the quantity of chemical N fertiliser required.



# **Addendum**

## **Session 3.1**

### **3.1.52 Improving the application technique for silage additive in loader wagons**

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These trials showed that the current practice of spraying additive only on top of the ingoing forage in loader wagons results in uneven distribution of additive in the forage, compared to the evenness achieved in precision choppers. This means a quality risk for silage made with loader wagons. When half of the dose of additive was sprayed on the ingoing forage from below, and half traditionally from above, the evenness of distribution was improved in the loader wagon. In the best case it became as good as in the precision chopper. For the application from above, narrow jets from a perforated pipe caused less loss of acid-based additive through evaporation and wind drift than flat-fan nozzles. The additive used was a mix of formic acid and ammonium formate.

### **3.1.53 Effect of timothy and X-*Festulolium* on growth characteristics and carcass quality in bulls**

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This experiment compares timothy and X-*Festulolium* varieties Felina and Felopa as forage for growing bulls. Thirty 1-year-old Norwegian Red bulls were assigned to one of three feeding groups by stratified block randomisation within weight in individual boxes and feeding. The forage was grown at Bioforsk's research station in Bodø (latitude: 67.28° N), Norway, and harvested at a NDF content of 500 g kg<sup>-1</sup> in dry matter in the summer of 2008. The grass was ensiled in round bales and fed *ad libitum*. The bulls were fed 1 kg d<sup>-1</sup> concentrate throughout the experiment. Animals were slaughtered at a live weight of 600 kg, and the carcasses were classified according to the EUROP system. Animals fed with timothy had an overall larger weight gain than the bulls fed with the X-*Festulolium* variants, though the weight gain decreased towards the end of the feeding period. The forage consumption in the timothy group was also larger. Grass type had no effect on the carcass classification.

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