Grassland and forages in high output dairy farming systems

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Wageningen, 2015

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Foreword

The dairy sector within the EU is currently confronted with many challenges as a consequence of political, economic and societal demands. These include price fluctuations, increasing competition in terms of farm inputs and products in the EU and on world markets, and increasing public demands for food product quality and safety, optimal animal welfare and biodiversity. The end of the milk quota system in 2015 represents an additional major change for the European dairy sector. Many countries are already responding to this change by exploring the possibilities and constraints of scaling up and intensification. The 18th Symposium of the European Grassland Federation therefore focuses on grassland and forages in high output dairy farming systems.

The issue of food security is asking for high output from agricultural systems. A major question is the extent to which societal demands, such as animal welfare and grazing, can be met in intensified production systems. Will further optimization of grassland management enhance profitability and reduce the environmental pressure of farming systems? The symposium focuses on high output at farm level (milk production per ha). Keynote speakers from a number of different regions have been invited to address their regional high output dairy farming systems in their specific context, the problems encountered within those farming systems and, if possible, the solutions found. Secondly, optimal use of grassland and fodder crops in high output systems is discussed. Finally, sustainable intensification in profitable animal production systems is examined focusing on high output and high (eco)efficiency at the farm level.

Many people have contributed to these proceedings and to the organisation of the Symposium: authors, external reviewers, members of Organising and Scientific Committees and sponsors. We would like to acknowledge the contribution of all and express our sincere thanks to all. Our special thanks go to the Flemish and Dutch members of the NVWV (Netherlands Society for Grassland and Fodder Crops) who supported the Symposium in many ways.

We hope that the 18th Symposium of the European Grassland Federation will lead to many new insights and connections and we encourage you to actively contribute to the Symposium. We wish all of you a nice stay in Wageningen and Dronten!

Jeroen Nolles	Agnes van den Pol-van Dasselaar	Marcia Stienezen
General Secretary	*Chair Scientific Committee*	*Chair Organising Committee*

Table of contents

Session 2.
Grassland and fodder crops in high output systems

Session 3.
High output and high (eco)efficiency

Session 1.
High output dairy farming systems

Grassland and forages in high output dairy farming systems in Flanders and the Netherlands

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Abstract

The dairy sector in the EU faces many challenges as a consequence of political, economic and societal developments. Many countries are responding to these changes by exploring the possibilities and constraints of scaling up and intensification. This also holds for Flanders and the Netherlands, where dairy farming systems are already intensive. This paper describes high output dairy farming systems in the Netherlands and Flanders and discusses their problems, solutions and perspectives associated with grassland and forages. The dairy farming systems are generally characterised by high fluxes of nitrogen and phosphorus through the systems. Research has led to a strong decrease in mineral losses to the environment in practice. The decrease in grazing is another concern of high output systems. Many activities have been initiated with the aim of stabilisation of the number of dairy cows grazing. Further scaling up of farms and intensification is thought to be possible in the Netherlands and Flanders because of high soil fertility, favourable weather conditions, a good infrastructure and well-educated farmers.

Keywords: Flanders, the Netherlands, high output systems

Introduction

Agriculture worldwide is facing multiple challenges. The most striking challenge is presented by the need to feed the increasing world population (FAO predicts a global population of 9 billion by 2050). Moreover, changing consumption patterns result in an increasing demand for animal proteins (e.g. FAO, 2006). More food must be produced and this has to be done in a sustainable way within the limits of our planet earth. Global resources like land, water and nutrients are scarce. Dairy farming systems contribute to the production of food and especially to the production of animal proteins. The European dairy sector is well equipped to produce animal proteins, and in many situations grass-based livestock systems have the capacity to produce these animal proteins from resources (grass, forages) that cannot otherwise be converted into food. The European dairy sector is also facing challenges like increased losses (nutrients, greenhouse gases) to the environment (soil, water, air), abandonment of rural areas and biodiversity losses. Vast areas of grasslands are not utilised. Importing feed from outside Europe leads to environmental problems in other parts of the world. National and European legislation (e.g. Nitrate Directive, Water Framework) aims to protects the environment but, at the same time, leads to restrictions for the dairy sector. In addition, societal demands have to be met, for example with respect to grazing, landscape, animal welfare and the use of antibiotics. The dairy sector responded in the past to these political, economic and societal challenges by scaling up and intensification. As a result of the abolition of the European milk quota in April 2015, further scaling up and intensification of the dairy sector are expected, especially in regions which currently already have a high production. The aim of this

paper is to describe the high output dairy farming systems in such a region, namely in the Netherlands and in Flanders, and to discuss the possibilities and constraints of grassland and forages in these systems.

Definition of high output dairy systems

When discussing high output dairy systems there are a few important points to consider. Firstly, 'high output' is a relative concept based on comparing systems and comparing their outputs that can vary in space and time. Outputs differ from one European region to another. Farms that were classified as 'high output' two decades ago may be mainstream at present. The general global trend in agriculture is an increase in output due to intensification to meet the growing global food demand.

Secondly, the unit of high output should be considered. The numerator is relatively easy to define. In the dairy sector the numerator of output is usually milk (kg milk or kg milk solids). The denominator, however, can be defined at multiple scales, e.g. high output per dairy cow, per ha of land, per farm, per labour unit, per region or per country. There is a further complication, that the output of dairy systems can be defined on a per-year basis and also per cow lifetime. In the latter case, dairy cows with a long lifetime may have a higher output. They may even have a higher average annual output, since the effect of the first non-productive years can be spread over a larger number of years.

Finally, it should be noted that output and input are usually related: the higher the input (e.g. fertilisation, animal feed), the higher the output. Increasing the input may lead to ecological problems, which is an undesirable development. Therefore, the concept of 'sustainable intensification' has been introduced (e.g. The Royal Society, 2009; Godfray *et al.*, 2010). Sustainable intensification of dairy production systems is intensification in profitable animal production systems, where yields are improved without damaging ecosystems, animal integrity and consumers concerns. This leads to eco-efficient farms with maximum output, minimum use of resources and minimum effect on the environment.

Dairy farming systems in Flanders and the Netherlands: developments and characteristics

At present dairy farms in Flanders and the Netherlands are usually specialised, i.e. their main activity is dairy production. In the Netherlands, forage production and grassland management have undergone substantial changes over the last 50 years (Van Dijk *et al.*, 2015). Yields, quality and utilisation of crops increased due to improved grassland management, fertilisation and breeding. The average number of dairy cows per farm increased tenfold to about 85, average milk production per cow doubled to somewhat more than 8,000 kg milk cow^{-1}, average milk production per ha tripled to about 15,000 kg ha^{-1} and the number of dairy farms declined tenfold to about 18,000 (Van Dijk *et al.*, 2015; CBS, 2015).

In Flanders, similar increases in farm size and production can be seen. Throughout Flanders, 78 farms with high economic profits per cow were followed during a period of 10 years (2003-2013), during which the average number of cows per farm increased from 64 to 77 and the milk production per cow increased from 7,400 to 8,000 kg milk cow^{-1}. On average, the grassland area increased from 21.0 to 22.6 ha, the maize area from 17.2 to 20.9 ha and the area for other forages from 1.3 ha to 1.4 ha, leading to an average increase of more than 5 ha per farm in this period. The average milk production per ha of those 78 farms increased from 17,000 to 19,400 kg milk ha^{-1}.

The developments in milk production per cow and numbers of dairy cattle is shown in Figure 1 at the national level for the Netherlands. Until spring 2015, the EU milk quota system limited the maximum amount of milk produced per country. The total number of dairy cows decreased following the introduction of the milk quota system in 1984 and the average milk production per cow increased. A similar development was seen in Flanders.
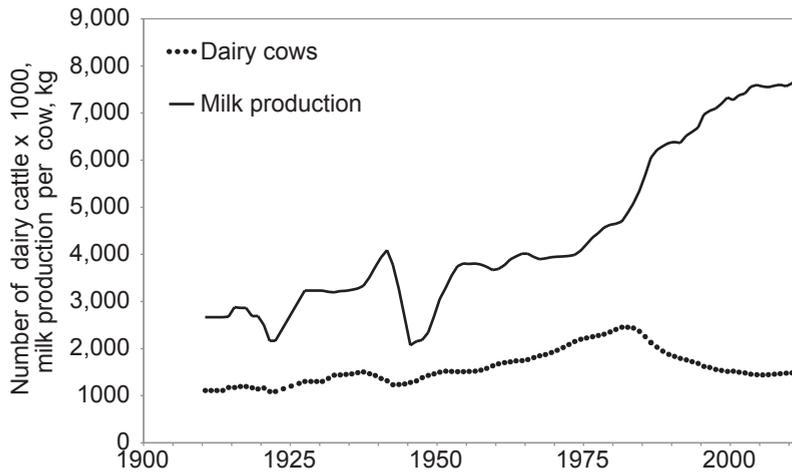
Figure 1. Changes in number of dairy cows and in milk production per dairy cow in the Netherlands from 1910 to 2011 (data CBS, modified).

Soils

Even in relatively small land areas, such as Flanders and the Netherlands, large regional differences in soil quality exist. Soil formation is strongly influenced by the North Sea and the rivers Scheldt, Rhine and Meuse that flow through these regions, and also by climate and human intervention. Flanders is almost completely situated above sea level, whereas approximately 60% of the Netherlands is situated below sea level (-1 to -7 meter) and protected by dykes, dams and dunes. Clay soils are mainly found near the sea, near the rivers and in the areas that were reclaimed from the sea. Peaty soils are found in the western and northern parts of the Netherlands. Sandy soils are mainly situated in higher parts of the Netherlands which are above sea level in the east and the south of the country. The Soil Map of Flanders shows that along the North Sea coast and the North West of Flanders the soil texture is mainly clay, whereas the central and most extensive area is sandy, becoming more loamy in the south of Flanders.

The regional differences in soil type are reflected in regional differences in soil quality. Part of this fertility was inherited from the sea and the river deltas, part is man-made (by e.g manure applications). The soils in the eastern and southern part of the Netherlands and in Flanders were originally mostly poor sandy soils. Current fertility status of soil organic matter content and soil P content in Flanders and the Netherlands is shown in Figure 2. The peaty (marine) soils in the West and the North of the Netherlands can be recognised as areas with a relatively high soil organic matter content. Soil P content is generally high.

Grass yield and grass quality

The temperate maritime climate influenced by the North Sea and the Atlantic Ocean leads to cool summers and moderate winters. Daytime temperatures vary from 2-6°C in winter and 17-20°C in summer. The annual rainfall of 700-800 mm is evenly distributed over the year. These are good conditions for abundant grass growth in the growing season (April – October). Gross yields of 16-18 tonnes dry matter (DM) yr^{-1} are no exception. However, the gross yield (i.e. the grass yield that is grown on the field) is less important than the net yield (i.e. the herbage that is either taken up by the dairy cow or mechanically transported from the field). For determination of net yield, the grazing losses and harvesting losses should be deducted from the gross yield. Grass yield and grass quality in Flanders are in the same order of magnitude as in the Netherlands. Aarts *et al.* (2005) estimated the net yield of grasslands in the Netherlands and calculated an average of 10.4 tonnes DM yr^{-1} (9.6 for peaty soils, 10.3 for clay soils, 10.4 for wet sandy soils and 11.5 for dry sandy soils). Variation among farms is large.
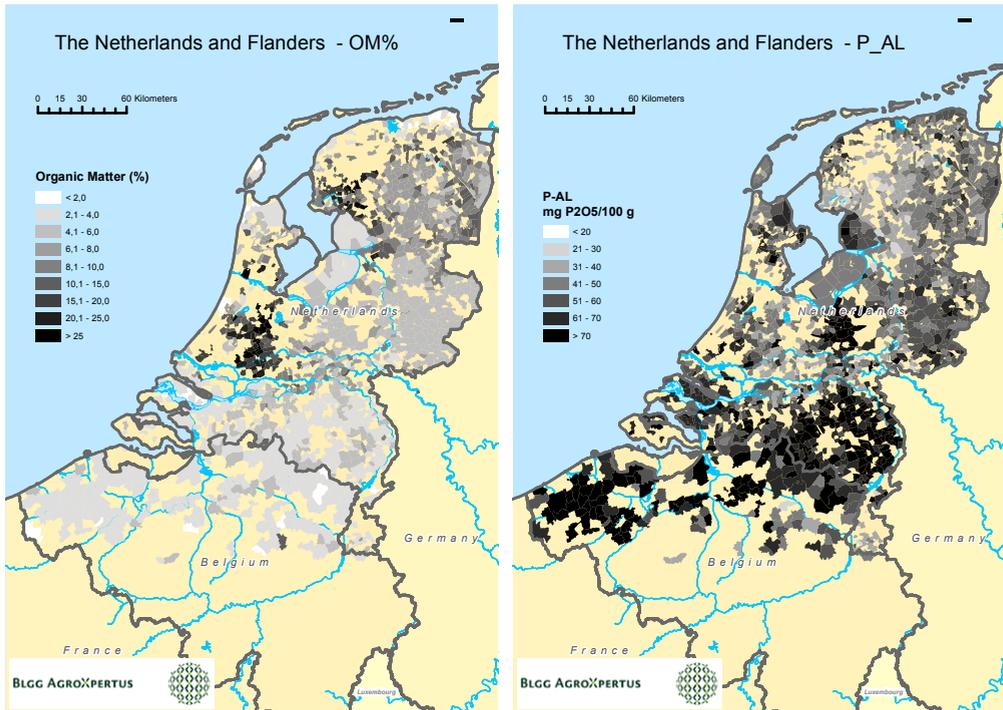
Figure 2. Examples of soil quality in Flanders and the Netherlands: a) soil organic matter content (%), and b) P content, P-AL, mg P_2O_5 / 100 g. Source: Blgg AgroXpertus, average of >70,000 samples in the Netherlands and approximately 5,000 samples in Flanders.

Trends in average grass quality during a period of 15 years in the Netherlands are shown in Table 1. Crude protein content and crude ash concentrations of grass decreased during the last years; those of K decreased and Se increased. The decrease coincided with a decreased fertiliser application. The increase in Se content can be explained by the increased use of Se-containing fertilizers (Reijneveld *et al.*, 2014; Abbink *et al.*, 2015).

Table 1. Median values and mean annual change (indicated by slope *b*) of grass quality; grass samples taken from grass silage in the Netherlands. The regression coefficient indicates the mean change of herbage quality per year for the period 1996 – 2009 (Reijneveld *et al.*, 2014).

Herbage characteristics[a]	Median	Slope *b*	R^2
Dry matter	435	n.s.	n.s.
Crude protein	165	-2.43**	0.52
Crude fibre	242	n.s.	n.s.
Crude ash	101	-2.53**	0.69
S	3.0	n.s.	n.s.
P	4.0	n.s.	n.s.
K	35	-0.30*	0.32
Mg	2.4	n.s.	n.s.
Ca	4.7	n.s.	n.s.
Na	2.5	n.s.	n.s.
Se	52	8.33**	0.51

[a] DM in g kg^{-1}, SE in mg kg DM^{-1}, all other in g kg DM^{-1}

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

Rations

Dairy cattle rations in Flanders and the Netherlands are in general characterised by relatively large amounts of supplementation, mainly maize silage, grass silage and concentrates. The distribution of silage maize over Flanders (Figure 3) shows many areas where a lot of silage maize is produced. Farms in those areas usually supplement more silage maize than farms in areas where not a lot of maize is produced. This is also true for the Netherlands.

An example of the development of rations on dairy farms in Flanders over the last 10 years is given in Table 2. The amount of grazed grass has been estimated using the known intake and the calculated needs of the dairy cows. DM intake from grass in Flanders has remained relatively stable throughout the years, but the DM intake from grass silage has increased at the expense of grazed grass. This is partly explained by the fact that the herd size of the dairy farms has increased while the area around the farm that could be grazed has not increased to the same extent. A similar development was seen in the Netherlands.

Nutrient losses

High output dairy farming systems in Flanders and the Netherlands are generally characterised by high fluxes of nitrogen (N) and phosphorus (P) through the systems. These elements cycle through the system by transfer between the components of the farm, i.e. from crops/feed to the herd, from the herd to manure, from manure to soil and from soil to crops/feed. Inadequate nutrient management of these intensive nutrient flows may cause high losses to the environment, which puts the quality of water, air and nature under pressure. Moreover, it reduces resource-use efficiency because not only exports as milk

Legende

percentage silomaïs 2013
- 0%
- 1% - 10%
- 11% - 15%
- 16% - 20%
- 21% - 25%
- 26% - 33%
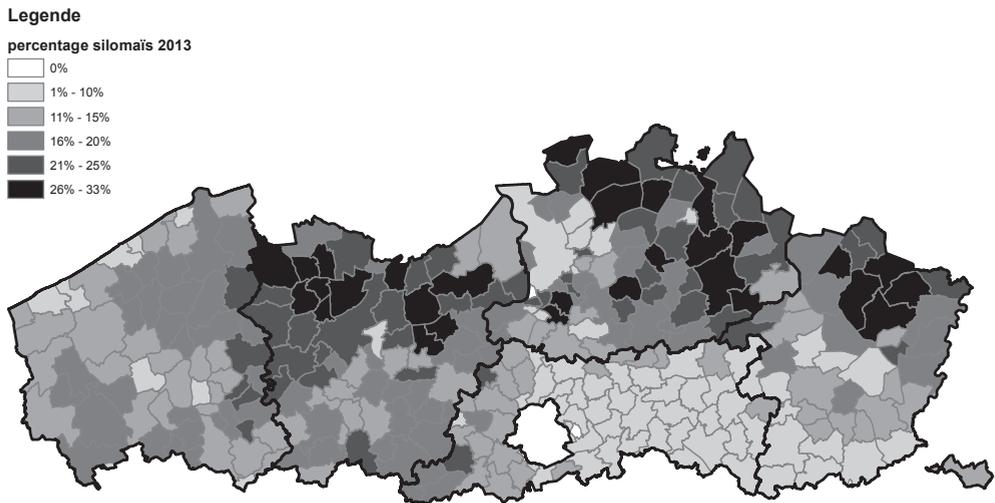
Figure 3. Distribution of silage maize in Flanders (% of total land area). Source: Landbouwcentrum Voedergewassen.

Table 2. Development of rations in Flanders during the period May-September (kg DM cow^{-1} day^{-1}); average of the 20% most productive farms in the data set of farm accounting by the Belgian Farmers Union.

	2003/2004	2008/2009	2013/2014
Grazed grass	7.03	4.33	3.60
Grass silage	1.34	3.37	3.40
Maize silage	7.32	7.70	8.21
Other	3.87	4.45	3.89

and meat but also losses from the systems are replenished by purchased feeds and fertilisers. From the mid-1980s onwards, an efficient use of fertilisers with minimal losses to the environment was promoted and research efforts were dedicated in that direction.

The experimental farm De Marke was set up with the aim to explore and demonstrate the possibilities to produce milk at an intensity of 12,000 kg milk ha^{-1} without violating strict environmental standards (Aarts *et al.*, 1992). Optimized mineral management on the pre-designed farming system resulted in a strong reduction of N and P surpluses compared to common practice (Aarts *et al.*, 2000). In the various management systems that were explored since 1993, N surpluses at farm level amounted to 98-165 kg ha^{-1}. P surpluses ranged from 0-6 kg ha^{-1} (Verloop, 2013). In the project 'Cows & Opportunities' the research on improvement of nutrient management was extended to commercial dairy farms on various soil types (Oenema, 2013).

In Flanders research was carried out to avoid losses to the environment and to increase the production efficiency at the ILVO experimental farm and at the Policy Centre for Sustainable Agriculture (Nevens *et al.* 2006; Meul, 2008). The Policy Centre identified top farms within a large set of monitored dairy farms and used the dataset to develop a monitoring and management tool to improve the eco-efficiency and sustainability in Flemish dairy farms (Meul *et al.*, 2009). Mineral balances at farm level were studied in the period 1987-1998 as a tool for efficient farm management: reducing NPK losses and improving financial output (Carlier *et al.*, 1992, Michiels *et al.*, 1998; Dessein and Nevens, 2007). Reduction of N losses as well as efficient N fertilisation is important for a better environment and sustainable use of N as a production factor (Nevens and Reheul, 1998).

The research has led to a strong decrease in mineral losses to the environment in practice in the years thereafter. Moreover, it led to more insight into the flows of minerals at farm level and to the development of practical tools for farmers. For example, in the Netherlands the model ANCA (Annual Nutrient Cycle Assessment) was developed (Aarts *et al.*, 2015) to provide insight to farmers into the impact of their management on the functioning of nutrient cycles. From 2015 onwards, ANCA will serve as a licence-to-produce for the dairy farms in the Netherlands with a manure surplus (which is about 70% of the number of farms). It will ensure that losses are minimised as much as possible.

Grazing

Another concern is the decrease in grazing. Table 2 shows this for Flanders. The same trend can be seen in the Netherlands where the percentage of dairy cattle with grazing decreased from 90% in 2001 to 70% in 2013. Grazing of dairy cows has several advantages, like more possibilities to express natural behaviour of dairy cows and the contribution to the image of the dairy sector, but also disadvantages, like more nitrate leaching and a less balanced diet (Van den Pol-van Dasselaar *et al.*, 2008; Hennessy *et al.*, 2015). It even affects the quality of the milk, since grazing increases the levels of unsaturated fatty acids in milk and meat (e.g. Elgersma *et al.*, 2006). During the last decade the decrease in grazing has become a societal issue, especially in the Netherlands (e.g. Elgersma, 2012). Public debates emphasize the high perceived-value of grazing for animal welfare. The grazing cow is even seen as an icon of the Netherlands. Therefore, in 2012 a voluntary agreement, the 'Treaty Grazing', was signed by many partners in the Netherlands with the aim of stabilising the number of dairy farms that practise grazing. By now, around 60 parties have signed the agreement indicating the importance of grazing in the Netherlands. Among the parties signed are representatives of dairy farmers' associations, dairy industry, feed industry, milk robot industry, banks, accountants, semen industry, veterinarians, cheese sellers, retail, NGOs, nature conservation, government, education and science. Related to this agreement, Dutch dairy companies currently provide the farmers that deliver milk a so-called grazing premium when they allow their cows to graze. The largest dairy company of the Netherlands raised this grazing premium on 1 January 2015 from 0.5 eurocent kg^{-1}

milk produced to 1 eurocent kg^{-1} milk produced. 'Pasture milk' is processed in separate milk streams and the majority of the Dutch supermarkets only sell such milk. There has been a revival of grazing in advice, education and science. The activities are expected to lead to a stabilisation of the number of dairy cows grazing. Recently, the Dutch Ministry of Economic Affairs has expressed their ambition to increase the percentage of grazing dairy cows to 80%. The challenge for Dutch farmers will be to combine these ambitions with animal welfare, environmental quality, ongoing upscaling and increasing use of automatic milking systems (AMS). Currently, 17.5% of all dairy farms in the Netherlands milk with an AMS and this percentage is increasing. In Flanders, the percentage stabilises at around 9%. Automatic milking often coincides with less fresh grass in the ration. Further upscaling is also a threat for grazing, since in general, large farms practise less grazing. These issues are addressed in research, e.g. in the European project Autograssmilk, which aims to develop and implement improved sustainable farming systems that integrate the grazing of dairy cows with automatic milking (www.autograssmilk.eu; O'Brien *et al.*, 2015).

Recent developments

As a result of the abolition of the milk quota, further scaling and intensification is expected to occur in Flanders and the Netherlands. The Dutch government recently installed new legislation to avoid an extensive increase of the herd size without an accompanying increase in the land area. If the excretion of P minus the permitted P-fertilisation of a farm exceeds 50 kg P_2O_5 ha^{-1} (this is the case for approximately 10% of the current Dutch farms) and the herd size increases, then the farm is obliged to buy or rent land to receive at least 50% of the extra P produced. The other 50% can be exported from the farm. If the P surplus of a farm is between 20 and 50 kg P_2O_5 ha^{-1} (approximately 15% of the Dutch farms), the farm is obliged to buy or rent land to receive 25% of the extra P produced. In all other situations, 100% can be exported from the farm. This legislation is expected to slow down excessive growth of farms in the Netherlands. A further limitation may be that the national phosphate ceiling, as agreed within the EU, will be exceeded, which may prevent further growth of the national dairy sector.

Also in Flanders, farmers who want to intensify or extend are confronted with legal restrictions. Farmers need to have nutrient-emission rights to keep animals on the farm. In 2015, the 5th manure action plan (MAP5) started in Flanders, with restrictions and regulations for N and P in the period 2015-2018. MAP5 focuses particularly on a reduction of the P-fertilisation. Finally, there is the programmed tackling of nitrogen to reduce the output and the effect of ammonium on nature in the neighbourhood of the farm. This aspect is integrated in the environmental licence.

However, even though the recent developments in Flanders and the Netherlands may slow down the further scaling and intensification, the baseline for dairy production is still good. The infrastructure is good (harbours, airports, roads), and therefore materials that are needed can easily be accessed. The Dutch agrosector is important for the Dutch economy; it ranks together with France in second place on the list of exporters of agricultural products, behind the United States. The Netherlands is a world-leading exporter of milk and milk products. Furthermore, there is a good knowledge infrastructure in Flanders and the Netherlands (universities, schools, advisory, farmers associations) that enables farmers to quickly assess up-to-date information to optimise their farm management.

Outlook on the future of dairy systems in Flanders and the Netherlands

Some of the problems encountered within high output dairy farming systems in Flanders and the Netherlands are addressed in this paper and some solutions are presented. There are, of course, many questions remaining. To what extent will societal demands, such as animal welfare, grazing and environmental quality, be met in intensified production systems? Will further optimization of grassland management enhance profitability and reduce environmental pressure of farming systems? An integrative approach for grassland management that is cost effective, environmentally sound and manageable

is essential in the context of the development of large-scale dairy enterprises with highly productive healthy animals. New functions of high output dairy farming systems may arise with corresponding revenue models, e.g. energy production, emission trading, and provision of other ecosystem services like cultural services. A diversity of dairy farming systems may develop. Van den Pol-van Dasselaar *et al.* (2014) showed in a survey with approximately 2000 respondents from different countries of Europe (mainly from Ireland, France, Belgium, the Netherlands, Poland and Italy) that the individual functions of grasslands are highly recognized and appreciated by all relevant stakeholder groups in Europe. All stakeholders considered that the large European grassland area is a valuable resource which is essential for the economy, environment and people. This could be exploited.

Further development of the dairy sector will require continuous development of people (education, training), tools (e.g. decision support systems) and techniques (innovations like sensors at cow and field level or techniques for manure refining). These developments are taking place in practice. Grasslands can remain as an essential part of dairy farming systems, producing feed for the dairy cattle. Grass production and utilisation should be stimulated by good grassland management, managing constraining factors like water shortage and using highly productive grass varieties and legumes. Soil (fertility) data, together with fertilization registration, grass growth, weather data etc., collected at different resolutions, scales, time, and together with historical data could all be integrated in decision support systems. Multiple layers of information need to be analysed and assessed. This data assessment, evidently, needs to increase grassland yield, improve herbage quality and ensure a prudent use of nutrients. It is also essential to increase the net yields of grazed pastures by reducing the grazing losses (trampling, urine and faeces) and by developing novel grazing systems for future dairy farms (large-scale, high productive, highly automated) that are technically and socially feasible and are economically viable and environmentally sound. The potential to improve the grass yield is enormous as can be seen by the current variation in grass yield in practice. Optimal use of grassland will lead to profitable farming with minimised environmental impact while addressing demands from society like animal welfare and grazing.

Conclusion

The number of political, economic and societal demands, both regional and European, that challenges high output dairy farming systems in Flanders and the Netherlands, is increasing. There are many challenges and constraints related to grasslands and forages, e.g. with respect to nutrient losses and grazing. The dairy farming sector in the Netherlands and Flanders shows much variation but also has a lot in common. It is well equipped to take its role in global food security, due to its high output contributing to actual food supply and due to the fact that it demonstrates the combination of high output and production of different ecosystem services. Solutions to problems are tailor-made and available at various levels, e.g. introduction of innovative tools and techniques and improvement of skills and expertise of farmers and farm advisers. Further scaling up and intensification is thought to be possible because of high soil fertility, favourable weather conditions, a good infrastructure and well-educated farmers.

References

Aarts H.F.M. (2000) *Resource management in a 'De Marke' dairy farming system.* PhD thesis, Wageningen University, Wageningen, 222 pp.

Aarts H.F.M., Biewinga E.E. and Van Keulen H. (1992) Dairy farming systems based on efficient nutrient management. *Netherlands Journal of Agricultural Science* 40, 285-299.

Aarts H.F.M., Daatselaar C.H.G. and Holshof G. (2005) *Bemesting en opbrengst van productiegrasland in Nederland.* Rapport 102. Wageningen, Plant Resarch International, 33 pp.

Aarts H.F.M., De Haan M.H.A., Schröder J.J., Holster H.C., De Boer J.A., Reijs J.W., Oenema J., Hilhorst G.J., Sebek L.B., Verhoeven F.P.M. and Meerkerk B. (2015) Quantifying the environmental performance of individual dairy farms - the Annual Nutrient Cycling Assessment (ANCA). *Grassland Science in Europe* 20, this volume.

Abbink G.W., Reijneveld J.A. and Linders P.B.J. (2015) The effect of decreased N and P applications on herbage quality in the Netherlands. *Grassland Science in Europe* 20, this volume.

Carlier L., Janssen G., Konings V., Tyvaert D. (1992) Mineralenbalans. *Landbouwtijdschrift Bemesting en leefmilieu* 2, 447-461.

CBS (2015) http://statline.cbs.nl

Dessein J. and Nevens F. (2007) *Erven van de toekomst. Over duurzame landbouw in Vlaanderen*. Steunpunt Duurzame Landbouw, 250 pp.

Elgersma A. (2012) New developments in The Netherlands: dairies reward grazing because of public perception. *Grassland Science in Europe* 17, 420-422.

Elgersma A., Dijkstra J. and Tamminga S. (Eds.) (2006) *Fresh Herbage for Dairy Cattle – the key to a sustainable food chain*. Springer (194 pp).

FAO (2006) *Livestock's long shadow, environmental issues and options*. Food and Agriculture Organization, Rome.

Godfray H.C.J., Beddington J.R., Crute I.R., Haddad L., Lawrence L., Muir J.F., Pretty J., Robinson S., Thomas S.M. and Toulmin C. (2010) Food Security: The Challenge of Feeding 9 Billion People. *Science* 327, 812-818.

Hennessy D., Delaby L., Van den Pol-van Dasselaar A. and Shalloo L. (2015) Possibilities and constraints for grazing in high output dairy systems. *Grassland Science in Europe* 20, this volume.

Meul M. (2008) *Concretisation and operationalisation of ecological sustainability of Flemish farms*. PhD thesis, Gent University, Gent, Belgium, 181 pp.

Meul M., Nevens F., Reheul D. (2009) Validating sustainability indicators: focus on ecological aspects of Flemish dairy farms. *Ecological indicators* 9, 284-295.

Michiels J., Carlier L. and Verbruggen I. (1998) *Mineralenbalansen en hun gebruik op melkveebedrijven. In: Naar een duurzame grasland- en groenvoederuitbating*. Ministerie van Middenstand en Landbouw, 27-49.

Nevens F. and Reheul D. (1998) Gebruik van toegediende stikstof door grasland en groenvoedergewassen. Fytotechnische mogelijkheden tot optimaal N-gebruik. Mineralenbalansen en hun gebruik op melkveebedrijven. In: *Naar een duurzame grasland- en groenvoederuitbating*. Ministerie van Middenstand en Landbouw, 85-108.

Nevens F., Verbruggen I., Reheul D. and Hofman G. (2006) Farm gate nitrogen surpluses and nitrogen use efficiency of specialized dairy farms in Flanders: evolution and future goals. *Agricultural systems* 88, 142-145.

O'Brien B., Van Den Pol-Van Dasselaar A., Oudshoorn F., Spörndly E., Brocard V. and Dufrasne I. (2015) AUTOGRASSMILK-Combining automatic milking and precision grazing. Book of abstracts of the 66th Annual Meeting of the European Federation of Animal Science.

Oenema J. (2013) *Transitions in nutrient management on commercial pilot farms in the Netherlands*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Reijneveld J.A., Abbink G.W., Termorshuizen A.J. and Oenema O. (2014) Relationships between soil fertility, herbage quality, and manure composition on grassland-based dairy farms. *European Journal of Agronomy* 56, 9-18.

The Royal Society (2009) *Reaping the benefits: science and the sustainable intensification of global agriculture*, London.

Van den Pol-van Dasselaar A., Vellinga T.V., Johansen A. and Kennedy E. (2008) To graze or not to graze, that's the question. *Grassland Science in Europe* 13, 706-716.

Van den Pol-van Dasselaar A., Goliński P., Hennessy D., Huyghe C., Parente G. and Peyraud J.-L. (2014). Évaluation des fonctions des prairies par les acteurs européens. *Fourrages* 218, 141-146.

Van Dijk H., Schukking S. and Van der Berg R. (2015) Fifty years of forage supply on dairy farms in the Netherlands. *Grassland Science in Europe* 20, this volume.

Verloop J. (2013) *Limits of effective nutrient management in dairy farming: analyses of experimental dairy farm De Marke*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Fifty years of forage supply on dairy farms in the Netherlands

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Abstract

Dairy farming in the Netherlands has shown big changes during the last 50 years as a consequence of various technical, economic and social developments. The cost of labour has increased greatly and therefore labour productivity has also increased. In order to achieve a reasonable financial income on the mainly small family farms, scaling up and intensification of those farms was necessary. Agricultural research and extension services significantly contributed to realising these goals. In particular, there was a need to increase the productivity of farmland, and both the quality and utilisation of the crops. The application rate of fertilizers, particularly nitrogen, increased strongly, as did the use of organic manures. Quality of grassland improved (due to re-sowing and use of high quality grass-seed mixtures) and the management was intensified. Planned grazing systems and new methods of hay and silage making led to significantly improved forage quality and a higher milk production. Including silage maize and concentrates, as well as the effects of breeding further contributed to increased milk production. All these changes meant that, over a period of 50 years, the average number of dairy cows per farm increased ten-fold, to about 85, the average milk production per cow doubled to somewhat more than 8,000 kg, the milk production per ha trebled to about 15,000 kg ha^{-1} and there was a ten-fold reduction in the number of dairy farms to about 18,000. These developments have coincided with the introduction of modernised cow houses, mechanisation and automation. The introduction of milk quota in the EU led to a slowdown in the developments. EU rules with regard to derogation, manure residues and N content of ground water, but also national rules with regard to environment and nature, have during the last years limited the further scaling-up and intensification of dairy farms.

Keywords: fifty years, forage supply, the Netherlands

Introduction

The Netherlands is a small and densely populated country. There are about 16.8 million inhabitants on about 4.15 million ha. This corresponds to 406 inhabitants km^{-2}. The area of cultivated land amounted to 2.3 million ha in 1960, but in somewhat more than 50 years this area decreased by about 500,000 ha due to conversion into urban areas, industrial areas and nature areas. The area available for grassland and forage crops also changed. At the moment there are about 990,000 ha of grassland and the area of land with forage maize has increased from nil in 1950 to 230,000 ha.

Agriculture was and still is of great economic importance for the Netherlands. The country is more than self-sufficient in many agricultural products. The total value of exports of all agricultural products amounted to about 75 milliards Euro annually during recent years. Cattle husbandry contributed significantly to that export, e.g. via dairy products, cattle and beef.

Dairy cattle husbandry developed quite strongly, especially during the last 30 years. This is illustrated in Table 1, where a number of key parameters for the period 1960-2013 are shown. They will be explained in more detail in the following paragraphs.

Grassland

Grass is the most important agricultural crop in the Netherlands. In 1960, the area of grassland was still 1.33 million ha. However, this area gradually reduced to the present area of about 990,000 ha, mainly due

Table 1. Developments in dairy cattle husbandry in the Netherlands.

	1960	1975	1985	1995	2005	2010	2013
Agricultural area (×1000 ha)	2,317	2,082	2,019	1,965	1,938	1,872	1,848
Grassland area (×1000 ha)	1,327	1,286	1,083	1,048	976	951	932
Forage maize area (×1000 ha)	0.5	77	177	219	235	229	230
Number of dairy farms (×1000)	183	91.5	58	37.5	23.5	19.3	18.5
Number of dairy cows (×1000)	1,628	2,218	2,367	1,708	1,433	1,479	1,553
Number of cows farm^{-1}	8	24	41	46	61	75	84
Kg milk cow^{-1} yr^{-1}	4,205	4,650	5,330	6,610	7,550	8,000	7,990
Kg concentrate cow^{-1} yr^{-1}	800	1,590	2,280	2,210	2,020	2,060	
Kg milk ha^{-1} yr^{-1} (×1000)	5.5	8.86	12.51	12.02	12.56	14.07	
Kg milk farm^{-1} yr^{-1} (×1000)	37	112.5	217	302	460	597	671
Kg milk in Holland yr^{-1} (mill. Mg)	6.7	10.3	12.5	11.3	10.8	11.9	12.2
Kg milk hr^{-1} labour	8	37	72	89	128	150	
Dairy cows ha^{-1} grass and forage crops	1.2	1.6	1.8	1.3	1.2	1.2	1.3

to converting grassland into maize. The area for maize increased rapidly after 1970 and amounts to about 230,000 ha at the moment. Furthermore, a lot of grassland was and still is being converted into extension of roads, urban areas, industrial areas and nature conservation areas. Grassland is not only used for dairy production, and part of the grassland area is also utilised by sheep, beef cattle, horses, etc.

Grassland can be found on all soil types of the Netherlands: clay, sand, peat and loess. The peat areas, with relatively high ground-water levels (mainly in the western and northern part of the Netherlands), are predominantly used as grassland. Before 1970 the majority of the grassland was permanent grassland, i.e. more than five years old. Rotation of crops hardly occurred. However, during the last 20 years the area with permanent grassland has dropped to about 70%, mainly due to rotation with maize or exchange of land with arable farmers for cultivation of potatoes, flower bulbs, etc.

In the past, the botanical composition of many grasslands left a lot to be desired, especially on plots far from the farm. The main reasons for this were low levels of fertilisation and mowing at a late stage of growth. Those grasslands mainly consisted of grass species of medium and low quality. After 1970, grass improvement received more attention as a result of the necessary intensification on dairy farms. Higher yields and better forage quality were then needed. Fields with moderate or low quality grass species were ploughed up and resown. At the same time the fields concerned were levelled and both fertilisation and drainage were improved. Sod sowing of grassland mainly occurred on low and moist fields where ploughing was not possible. It was also used to improve the quality of existing grassland by sowing good, productive varieties, e.g. after a severe winter. A lot of grassland was also improved in a re-allotment project. As a result of allotment more paddocks became available in the vicinity of the farm. This also improved the general management of those paddocks: more alternation of grazing and cutting. When maize was introduced in the Netherlands many fields with medium or low quality grassland were ploughed up and utilized for maize. After one or more years those fields were then resown with grass. At the moment, on average about 10% of all grassland is resown annually. The actual annual resown area is related to the damage caused by drought or frost. In order to limit N leaching, it is obligatory to resow in spring on sandy soils and before 15 September on other soils.

For grassland improvement, mainly mixtures of good and productive grass species and varieties are used. There are many mixtures available, which mainly contain perennial ryegrass varieties, both mid-late

and late heading. Sometimes timothy and clover seeds are used as well. The use of specific mixtures is increasing, e.g. mixtures for mowing only, for grazing and mowing, with additional structure and with clover. There are also mixtures for sod sowing and/or temporary grassland. Diploid varieties are increasingly being replaced by tetraploid varieties.

Good quality grassland can easily produce 11-13 Mg DM (gross weight) ha^{-1} when it is intensively managed. With the best grass species and varieties a gross yield of 14-16 Mg DM ha^{-1} is possible and on very high quality soils even more. However, it is not the gross yield that is most important, but the final utilisation of the forage by the cattle. Restriction of losses during grazing and silage making is then crucial, of course.

Fertilisation of grassland and forage maize

A strong intensification took place in Dutch agriculture from 1960 onwards, mainly because of greatly increasing labour costs. This necessary intensification was stimulated by research and extension services, e.g. by demonstration farms and so-called Nitrogen Pilot Farms in the majority of the Dutch provinces. Around 1950, grassland was fertilized with limited amounts of stable and liquid manure and a limited amount of additional fertilizer. By 1960 the N fertiliser rate was 115 kg N ha^{-1} of grassland and it increased to 350 kg N ha^{-1} by 1985. On sandy soils the N fertilisation was higher, but on peat soils lower because of additional N mineralisation from the soil. In addition to the 350 kg N ha^{-1}, 60-100 kg active N ha^{-1} became available from applied animal manure. Due to the increasing fertilisation and better management, both production of grassland and the number of cows ha^{-1} increased. In the same period many cubicle houses were constructed, which led to a change from solid and liquid manure to slurry. In addition, the number of pigs and poultry increased strongly, in particular in the sandy areas. This meant an enormous increase of the amount of animal manure. On the farms concerned, storage facilities for manure were often very limited and much of this manure was, therefore, not applied during the growing season. Of course, this manure caused an additional burden on the environment and soil. In 1987, the government therefore drew up rules for storage and application of manure in order to limit NH_3 emission and N leaching to ground and surface water. Amongst others, this meant covering of manure storage, changes in method of manure application (sod application or manure injection to reduce emissions) and the period of manure application (during the growing season only) and limiting the amount of animal manure per ha. Differentiations were made for various soil types and land use with respect to maximum fertilisation. In addition, standards for use and losses of N and P per ha grassland and ha forage maize were set.

The Netherlands is allowed by the (EU) derogation arrangement to apply 250 kg N from animal manure per ha grass and forage maize. The total fertilizer standards for the amount of N, and of P as well, have been gradually sharpened during the last years, in particular for those areas with sandy soils where the nitrate content in the ground water still is too high. As a consequence of the maximum amount of animal manure, application of N and P fertilizer sharply decreased in practice (Figure 1). In the years 2010-2012, about 120 kg N fertilizer ha^{-1} was applied on grassland. The amount of applied fertilizer P ha^{-1} decreased also (Figure 1). From 2014 onwards, application of fertilizer P on grass and forage maize is forbidden.

Due to the abolition of the milk quota in 2015, new rules apply for farmers that wish to enlarge or to intensify their farms. The additional amount of manure produced by the enlarged herd needs to be applied on the farmer's own land in a justified way or processed and removed from the farm. For a dairy farmer it will also be important to restrict the supply of N and P in imported concentrates and roughage and to utilize all farm manure as efficiently as possible in order to produce high amounts of forage and to maintain a high level of milk production within the rules.
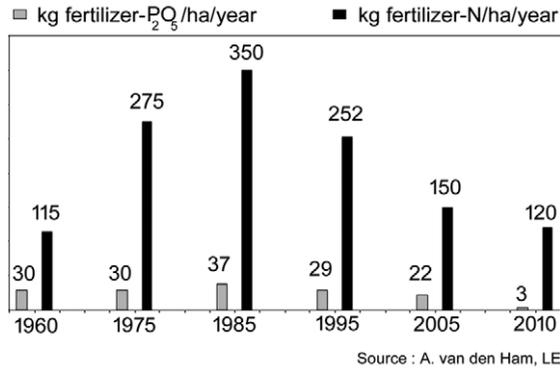
Figure 1. Fertilizer P and N use ha^{-1} grassland yr^{-1} in the Netherlands in the period 1960-2010.

In the past, forage maize was always fertilized with a lot of manure, supplemented with a restricted amount of fertilizer. Application of 100 Mg of slurry ha^{-1}, or sometimes even more, occurred in practice until 1987. After that, the amounts of N and P, both from animal manure and fertilizer, have been restricted by rules. Nowadays, fertilization in maize rows is more and more common practice for optimum utilization of minerals and a high yield of forage maize.

Grazing

In the past all dairy cattle used to graze in summer time. In spring, cows went outside and they came back into the cow house in autumn; in summer time they were milked in the field. However, over the course of years a lot changed: the number of cows per farm increased (see Table 1) and both land and cattle needed to produce more. Management of grassland changed strongly as well. Until about 1970 mainly extensive grazing systems were practised (continuous grazing or extensive rotational grazing), such as grazing on one large paddock for a couple of weeks. A limited area of grass was cut at a rather late stage of growth for forage in winter time, mostly as hay. Both yield and quality of that hay left much to be desired.

Both research and extension services stimulated farmers to adapt the grazing and forage production. New grazing systems and new forage production systems became available. In addition, more cubicle houses were constructed where the dairy cows were milked inside instead of outside. This created the possibility to keep the cows inside for a longer period and to feed them there. Especially after 1990 the number of dairy farms decreased and the remaining farms increased in size. This led to changes in the grazing systems (Figure 2).

For cattle, various grazing systems can be applied that vary in:
- number of hours grazing per day;
  - day and night grazing;
  - grazing only during day time, housing at night, feeding additional maize or grass silage and sometimes fresh grass;
- number of days grazing per paddock;
  - intensive or strip grazing: cows get once or twice a day a new plot for grazing;
  - rotational grazing: cows get a new plot each 2 to 6 days;
  - continuous grazing: cows graze for a longer period of time (3-6 weeks) on a large paddock. The grass allowance of the paddock can be kept relatively stable by adapting the land area or by supplemental feeding.

Next to grazing, there are also farmers that keep their cows inside for the whole summer and feed them freshly cut grass (zero-grazing) or silage (summer feeding). Various combinations of systems can be found in practice as well. Each of the systems has pros and cons. The best system for a certain farm mainly depends on the infrastructure of the farm, available man-power, number of cows, stocking rate and allocation of grassland. The best system can also change during the year. Consistent management is important for all grazing systems.

During the last 15 years the number of cows that graze in summer time has decreased (Figure 2). In 1997 somewhat more than 92% of all cows were grazing in summer, whereas by 2013 this percentage had decreased to 70%. In addition, both the number of days and hours d^{-1} that cows are grazing has decreased. In particular, large dairy farms apply less grazing. As a result of scaling and increasing use of milking robots, it may be difficult to maintain the percentage of grazing cows at 70%.

Currently, grazing of cows is encouraged in the Netherlands. Dutch people like to see dairy cows in grassland. The dairy industry is stimulating grazing by paying an additional 0.5-1 eurocent kg^{-1} milk produced by grazing cows. It was possibly as a consequence of this higher milk price that the percentage of grazing cows did not further decrease in 2013. New initiatives, e.g. for farmers with milking robots, are now being undertaken to provide further stimulation to dairy cow grazing.

Forage utilisation

Forage utilisation strongly changed between 1960 and 2015 (Figure 3). In the years between 1960 and 1970 hay was the main forage for winter time. Grass for hay was mostly cut at a rather late stage of growth and particularly on fields that were far away from the farm. The quality of that hay was often
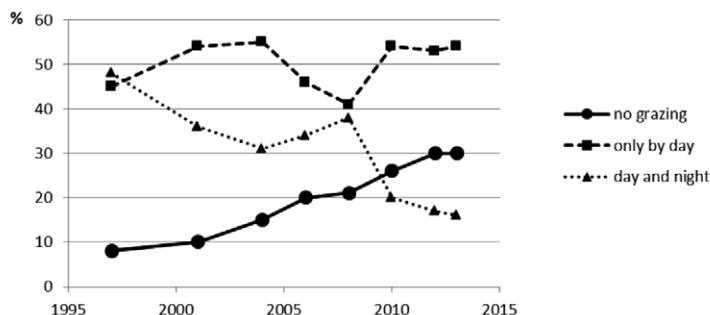
Figure 2. Grazing, % of dairy cows in the Netherlands in the period 1997-2013; source: CBS, 2014.
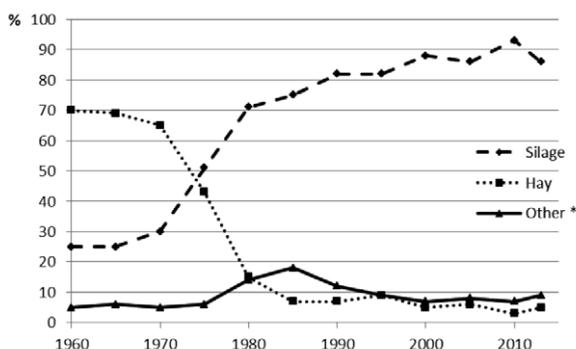
Figure 3. Destination of mown grass in the Netherlands, 1960-2013. * = mostly summer feeding and artificial drying (1-3%), source: CBS.

low, partly as a consequence of the variable climate in the Netherlands. In order to limit the weather risk, farmers increasingly switched to silage making. This change was also stimulated by new and better silage making methods. The switch from hay to silage gave an improvement in forage quality. In addition, it also improved the overall grassland management. More plots were cut at a younger stage of growth and in addition grazing and mowing were more alternated. Most plots were cut at least once, and often twice for winter forage. As a consequence, cows could regularly have young and clean grass.

Hay making

Making dry hay in the traditional way often meant a long field-period (5-7 days) and associated chances of unfavourable weather. To reduce weather risks new ways of making better hay were tried. By putting half-dry hay on a kind of tent constructed of sticks, the weather risk could be reduced. However, this method was rather labour intensive. Thereafter, barn drying of hay was developed and practised on farms for some time. Hay with a dry matter content of 60-65% was dried in a barn or haystack with cold or sometimes even with warm air. The field period was shorter, the weather risk less, and the quality of the hay better. However, this method often required an investment in hay storage. A general problem of hay storage is the risk of heating.

As a result of the development in making silage and storage of silage, the amount of hay strongly decreased after 1970. In the last 10 years only 5% of all grass cut for forage for use in winter-time is conserved as hay. That hay is generally made under favourable weather conditions and is compacted as small or large bales. A considerable quantity of hay is harvested in nature-protected areas as well. A limited amount of hay is also attractive for a number of farms as a reserve stock for calves, sick animals, etc.

Ensiling grass

In the course of the years various silage making systems have been practised. In the beginning (1950-1960), it was mainly the traditional 'warm' method that was applied. During a period of 2-3 weeks an amount of grass was put on a heap, and grass was added almost daily. The intention was to create a certain temperature in that heap in order to realize an acceptable conservation. The result was mostly disappointing and involved great losses. Because of these disappointing results more and more farmers switched to a so-called 'cold method' whereby grass was ensiled over a short period (1 or 2 days) with an additive. In the beginning the AIV method was used (developed by the Finnish Professor A.I. Virtanen, about 1930), whereby a mixture of hydrochloric acid and sulphuric acid was added to the rather moist grass. This method usually resulted in a good conservation, but it was also rather labour intensive and it was dangerous because of the rather aggressive acids used. Around 1950 the so-called Hardeland method, originally a German method, became popular for some time. In this method, grass was ensiled, within a few hours, with a stationary chopper and addition of fodder beet or molasses. This method gave very good results, but was also rather labour intensive. Ensiling with a flail type forage harvester was therefore more attractive. Grass was mown, bruised and loaded in one operation. Conservation results were mostly good. It was important that the grass was somewhat older (contained some stems) and contained sufficient sugars. Ensiling young grass rich in leaves and protein often led to less-good results. The relatively low dry matter content of the silage was a disadvantage and the silage effluent also sometimes presented a problem.

The wilting method had already become popular by the 1960s. After a field period of 2 to 3 days the grass was ensiled at a dry matter content of 35 to 45%. Wilting leads to a higher osmotic pressure in the grass cells which inhibits unwanted bacteria to develop in the silage. Wilting appeared to be the best and cheapest conservation method for young, protein-rich grass. Basically, for this ensiling method additives are not needed and there are no problems with environmental pollution caused by silage effluent, while intake of the silage by cattle is quite good. However, a quick ensiling is important (preferably in one day)

and an air-tight silage storage. The rise of the forage wagon and of good quality plastic sheets contributed a lot to a quick expansion of the method. Hay making decreased rapidly. In the last 10-15 years, 85-90% of all grass cut for winter forage has been ensiled, mainly as wilted silage.

Silage additives

In the Netherlands silage additives are used to a limited extent. In the past, mostly acids, salts or molasses were applied. In recent years mainly mixtures of bacteria are used. Additives are applied only if less-good conservation results are expected, for instance when the grass is not sufficiently dry, high in protein or low in sugars, or when the field period lasted too long. High dry matter silages can heat up when they are opened. Prevention of this problem is possible: sufficient compaction during ensiling, correct airtight storage and sufficiently rapid feeding of the silage. There are also special mixtures of bacteria that can restrict heating of the silage. Such mixtures are used in practice on a limited scale. Overall, 5-10% of wilted silages are treated with bacteria.

Mechanization of forage management

Mechanization in silage making increased strongly, particularly after 1975. The first simple machines for mowing, tedding, raking, loading and transport were followed by larger machines with a higher capacity. Larger machines were also needed because of the increasing size of farms. The rise of the forage wagon and the self-propelled chopper (particularly for maize) were especially important. Many farms still use their own machinery for harvesting activities. However, increasingly, contract workers are involved, who take care of loading and transport. Contract workers have available large forage wagons, choppers and balers and can execute all the activities at reasonable costs per ha. In general, contracting costs are lower than the farmer's own mechanisation costs.

Initially, self-propelled choppers were exclusively used for harvesting maize, but gradually they were also used for grass. Chopping of grass has a positive effect on the preservation and density of the silage due to the bruising and mixing during chopping. Ensiling large bales (both round and rectangular, both with and without plastic covering) also became popular in the Netherlands. It is estimated that 15-25% of grass is ensiled in this way. The method is particularly attractive to store special lots separately and in case silage needs to be sold. In addition, it is not necessary to immediately transport the bales to the storage yard after pressing and wrapping them.

Storage of silage

As a consequence of the strong extension of silage (grass and maize) on farms, storage of silage significantly changed. Before 1960 the limited amount of silage was mainly stored in round heaps or in low, round silos. The silages were covered with plastic plus soil or with a complete plastic cover. After that, storage in clamps, plus plastic and soil, became popular. However, when the silage was mechanically removed from the clamp in winter, it appeared that a concrete surface for the clamp was needed. Removal of the soil cover from the silage led to more objections: much time required, a heavy job and problems during frost. Gradually, the soil cover was replaced by an additional sheet of plastic or by a special, thicker sheet that also provided protection against damage by birds or wind. In the period from 1975 till 1990 larger farms built quite a few tower silos and combined this with mechanical feeding. The majority of these tower silos are no longer used, or have already been dismantled due to their moderate filling capacity, the high investments and the vulnerability of the entire system. Today, most silage is stored in large clamps on concrete surfaces or in bunker silos. In particular, the number of large bunker silos has increased during the last years. Advantages of those silos are the limited investments, correct storage and various machinery available for filling the silo and removing the silage.

Artificial drying of grass

In the Netherlands artificial drying of grass and lucerne has only been carried out on a limited scale. One of the reasons involved is the high cost of energy. Before 2000, many small drying plants existed. However, only 5-8 larger plants have been left. Of all grass that is cut during a season only 1-3% is artificially dried. The amount of grass that is dried depends on the grass growth in a certain year. In favourable growing years farmers are offering their surplus of grass to drying plants. Previously the dried grass and also the lucerne were mainly stored as bales. For many years a large proportion of the dried products has been pressed into pellets and used as concentrates.

Forage quality

In the Netherlands, forage quality has been analysed for many years. Every year, many thousands of samples, mainly from silages, are investigated by a few laboratories. The investigation is mainly directed to preservation and feeding value and is often complemented with mineral composition. The many available data show that the net energy value of forage has increased by 5-8% over the years. Various aspects have contributed to this: better fertilization and grassland management, better systems for silage making and for storage. As a consequence of more and better forage produced, milk production per cow and per ha increased strongly. In the period from 1960 till 2014 average milk production doubled from 4,200 to 8,500 kg cow^{-1} and the milk production per ha almost tripled from about 5,500 to 15,000 kg ha^{-1}. However, we should not forget that cattle breeding also contributed to these production increases.

Forage crops

Before 1960 fodder beets were the main forage crop, with an area of more than 40,000 ha. The palatable fodder beets were attractive for farms with a surplus of forage. Fodder beet can replace a part of concentrates. However, as a consequence of intensification after 1960, more forage was needed. Fodder beet is a very labour-intensive crop. Much labour is needed for cultivation, storage and processing. Therefore, fodder beet was rather rapidly pushed aside by forage maize.

The area of forage maize increased rapidly and it now amounts to about 230,000 ha. Forage maize is an attractive crop: under favourable conditions it produces 16-18 Mg DM ha^{-1} of feed with a high energy value. Cultivation, harvesting and silage making of forage maize are relatively easy. Maize silage also fits quite well in a diet with fresh grass or grass silage, which is rather rich in protein. Many new maize varieties have been developed, which produce more and have better resistance against diseases such as stalk rot (*Fusarium* spp.) and smut (*Ustilago*) and are also tolerant to *Helminthosporium*. In the Netherlands, mainly early and very early varieties are grown because of the climate. Developments with regard to fertilisation, weed control and mechanisation also contributed to a strong extension of the crop. The stage of harvesting changed gradually. In the beginning, maize was harvested when the DM content was 28-30%. In recent years, maize is harvested at 34-36% DM. At this DM content, the starch content is rather high and silage-making losses are rather low. If the silage is well compacted and correctly sealed, the chance of heating is limited. As a consequence of the ever-larger choppers, harvesting of maize can take place in a short time frame. Most maize is grown on sandy soils in the east and south of the Netherlands. Some maize is grown on pig and poultry farms and is often sold to cattle farmers. In addition, a restricted area of maize is harvested as maize grain or CCM (Corn-Cob-Mix).

In the Netherlands the area with lucerne has been about 6,000 ha for many years. Lucerne is mainly grown by arable farmers in the provinces Groningen, Flevoland and Zeeland on a contract basis for drying. The dried product is often processed with other feedstuffs. Other forage crops, like field beans, peas, lupins and soya are hardly grown in the Netherlands, mainly because of the low yields in comparison to maize.

Conclusions

In last 50 years dairy farming has changed greatly in the Netherlands. Farms became clearly larger and the management more intensified. The farmers have been guided by research, extension services and by trade and industry. Grassland has been improved and fertilisation adapted. Grazing systems intensified and for forage management other and better methods with lower losses have been applied. The amount of forage maize in the cow's diet increased. As a consequence of all these changes, yield and quality of forage increased and the milk production per cow and per ha increased as well. These developments have led to a good economic perspective of the dairy farming sector in the Netherlands. The sharpening of EU rules for nature and environment will limit further scaling up and intensification of dairy farms.

Acknowledgements

Portuguese dairy farming systems

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Abstract

Milk production is responsible for about 11% of global agricultural output in Portugal. Two regions, which together represent less than 10% of the land area of the country, contribute to 80% of Portuguese milk production: the Azores islands and the Northwest (NW) mainland area. The two systems are strongly specialized on milk production, but differ in terms of land use and intensity of inputs applied. The Azores dairy farming system houses 33% of national dairy livestock and is responsible for 30% of the annual 1,900,000 Mg Portuguese milk production. In this system, four-fifths of the surface area of dairy farms are occupied by permanent grasslands which are grazed all year round. Grazing is complemented by maize and ryegrass silage obtained from the remaining one-fifth of the farmland area. The more intensive NW dairy system is based on a double-cropping forage system (zero-grazing) that uses maize as a summer crop and Italian (annual) ryegrass as a cover crop in winter. This region is responsible for more than 50% of national milk production and holds 45% of national total of dairy cows. The high silage yielding potential and the annual use of up to 3.5 Mg concentrate feed per dairy cow allow animal stocking rates of 4-7 LSU ha^{-1}. This farming system may generate large N losses, particularly by nitrate leaching. Environmental issues currently play an important role driving changes and adaptation measures to improve system sustainability to comply with legal regulations. These modifications are being accompanied by very fast changes in farm structural characteristics; between 1993/1994 and 2009/2010 the number of dairy holdings has been reduced by more than 85% and the number of cows per farm has increased proportionally. The main problems affecting the Portuguese dairy sector at present are evaluated and possible solutions are suggested to face the upcoming challenges.

Keywords: intensive dairy systems, sustainability, NW Portugal, Azores

Introduction

In the last decade, Portuguese total milk production has shown some fluctuations with an average value of about 1,900,000 Mg year^{-1} and a slight tendency to decrease in the last years (Figure 1). Milk production represents a value of ca. 750 M €, i.e. 27% of animal production output and 11.4% of total agricultural output (GPP, 2013). In 2012/2013, milk production deliveries were 1,843,000 Mg (1.27% of EU27 production) providing only 91.2% of the national quota. In the same period, there were 7,436 dairy holdings with a total of 242,000 dairy cows. Animal average productivity was 7,615 kg milk cow^{-1} year^{-1}. In 2013, in terms of trade balance, Portugal showed a degree of self-sufficiency of 94% for the whole set of dairy products, with 108, 51 and 75% being the respective values for the classes 'milk and cream', 'yoghurt' and 'cheese'.

Portuguese dairy production is concentrated in two main regions – the Azores islands and the Northwest (NW) mainland area, which house, respectively, 33 and 45% of the national dairy livestock and occupy together an area that accounts for less than 10% of the national territory (Figure 2). In the Azores, dairying is based on permanent grasslands grazed all year round, while the more intensive NW dairy system is a zero-grazing system based on maize and annual ryegrass silage. Due to its more intensive production, the NW system is responsible for more than 50% of milk production.
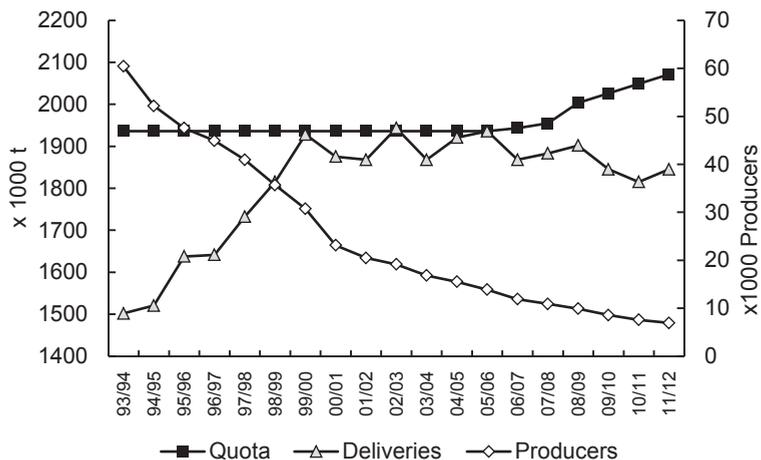
Figure 1. Recent evolution of Portuguese milk deliveries and numbers of producers (adapted from Cardoso, 2014).
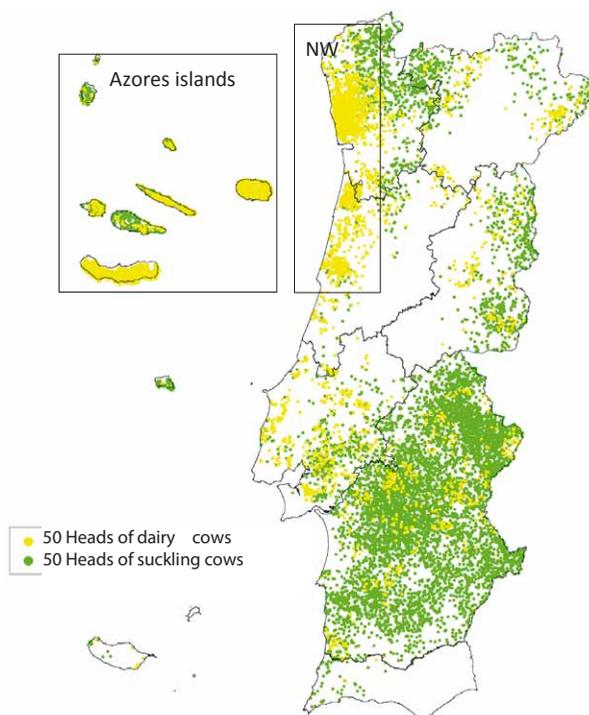
Figure 2. Distribution of dairy cows (dark spots) and suckler cows (light spots) in Portugal (INE, 2011).

The Northwest mainland dairy system

The Northwest dairy area of mainland Portugal comprises the coastal sub-regions of Entre Douro e Minho (EDM) and Beira Litoral (BL) (Figure 2). These regions are densely populated and land is a scarce and expensive resource. Forestry occupies about one-third of total area and land used by agriculture in the region represents 63% of the farm surface (INE, 2011). In general, soils on cropland areas are sandy loams derived from granite, deep (>1 m), well drained, and with a slope commonly less than 5%. The

altitude varies between 10 and 100 m.a.s.l. The annual rainfall varies between 1,200 and 1,700 mm with 80% of this total occurring between October and April.

In the last decades an intensive zero-grazing dairy farming system has been developed in the region based on two forage crops per year for silage making: maize (irrigated) and a winter crop consisting of annual ryegrass or a mixture of cereals with annual ryegrass. These crops allow high annual forage yields to be achieved, typically 20-24 Mg dry matter (DM) plus 7-9 Mg DM ha^{-1} for the maize and the winter crop, respectively. In the dairy counties, maize grown for forage occupies between 30 and 70% of agricultural land. Cows are fed with a total mix ration and kept 'indoors' all the year round, generally kept in covered and concreted cattle sheds where they are in a state of semi-freedom. The high forage yielding potential and the use of up to 3.5 Mg of concentrate feed per dairy cow allow animal stocking rates of 4 to 7 LSU ha^{-1} (including herd replacements). Cow-replacement rates are very high reaching, on many farms, values over 30%. In the majority of cases, the animal manure is stored directly in pits located beneath cattle sheds. Few farms have a central pit external to the cattle sheds. The storage capacity of liquid manure varies between 2 and 6 months. Slurry spreading to fields is mainly done twice a year just before the sowing of each crop (May and September/October), although application to the winter crop in February (top-dressed) has increased markedly in recent years. Slurry application may achieve amounts between 100 and 120 m^3 ha^{-1} yr^{-1} (equivalent to 300-360 kg N ha^{-1}). In addition to the slurry applied, the crops often receive mineral fertilizers at levels which may represent an extra annual input of 100-200 kg N ha^{-1} and up to 100 kg P$_2$O$_5$ ha^{-1}; these values are decreasing as a result of technical advice and information campaigns (De Roest *et al.*, 2008). In a 3-year study (2003-2005) based on farm surveys, Fangueiro *et al.* (2008) reported that the less-intensive and more-intensive dairy farms of the region showed annual N inputs, respectively, of about 620 and 1,060 kg N ha^{-1} and that the feed concentrates represented 64-73% of these inputs; milk deliveries accounted to 60-70% of the total outputs and farm N surpluses were estimated to range from about 400 to 610 kg N ha^{-1} yr^{-1}. Therefore, this cropping system may generate high environmental impacts due to large N losses, particularly by nitrate leaching on the most intensive farms. Trindade *et al.* (1997) found that annual nitrate leaching losses measured over a 2-year period from fields under a double-cropping forage system similar to that described above ranged from 154 to 338 kg N ha^{-1} yr^{-1}.

The average size of specialized dairy farms in the region is small (265 Mg milk per farm in 2013) (Cardoso, 2014) and the farm arable area is divided into several blocks separated from each other by roads or other obstacles, which represents a major constraint to grazing development. There is a lack of data at regional levels, but, considering global values for Portugal, changes in farm structure characteristics are occurring very fast. Between 1993/1994 and 2009/2010, the number of dairy holdings has been reduced by more than 85%. Between 2005/2006 and 2009/2010, only the number of farms that are producing more than 400 Mg milk yr^{-1} has increased, and in the farm-size class of less than 20 Mg milk yr^{-1} a decrease of 60% in the number of producers was observed; as a consequence, 50% of Portuguese milk production is assured by only 10% of dairy farms (CEGEA, 2012). Between 1999 and 2009, the average number of dairy cows per farm increased in the EDM and BL sub-regions, respectively from 11 to 34 and from 7 to 15 (INE, 2011). In 2005, the estimated average value of milk production per cow in the EDM sub-region was about 7,400 kg yr^{-1} while in the BL sub-region it was below 6,000 kg yr^{-1} revealing differences in the farmers' ability for farm and herd management and the existence of different farm conditions. In the well-managed and progressive farms the productivity of the cows is often above 9,000 kg milk yr^{-1}. Organic production is limited to a few farms (less than 10).

The Azores dairy system

Dairy farming in the Azores is based on permanent grasslands grazed all year round. In 2009, permanent grasslands covered 90% of the agricultural area (AA) and the remaining 10% of AA was mainly (90%)

maize for forage. The region's climatic conditions are especially suitable for all-year grass growth, with mild winters and moderate summer temperatures resulting only in a short drought period. Annual rainfall ranges from 900 to around 2,000 mm and average temperatures in January and July are 14 and 22 °C, respectively.

Farm activity includes milk and beef production although, on average, milk represents more than 80% of farm revenue. In 2009 there were 3,225 milk producers and the average dairy farm size was 20.8 ha, which was fragmented into 21 blocks (0.99 ha per block) and holding 31 dairy cows (less than 1.5 cows ha^{-1}). The average milk production per farm is 175 Mg yr^{-1}. Animal productivity in the Azores is smaller than in the NW region, showing in 2008 and 2012 values of 5,200 and 6,150 kg milk cow^{-1} yr^{-1} (GPSRAF, 2011; SREA, 2014). Milking is done in the grazing areas using mobile milking parlours. In the last years, building of fixed milking parlours has increased markedly as a consequence of changes afforded by land reparcelling projects promoted by the regional government. During milking, cows are supplemented with concentrate feeds and maize or grass silage but technical management of diets, herds and pastures needs to be improved. Use of concentrate feed is about 0.2 kg kg^{-1} milk and grazing is performed during winter preferentially on low altitude pastures; during summer high altitude pastures (over 800 m) are utilized by animals.

Advantages and disadvantages, threats and solutions for the Portuguese dairy sector

Advantages of Portuguese dairy production can be summarized as follows:
- high crop yielding potential of the NW and Azores regions, which ensures high forage productivity at the farm level;
- the competitive, up-to-date and well organized regional milk industry;
- producers receive strong support from dairy cooperatives at the technical level (labour and machine rental, technical support for fertilization, animal nutrition, reproduction and health) as well as at the commercial and administrative level (sale of concentrates at low prices, accounting services, investment projects, subsidy applications, etc.). The farmers' cooperative support is especially well organized in the mainland NW dairy region.

The disadvantages/weak points of Portuguese dairy sector are linked to:
- size and structure of farms: their location in areas with high population density which results in high land price (30,000 to 60,000 € ha^{-1}, in the NW region);
- in the Azores, technical management of the farms and herds is poor;
- high production costs compared to other producing countries; particularly in the NW region, animal feeding costs increased sharply in recent years due to rising concentrate-feed prices, which reduced the ability to compete internationally;
- high demanding national regulatory requirements in terms of food security, environment, animal welfare and licensing. Investments needed for the adaptation of farms to the entry into force of new environmental legislation;
- dairy industry limited capacity for price negotiation and excessive share of large retailers in the marketing margin; increasing pressure from the distribution sector in reducing the room for negotiation;
- peripheral status of Portugal relatively to major European markets, and in particular the insularity of the Azores, result in high transport and logistics costs.

Important threats to the Portuguese milk sector are the uncertainties linked to the ending of the quota system, increasing concurrence with other EU regions (mainly Spain) and consequently the reduction of the milk price.

The milk sector is certainly the best structured Portuguese agricultural chain and their national and regional organizations together with governmental support services are aware of the need to adapt the productive structure and they are committed to innovation. Envisaged solutions to improve sustainability of Portuguese dairy systems include:

- improved technical management of farms and herds to increase productivity and reduce production costs;
- reinforcement of farmers' organizations;
- diversification into innovative dairy products with higher added value for external and internal markets, and;
- increasing exports and strengthening the internationalization of the industry in addition to modifying the idea that export is a solution only for the disposal of surpluses.

Acknowledgements

References

Cardoso F. (2014) Socio-economic importance of the Portuguese dairy sector, *Presentations from the workshop Eco-efficient production in the dairy chain*. Vairão, Portugal, 28 pp.

CEGEA (2012) *Impacto da Reforma da PAC Pós-2013 no Setor do Leite em Portugal*. Centro de Estudos de Gestão e Economia Aplicada, Universidade Católica Portuguesa, Porto, Portugal, 108 pp.

De Roest K., Menghi A. and Trindade H. (2008) Adaptation des systèmes laitiers méditerranéens au nouveau contexte de prix des aliments. *Fourrages* 196, 447-459.

Fangueiro D., Pereira, J., Coutinho, J., Moreira N. and Trindade H. (2008) NPK farm gate nutrient balances in dairy farms from Northwest Portugal. *European Journal of Agronomy* 28, 625-634.

GPSRAF (2011) *Caracterização da produção de leite nos Açores no ano de 2008 a partir do universo de referência dos produtores com quota na campanha leiteira 2007/2008*. Gabinete de Planeamento da Secretaria Regional da Agricultura e Florestas, Horta, Azores, 226 pp.

GPP (2013) *Agriculture, Forestry and Fishery Indicators 2012*. Gabinete de Planeamento e Políticas. MAMAOT, Lisboa, Portugal, 108 pp.

INE (2014) *Estatísticas agrícolas 2013*. Instituto Nacional de Estatística, Lisboa, Portugal. 168 pp.

INE (2011) *Recenseamento Geral Agrícola 2009*. Instituto Nacional de Estatística, Lisboa, Portugal, 185 pp.

SREA (2014) Serviços Regionais de Estaísticas dos Açores. Azores statistics http://estatistica.azores.gov.pt.

Trindade H., Coutinho J., Van Beusichem M.L., Scholefied D. and Moreira N. (1997) Nitrate leaching from sandy loam soils under a double-cropping forage system estimated from suction-probe measurements. *Plant and Soil* 195, 247-256.

High output farming systems in Europe: the French case

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Abstract

This paper focusses on dairy production systems in France. First, the huge diversity in production backgrounds and systems will be presented to put its main variation factors to the fore: the differences between plains and mountains, the low level of specialization of the dairy farms and the differences in terms of density of farms on the territory. The relatively high availability of land as well as the moderate price of agricultural land in France compared to the other European and world dairy farming areas are put to the fore. The feeding systems for each class of production system are described to underline the strong link between land, forage production and performances of dairy herds. The search for high levels of self-sufficiency in dry matter, energy and proteins in French dairy farms also accounts for the relatively low levels of stocking rates and milk production per hectare reached in many areas. Finally, the relations between the high production output strategies and some environmental issues such as nitrate leaching and biodiversity are discussed. The issue of the definition of 'high output farming systems' in such contrasting situations is addressed.

Keywords: dairy farming, France, high output, self-sufficiency, eutrophication

Introduction

The qualification of dairy farming systems as 'high output' systems may have different meanings in different countries. In France, dairy farms are generally not qualified in terms of productivity and it is not common to distinguish 'high output farms'. Productivity can vary widely due to the strong diversity of the territory, in terms of climate, soil quality, altitude, and types of productions. Consequently, productivity in France (national average) is far below most of our neighbouring dairy farming areas. Moreover, the strong environmental regulations restrict the stocking rates and thus 'the milk produced per ha'. But one of the main factors is that land is available at low cost. Therefore, the target of dairy production systems in France is not to maximize the amount of milk per ha, but to meet the feed requirements of the animals as much as possible with home grown fodder and crops. Efficient use of resources is an important aspect in these systems. Inputs of nutrients are tuned to the requirements of the production system. This strategy is important to reduce losses to the environment, e.g. through nitrate leaching and greenhouse gas emissions. Finally, the notion of 'high output per hectare' may, besides production per hectare, refer to a variety of outputs, such as added value (e.g. the mountain regions with PDO cheeses), or ecological services provided, like water quality, biodiversity, landscapes, rural activity. These are the issues addressed in this paper.

Classification of the production systems and areas

In 2013/2014, France produced 23.29 million l of milk from 68,224 farms delivering an average of 341,000 l per farm per year (FranceAgriMer, 2014). Some 70% of this production is from farms on plains, while 30% is from farms located in mountains/unfavourable areas. The average quota per farm reached 366,888 l with mountain regions (221,000 l), far below lowland areas (355,000 l) (Table 1).

The bovine dairy chain is a major actor in France's territory use and occupation, in its agricultural job sector and in the economic activity of many French regions. The French production systems vary a lot

Table 1. Productivity of dairy farms per area, France (source: RGA 2010 analysed by Institut de l'Elevage).

Zone[1]	# farms	Agr. area (AA, ha)	Forage area (FA, %)	Maize silage % FA	Stocking rate (LU ha^{-1})	# cows	Quota per farm (×1000 l)	Quota cow^{-1} (l)	Quota per ha AA (l)	Quota per ha FA (l)
LDA	34,369	89	74	30	1.6	54	351	6,500	3,900	6,600
West	24,482	82	71	35	1.6	52	352	6,800	4,300	7,000
CLA	22,044	119	51	28	1.6	51	361	7,100	3,000	7,400
intensive	10,132	104	48	36	1.9	50	357	7,100	3,400	8,600
MPA	17,444	75	91	5	1	38	221	5,800	2,900	3,700
Jura	2,892	95	92	1	0.9	44	257	5,800	2,700	3,000
Other areas	2,791	101	76	13	1.1	45	303	6,800	3,000	5,300
France	76,648	95	69	23	1.4	49	323	6,600	3,400	5,800

[1] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

between regions for obvious geographical reasons, as well as historic and sociologic reasons. For dairy production, production models can be very different and be as economically efficient as long as they are well mastered by the farmers. This is an undeniable asset to adapt to the background evolutions in terms of production conditions, rules and markets.

In relation to the agricultural potentials, to the production systems developed, and the density of the farms on the territories, three main dairy production areas can be described (Figure 1, from Agreste, 2013, and Dossier Economie de l'Elevage, 2013):
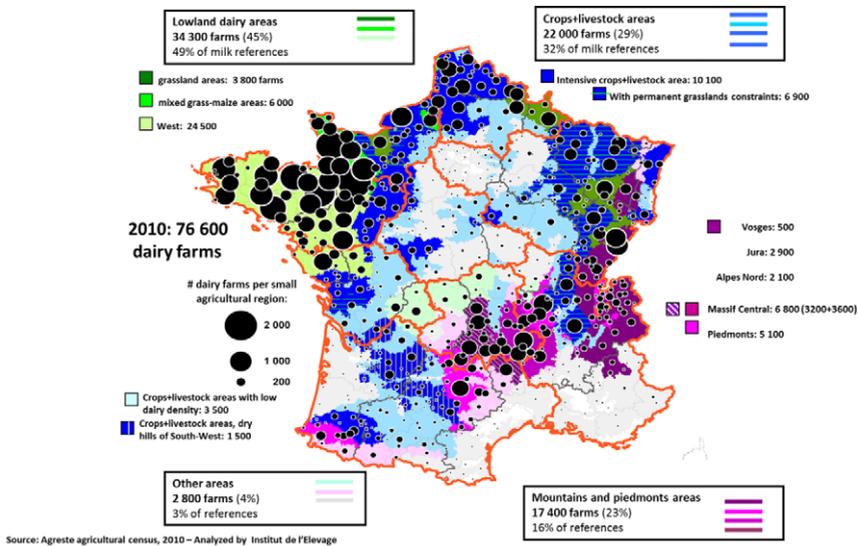
Figure 1. Classification of French dairy systems (source: Agreste, RGA 2010, analysed by Institut de l'Elevage).

- The lowland dairy areas (LDA) cover western France (including Brittany). This area included 45.6% of the dairy producers in 2012/2013 (Table 2) and represents 51.6% of the milk deliveries.
- The dairy crops and livestock areas (CLA) include intensive high-potential areas like Nord-Picardie. Some 28% of the farms are located in this area, producing 31% of the French milk in 2012/2013.
- The dairy mountains and piedmont areas (MPA) include eastern mountains like the Jura and piedmonts regions. Some 22% of the farms are located in this area, producing around 15% of the French milk 2012/2013. The average delivery per farm is much lower than the French average.

Over the last five years, the amount of milk produced increased by 3.5% in the LDA, by 2.3 % in the MPA but decreased by 2.4% in the CLA (Perrot *et al.*, 2014). The number of farmers decreased by 15% in the LDA and MPA, and by 20% in the CLA (FranceAgriMer, 2014).

The lowland dairy areas (LDA)

These areas the main dairy farming areas, except in mountains, are characterized by a high density of dairy farms (43 per 100 km^2, Table 2). The West lowland area includes Brittany and Pays de la Loire regions with intensive dairy farms and a large resort to maize silage. The soil and climatic conditions are favourable for forage production and account for the large development of dairy production over the last 50 years. Because of the high density of farms, their size remained moderate for a long time (currently 52 cows, 82 ha), leading to a high level of specialisation (42%) compared to other regions, and the frequent association with pigs or poultry production after the implementation of the quota system. The dairy systems are relatively intensive for France, with a stocking rate around 1.6 livestock units (LU) per ha of forage area (FA). The production per cow reaches 7,000 l per ha FA (4,300 l per ha agricultural areas, AA). The high forage and animal intensification levels in these areas, as well as the presence of pig and poultry units, have created high nitrogen surpluses with frequent high nitrate levels in rivers. The strong environmental regulations applied to these areas after 1991 led to a decrease in these levels but also contributes to the reduction of the animal pressure per hectare.

The dairy crops and livestock areas (CLA)

Because of the high quality of soils on sedimentary materials, most of the farms in this class have developed commercial crops and only 22% of the dairy farms are considered as specialized (Table 2). The farm density is lower than in the previous area (10 for 100 km^2). The intensive CLA cover the western and northern borders of the Parisian basin together with Alsace and part of the South West. Again, dairy production is relatively intensive with a large resort to maize silage (1.9 LU per ha, 36% of maize silage on FA). In many areas, cows can be fed partially with by-products of the crops' industrial chain (sugar

Table 2. Contribution of farm categories to French dairy production, 2012 (Source: FranceAgriMer, 2014; SAFER, 2014).[1]

Zone[2]	% farms	% deliveries	% specialized	% dairy PDOs	#dairy farms per 100 km^2	Average land € ha^{-1} (min-max)
LDAs	46.5	51.6	37	3	43	Brittany
West	33.2	37.3	42	1	44	5,240 (2,120-7,540)
CLA areas	28	31	23	4	10	Nord Pas-de-Calais
Intensive	13.4	14.7	22	2	17	12,340 (1,160-30,450)
MPAs	22	15	67	38	25	Franche-Comté
Jura	4	3.2	84	87	30	4,640 (2,510-8,690)
Other areas	3.5	2.4	41	6	2	
France	100	100	40	12	14	5,750

[1] The colour of lines refers to Figure 1.

[2] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

beet pulp, brewery and distillers' grain). The dairy production per cow reaches an average of 8,000 l per year and 8,600 l per ha FA (3,400 l per ha AA). Because the forage area represents only 48% of the agricultural area, the notion of 'milk produced per ha agricultural area' has little significance, particularly when compared to farms of the other areas (plains and mountains).

The mountains and piedmont areas (MPA)

These areas are characterized according to their dairy processing chain, strongly linked to local production schemes. The farm density is quite high (25 dairy farms per 100 km^2) but the average quota is far below the level reached in the two previous zones: 221,000 l versus 351-361,000l (Table 1). The climatic conditions with cold winters and wet summers account for grassland-based production systems. The average stocking rate reaches only 1 LU per ha. The Eastern mountains including Jura and Northern Alps include specialized dairy farms (84% of the dairy farms in Jura, Table 2) producing for PDO cheese chains (87% of the farms) with a high milk price. The average farm has 44 cows on 95 ha and is highly specialized in forage production (92% of the AA). For each PDO, a contract defines the breed and types of feed allowed with generally no silage permitted and a limited level of concentrates. The cow breed is usually not Holstein, with an average production level between 5 and 6,000 l per year. The milk production reaches only 3,000 l per hectare FA (2,700 l per ha AA).

In conclusion, French dairy farming is characterized by substantial differences between its three main production areas. The average stocking rate is 1.4 LU per ha, milk produced amounts to 5,800 l per ha of forage area (ranging from 3,000 in the Jura mountains up to 8,600 in intensive crops and livestock areas). The level of milk produced reaches an average of only 3,400 l (2,700-4,300) per ha of agricultural area but has little significance in low specialized areas.

Milk production per hectare and stocking rates

This productivity per hectare appears to be relatively low compared to the European neighbouring countries studied during the European Dairyman project (De Vries *et al.*, 2013; www.interregdairyman. eu). The productivity of the 128 pilot farms that participated in the European DAIRYMAN project, ranged from 6,519 in Luxemburg up to 19,735 l per ha of forage area in the Netherlands (Table 3; Bechu, 2013). In 6 of the areas studied, the milk per hectare of FA is close to or above 10,000 l. The level

Table 3. Intensification level per hectare of specialized dairy farms in some European dairy farming areas, data for the 128 pilot farms of Dairyman project (sources: Bechu, 2013 and De Vries *et al.*, 2013). For Dairyman data: years 2009-2010-2011.

Region Dairyman[1]	Belgium, Flanders	Belgium, Wallonia	France, Brittany	France, Nord Pas de Calais	Germany, Baden-Würtemberg	UK, Northern Ireland	Republic of Ireland	Luxemburg	the Netherlands
No. of farms	11	10	8	7	7	10	21	4	16
Stocking rate LU ha^{-1}	2.6	1.9	1.4	2.0	1.7	2.1	2.3	1.3	3.0
Milk per cow (kg)	8,425	7,438	7,119	8,220	8,734	7,413	5,088	7,413	8,670
Milk ha^{-1} FA (kg)	15,803	9,948	7,224	10,736	10,061	11,958	8,480	6,519	19,735
Milk ha^{-1} AA (kg)	13,979	5,870	5,884	5,291	7,078	10,743	7,501	3,821	19,733
g concentrate kg^{-1} milk	170	247	121	216	245	302	155	216	232
N min ha^{-1} AA (kg)	120	95	41	121	79	145	183	86	105
N balance ha^{-1} (kg)	186	141	98	145	140	243	179	112	194

[1] AA = agricultural areas; FA = forage area; LU = livestock unit.

of milk per hectare of total AA also exceeds 10,000 l ha^{-1} in Flanders (Belgium), Northern Ireland and the Netherlands. These data are consistent with the calculations of the stocking rates in these farms. In western France it is rather low, considering that the forage production potential is high in this region. This is caused by the severe environmental regulations and the strong incentives to limit impacts of agriculture on water and air quality. This is illustrated by mineral N inputs per hectare that amount to only 41 kg per hectare AA, which is much lower than in Ireland for instance

Finally, compared to the rest of the world's dairy farming areas, using data of the IFCN typical farms (IFCN, 2014), the different French areas and examples chosen belong to the bottom list in terms of milk per hectare, with figures almost always below 5,000 l. This is far below the Netherlands or Lombardy (Italy) in Europe, Australia or New Zealand (between 10 and 20,000) or indoor feeding systems with no land, as in Japan or Israel. The French Franche-Comté mountains are particularly low in terms of milk per hectare and stocking rate because of the limited production potential, and the mixed crops and dairy systems combine a high production per hectare of forage area with a stocking rate but a high share of non-forage area, leading to this low figure of milk produced per hectare of total agricultural area.

Effects of land price

The relatively low production intensity can partly be explained by the relatively low land prices. The average cost for one hectare of agricultural land free of tenancy in 2013 reached 5,750 € with variations between regions, with only 2,530 € per ha in Franche Comté mountains but 12,340 € in Nord Picardie with high quality soils and then pressure for crop production. Compared to all other dairy regions from the FNSAFER database and the costs reported by the IFCN experts for typical farms, French regions are far below Denmark, Italy, Western Germany, Ireland and New Zealand around 20,000 € per ha, or China, India, Switzerland or the Netherlands over 45,000 € per ha. Thus, France appears to be the only area in the world to produce large amounts of milk with a land cost below 10-15,000 € in almost all its producing regions.

Another explanation is the strong link between land and quota in France: it has been kept during the whole quota period with no possibility for farmers to increase their milk deliveries without buying or renting the land 'bearing' the milk quota. No leasing or quota market system without land was ever implemented. The target was to maintain a more even distribution of dairy farms over the country, even in unfavourable areas. This forced farmers to increase land size in order to produce more milk, which slowed down their development. It explains the implementation of other production on dairy farms and the low level of specialization still observed, except in mountain areas.

Thus, the main target of the production systems in France is rather oriented towards an increased self-sufficiency in animal feed to limit the production cost and keep the link between territory and milk products, rather than to maximise the production per hectare.

French dairy systems aim for self-sufficiency, not productivity per hectare

French dairy production systems are strongly linked to the ground

First of all, the French dairy production is linked to the ground and is mostly based on forage self-sufficiency of the farms, to be able to face the requirements of the herd; maximizing the quality of the home grown forages will enable a good transformation of their energy value into milk by the cows. The French bovine dairy production sector shows its strong link with land and forage production through its resort to maize silage (46% of the diet in DM), and to grass: grazed, zero-grazed, silage, haylage or hay (29% of the diet in DM of dairy cows, Figure 2). The total DM intake is estimated at 6.9 Mg DM per cow per year (Brunschwig *et al.*, 2014). Altogether, forages represent 78% of the diet of French dairy cows.
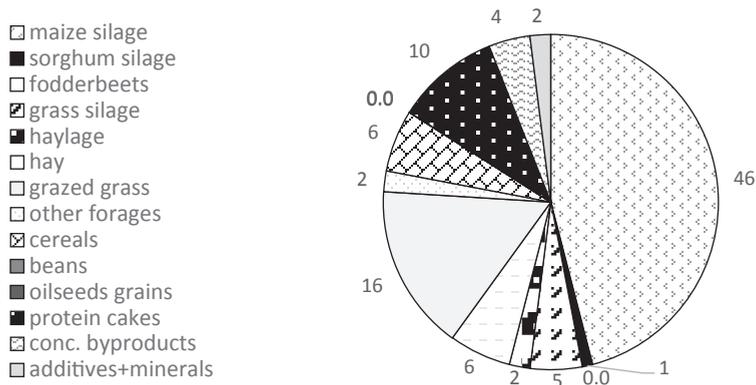
Figure 2. Diet composition of the French dairy cows (source: Brunschwig *et al.*, 2014).

Almost all French farms practise grazing during one period of the year (92%; Autograssmilk, 2012) in variable proportions; thus, this practice is decreasing with the ongoing enlargement of farms and the development of robotic milking. According to the area and the grass growth duration, the farm structure and the aims of the farmer, dairy cows go out of the sheds between 2 and 10 months per year. For the largest farms, grazing is often restricted to heifers and dry cows. Only 9% of the cows are considered 'not grazing' and 22% 'little grazing' (below 0.15 ha per cow). The contribution of grazed grass to the cows' diet ranges thus from 500 kg up to 3.0 Mg DM per year but it remains the main nitrogen source for the animals.

Farmers regularly adapt the ration of the cows with concentrate feeds. They represent on average 22% of the diet, but only 3 of these 22% are home grown. The specificity of French use of rapeseed cake can be underlined: though generally not grown on farms, this is produced in France and contributes to the national self-sufficiency in animal feed and proteins. It is the main nitrogen source for industrial animal compounds, although France still imports soybean for its dairy cows, while exporting rapeseed.

Regions and rations

The characteristics of the different production systems account for the forage systems implemented by the farmers and thus the cows' diets during the year. It also explains differences in terms of self-sufficiency in total dry matter, energy and proteins.

In the LDA, such as the West lowland (e.g. Brittany), the forage system is based on maize silage for winter (38% of the forage area, see Table 4) and grass. Temporary grasslands are in rotations with maize silage and crops. These grasslands usually stay in place for 5-8 years and mainly comprise grasses or mixtures of grasses and white clover (50% of the sowings). Farms grow an average of 22 hectares of crops, mostly cereals: part of them are kept for the dairy animals after flattening or mashing on farm or by a contractor. Thanks to the high-energy value of forage, over 0.90 UFL per kg DM[1] all year long, the resort to concentrates is limited to an average of 187 g per kg milk produced, and even less in Brittany (121 g per kg milk in the pilot farms of Dairyman project, see Table 3). This is the lowest regional level in France and can be considered as very efficient compared to other situations of over 200 g, except Ireland (152) and Flanders (170).

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[1] UFL = Unité Fourragère Lait; Net energy for lactation in MJ = UFL × 6.7 for grass (all types) and UFL × 6.8 for maize silage.

Table 4. Farm characteristics for French typical farms in the dairy farm networks (source: Réseaux d'Elevage, 2012).[1,2]

	LDA	West, maize	CLA	Maize <80 VL	MPA	PDO Franche Comté
No. of farms in France	17,580	7,550	16,720	4,680	1,2430	2,150
No. of farms in networks	138	36	90	18	96	12
Total AA (ha)	96	96	197	150	80	129
Incl. commercial crops (ha)	23	22	117	95	8	8
Milk delivered (×1000 l)	511.7	553.1	598.2	567.3	326.7	355.6
No. of cows	68	71	72	67	49	57
Milk prod cow^{-1} yr^{-1} (kg)	7,650	7,957	8,380	8,604	6,742	6,582
Concentrates kg milk^{-1} (g)	207	187	237	224	249	213
Forage area (% AA)	76	76	41	37	90	94
Maize/forage area (%)	31	38	33	44	10	0
Stocking rate (LU per ha)	1.5	1.7	1.7	1.8	1.00	0.8
Milk per ha FA (kg)	7,742	7,916	8,671	11,096	5,297	3,247
Milk per ha AA (kg)	5,330	5,761	3,037	3,782	4,084	2,757
Input N min fertiliser (kg per ha AA)	81	78	121	133	44	40
N balance per ha AA (kg)	95	88	81	92	60	44
Valor. grass yield Mg DM ha^{-1}		6.01		6.15		4.25

[1] AA = agricultural areas; FA = forage area; LU = livestock unit; DM = dry matter.
[2] The colour of lines refers to Figure 1.

In the dairy CLA, the production systems like in Nord Picardie are often based on temporary grasslands, together with a high share of maize silage (44% of the FA; Table 6). The farms also produce 95 ha of crops on average, accounting for a high mechanization level and the management of large areas of maize in the rotation system. The home-grown cereals contribute to the dairy cows' diets. Thus the productivity is higher than in the other regions (11,000 l per ha FA) but with a greater resort to concentrates and by-products, as many are widely available (224 g per l milk).

Because of the large resort to maize silage, the weak point of these two first systems is the lack of protein concentrates that cannot be produced locally for climatic reasons; they are the highest cost component of the feeding cost, and therefore of the milk production cost.

In the MPA, the forage systems of these areas are based mainly on permanent grasslands with a multi-species botanical composition. These fields are grazed from April till October and most of them are cut for hay making to build stocks of hay for winter feeding, in particular in the cheese PDOs where silage is forbidden. The resort to concentrate is higher than in other dairy areas (213 g per l milk, Table 4), but limited by PDOs restrictions (1,800 kg DM). These systems based on hay and with little solutions to grow crops (8 ha out of 129 for Franche Comté systems) may lack both energy and proteins to properly balance the dairy cows' diets, but mainly lack total dry matter self-sufficiency during the bad' forage years.

Animal feeding and feeding self-sufficiency

Feeding efficiency is defined as the balance between the herd requirements and all the resources than can be harvested or grown on farm (Elluin *et al.*, 2014; Rouillé *et al.*, 2014). This factor can be analysed through three indicators: the mass self-sufficiency (in kg DM), the energy self-sufficiency in UFL (energy unit of the French INRA feeding system) and the protein self-sufficiency in kg of crude proteins.

For the total diet (Table 5), the mass self-sufficiency is globally high and varies between 79 and 81.6% according the production system/area. The forage self-sufficiency is very high and is around 97% in all systems. The concentrates mass self-sufficiency remains weak to moderate, between 12% in plains and 26% in mountains. Because of the large share of forages in the diets (concentrates limited to 18.1 to 21.0% of the mass DM), and of the high-energy value of the forages, the energy self-sufficiency values are close to the mass self-sufficiency values. Finally, the different production systems are mainly discriminated by their self-sufficiency in proteins and protein concentrates. The protein global self-sufficiency is much lower than the mass or energy self-sufficiency (between 53 and 74% of the diet). The forage protein self-sufficiency is high and close for all systems (97%). But the concentrate protein self-sufficiency remains low and much lower with lowland maize-based systems (around 5%) compared to mountain grass-based systems (15.9%). The higher productivity and nitrogen requirements of the animals reared in plains also accounts for the lack of self-sufficiency in these systems.

Self-sufficiency is a competitiveness asset for the French dairy chain

On average, French dairy farms produce 83% of the feed used by their herds (Rouillé, 2014). This high level, together with the diversity of production systems, is considered by the whole dairy chain as an important asset in terms of competitiveness, although it might be threatened after the end of the quota system. Actually, the volatility and relatively high prices of purchased feeds on the markets have a lower impact on French dairy farms than in other countries. The recent study made by IFCN and the IDF federation for FAO (FAO, IDF and IFCN, 2014) show that many large dairy sarming areas suffer from a lack of self-sufficiency with high feed prices. Many countries are below 80% of global self-sufficiency with some American or Spanish typical farms around 20% for the total diet and only 40% for the forages. The Danish or Dutch systems reach around only 70% of total self-sufficiency with no home-grown concentrates at all. The other group of countries or regions shown are above 80% of global self-sufficiency. The three French areas chosen to illustrate this paper belong to this group, as well as some German and Italian typical farms. The Irish grass-based systems reach almost 100% of forage self-sufficiency, but lack 20% of their dry matter because they must buy their concentrates. The New Zealand systems are more sensitive to drought than the Irish ones and this has an impact on their purchases of feed.

As a conclusion, the high level of self-sufficiency in good quality forages (grass and maize silage), the possibility in plains to also grow the energy concentrate (cereals) and the relatively high availability of land gives a competitiveness asset for French dairy farms as long as they keep a production system based on forages. Together with the low land price compared to that of other producing countries, it underlines the importance of criteria such as 'milk produced from forages per hectare' or 'autonomous milk production'

Table 5. Self-sufficiency levels for dairy herd, per class of French dairy system, based on data of pilot farm networks (Source: Réseaux d'Elevage, year 2008; Cniel-Idele, 2012).

System[1,2]	Dry matter self-sufficiency (%)				Energy self-sufficiency (%)			Protein self-sufficiency (%)		
	total diet	forage	concentrates	concentrates in diet	total diet	forage	concentrates	total diet	forage	concentrates
LDA, maize	81.6	97.2	12.0	18.3	79.8	97.1	13.8	57.7	97.9	4.8
CLA, maize	79.0	96.8	11.9	21.0	77.4	97.6	13.6	53.2	96.7	5.1
MPA, grasslands	84.4	97.3	26.3	18.1	82.0	97.7	29.3	74.1	97.8	15.9

[1] The colour of lines refers to Figure 1.

[2] LDA = lowland dairy areas; CLA = dairy crops and livestock areas; MPA = dairy mountains and piedmont areas.

rather than milk produced per hectare. To keep this asset, and maintain a relatively low feeding cost, French systems must find the best balance possible between grass and maize silage in areas where both crops can be grown. The differences between systems in terms of protein concentrates (the highest cost of the diet for a lactating cow) come from the share of maize silage in the system (Paccard, 2003; Rouillé, 2014). The differences between systems come mainly from criteria describing the farm structure such as: the stocking rate, the production per cow and the concentrate per cow. In Paccard's study, based on 383 farms of the Réseaux d'Elevage[2]/dairy farm networks, a statistically significant negative relation was found between mass self-sufficiency and the global intensification level. Self-sufficiency in proteins was also statistically reduced by the same three variables and the part of maize silage in the system. The autonomy in concentrates only discriminated organic production systems from the others.

In the same study, Paccard also found statistical relations between mineral balances of the farms (inputs-outputs for N, P and K) and self-sufficiency in feeds. The self-sufficiencies for total diet and concentrates in crude protein, energy and dry matter appeared to be negatively correlated to the nitrogen mineral balance. This is consistent with a lower nitrogen concentrate purchase leading to a lower N-input level. But this study also confirmed the high relation between the mineral balance, the mineral nitrogen inputs per hectare and the nitrogen concentrate purchases. Criteria such as stocking rate and milk per hectare of FA appear to have a negative impact on mineral balance and self-sufficiency in protein concentrates. Under French conditions, intensification of animal production through nitrogen concentrates, and intensification of crops through mineral fertilizer are strongly related. It is not the case in New Zealand for instance, with intensification per hectare but low animal productivity, or in countries with feed purchases. Moreover, mountain situations such as Franche Comté, with a low intensification per hectare but a relatively high resort to concentrates, must be studied separately.

Therefore, the milk produced from home-grown forages appears to be correlated to 'other outputs' of the system such as mineral balance and its possible negative impacts on the environment. The intensification level of the production systems must thus be chosen taking these aspects into account in order to limit the risks of possible negative impacts on water or air quality. They will also be driven by the environmental regulations implemented.

Avoiding negative outputs (environmental effects) by limiting inputs

Environmental impact

The 76,000 French dairy farms are using some 20% of the territory and thus have a major role to play towards the environment (Dollé, 2013). In the coming years they will have to face challenges such as producing good quality dairy products in larger quantities but also keeping high levels of environmental, social and economic performances. In terms of environment, the challenges are particularly related to the limitation of risks of pollution of air and water, and to the preservation of biodiversity.

For agricultural activities, the eutrophication potential is mostly due to nitrate leaching and phosphorus run off, which are related to the inputs in organic manure/slurry and mineral fertilizers. To limit these risks, the French state assigned targets to the agricultural sector by designing areas at risk of eutrophication; they are almost all classified as 'vulnerable zones' (44% of the French territory) in the European Nitrates Directive (1991). Most of the intensive lowland production areas are limited to 170 kg organic N per ha, and 210 kg total N per ha since 2010 (Grenelle de l'Environnement laws). Many dairy production areas like Brittany face an even more restricted resort to N fertilization in 'green algae catchment basins' with a total amount of N allowed between 140 and 160 kg total N per ha. France unlike other European dairy

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[2] French bovine dairy farms reference network made of 630 farms followed on a regular yearly basis

countries (Ireland, the Netherlands) has no derogation to apply a higher fertilizer level on grasslands, as the water quality in many areas remains considered as too poor by the European Commission; this statement leads to regular convictions of the French state by European courts, and makes it impossible to apply for a 'nitrogen' derogation. With the French average cow producing 'officially' 85 kg of N per year before 2013, and being followed by 0.3 LU (calves and heifers) for its replacement, the nitrates regulation automatically limited the stocking rates below 170/(85×1.3)= 1.54 LU per ha of total area. The new regulation with an excretion around 100 kg N according to the share of grass in the diets will lead to even lower levels of possible stocking rates.

Agricultural practices have an impact on biodiversity (Clergue *et al.*, 2005). The agricultural specialization of some regions has a negative impact, while the diversity of productions, the presence of mixed and imbricated vegetal covers, the existence of agro-ecological structures such as hedges and grasslands can have a positive impact. The permanent grasslands present a high potential of biodiversity influenced by practices: a good management of grazing and/or mowing, a stocking rate adapted or a good level of fertilization, contribute to preserve the wildlife and the flora (Amiaud *et al.*, 2014). Dairy farming, as a user of grasslands and crops, has lots of assets because it directly monitors areas with agro-ecological services (Ryschawy, 2013). This target is translated into European regulations and French frame laws to support sustainable farming systems defined by extensive practices (low stocking rates for instance). Again this will limit the possibility of intensification in MPA to keep the subsidies related to environmental rules and therefore the level of milk production per hectare. But at the same time, other productions or services will be provided through good grassland management: landscapes, high quality water and air, biodiversity, limitation of snow avalanche risks, maintenance of footpaths and ski slopes and tracks (Huygues, 2014). Moreover, the production services may appear limited in amount per hectare but this relative extensive production per hectare is creating more jobs on the territory than in more intensive areas (Perrot, 2008 and 2010). In Franche-Comté for instance, thanks to the high added value of the PDO cheese, it is considered that one farm job creates 7 other jobs in the dairy chain (Rieutort, 2014). The production per hectare should then include the total added value created and not only the milk per hectare produced to better estimate the total production and services offered by dairy farms in such situations.

A strong link between practices and environmental performances

The analysis of environmental impacts shows differences between production systems related to the part of grass in the system, the stocking rate and the breeding practices (Dollé, 2013):

- The share of grazed grass in the diets: it limits the inputs of protein concentrates and reduces the GHG emissions thanks to the longer time spent by animal outside.
- The management of the herd: the replacement rate, the sick cows, the age at first calving influence the number of 'unproductive' livestock units and thus the stocking rates.
- The level of inputs (concentrates, mineral fertilizers, fuel). The lack of self-sufficiency creates a strong dependency for energy resources and a high and risky N balance.

The search for improved environmental practices to limit risks on water quality (first mitigation targeted in the 1990s) together with the regulation frame account for the relatively low level of mineral input per hectare on French typical farms (Table 4) and pilot farms of the Dairyman project (Table 3). The mountain systems with their limited potential of permanent grasslands and relatively low level of quota per hectare only use around 40 kg of mineral N per hectare. In relation, they show a limited N balance (44 kg per ha for Franche Comté systems) but also a low stocking rate of 0.8 LU per ha and a yield of 4.25 Mg DM of grass per ha. The CLA systems (maize <80 cows) use an average of 133 kg of mineral N per ha with a limited balance (92 kg) and limited risks of leaching, but also reach only a relatively low level of grass use (6.15 Mg DM per ha). Finally, the systems of the West lowlands use, on average, only 78 kg

of mineral fertilizer; the balance is also limited but again grass yield (6 Mg DM per ha) is low compared to the potential that could be reached with higher levels of fertilization, but also with higher risks for the environment. Compared to the other dairy basins studied in the Dairyman project, the Breton pilot farms show the lowest mineral N inputs and N balance per hectare (Foray, 2013). These practices account for the relatively low level of stocking rate and milk per hectare (figures already discussed). They are related to the strong regulations implemented.

The aim to reach a low N balance to limit the risks to the environment leads to a moderate level of milk produced, by hectare and stocking rate. The environmental study led within the Dairyman project puts two contrasted situations to the fore (Table 3; Béchu, 2013). The 'intensive' production systems (Flanders, the Netherlands, Northern Ireland, Ireland) show a high N balance per ha; except in Ireland, these regions are characterized by a high level of milk production per hectare. In contrast, the less-intensive systems, including the French regions, show a lower level of N balance with a lower milk production per hectare. The French mountain regions added to this sample (Figure 3) combine a much lower level of balance (40 kg per ha) and of milk per hectare (3,200 kg). The link between the two criteria appears on that Figure as well, as the link between mineral fertilizer inputs and N balance for Dairyman pilot farms. This is why French authorities try to reduce the impacts linked to N management by limiting the inputs or the stocking rates: these indicators are considered as relevant tools to improve water quality at the end of the chain, and as a consequence it also limits the possible development of 'high milk output systems'.

Conclusion: future challenges and perspectives

French production systems keep a strong link between land and dairy production with a relatively low level of inputs and outputs per hectare, because land is widely available, the quota system has kept a strong link between quota and land, and because of the environmental regulations in the most intensive regions to limit negative 'outputs' of dairy production. This also explains the moderate level of valorisation of forages per hectare in many areas, which could be improved and lead to higher milk deliveries in the northern half of the country, if dairy processors asked for this. Several negative aspects should be underlined:

- Despite or because of a relatively low population density and in particular in some rural areas of the territory, the land is not properly monitored with the equivalent of one county disappearing every ten years (890,000 ha AA) for human activities (roads, houses, commercial areas); though the agricultural chain has expressed many warnings about the decreasing area available to produce human feed in the country, this trend has not been slowed down in the last period of time (Perrot, 2013). Moreover, the quota system with a strong link between quota and land has reached its target to keep milk production all over the country: 92% of the local communities have at least a dairy farm in the 2010 census. But it also pushed farmers to take land far from their cowshed to have access to

Figure 3. Milk per hectare forage area (FA) in relation to N balance for specialized dairy farms in some European dairy basins (Bechu., 2013, for Dairyman project; Réseaux d'Elevage, 2011/2012).

the quota linked to this land. This has created larger farms but with lots of fields far from sheds and not grazeable by the cows, leading to production systems with higher production costs. No real local of national policy to better monitor land through exchanges for instance has been developed until now and this fragmented land threatens the current and future economic efficiency of production systems which tend to be self-sufficient in feed (and in proteins in particular, grass being the largest source of protein feed available).

- The relatively high availability of land leads to an under-use of the production potential of grass. In many areas it does not exceed 5 Mg DM used per LU per ha, in particular in regions with permanent grasslands widely available. This is due to management practices such as low fertilization levels of N, P and K, and extensive management practices because there is no need to harvest more. The global dairy production of France could be much higher with an improved management of these areas.

- The environmental regulations with no derogation for N application on grasslands currently limits the yields in areas with high forage potentials and high density of dynamic farmers. As a consequence, the average stocking rate has dropped down to 1.6 LU per ha FA in western dairy farms (RGA census, 2010). Together with the quota/land system until 2015, this accounts for the absence of any steep increase in dairy production in areas with good forage potential both for grass and maize and with a good farmers dynamic, breeding oriented, wishing to milk more cows, which is not the case in other areas with less environmental restrictions (Perrot, 2014).

The French dairy production sector is facing an evolution that many European countries have faced earlier, with the increasing size of the farms and the development of indoor production systems with less grazing and more resort to concentrates to reach higher production levels per cow. This can lead to a loss of competitiveness with a decrease of feed self-sufficiency levels and higher feeding costs on dairy farms. Keeping this strong link between dairy production and forage and territory should be a major target both for economic and environmental purposes. It also contributes to the specificity and the image of dairy products for consumers. Finally, the outputs of dairy production per hectare, per cow and per territory should not only include milk and milk products but also all the other services (Huygues *et al.*, 2014) that are provided for society by the land monitored by dairy farmers: provisioning services such as milk production and low-cost animal feed; regulating services such as biodiversity, mitigation of GHG emissions, of avalanche controls; cultural services like beauty of landscape and tourism, and supporting services such as competitiveness or feed protein supply. The most dynamic sector for dairy production in terms of replacement rate of farmers is located in the Jura mountains with 1 settlement for 2 retirements, a rate much higher than the French average (1 for 3.8 Agreste, 2013). In this region, the production output per hectare, per animal or per farm may appear relatively low compared to other regions; though dairy production there has a strong role in keeping landscapes and biodiversity, and a high added value on the territory thanks to the high quality products processed under PDO specifications.

As a conclusion, France has a high natural potential to increase the outputs of dairy production after the end of quotas, although the limiting factor in the coming years will probably be the lack of farmers rather than the lack of land. The sustainability of these systems remains strongly related to the high link between land, forage production and milk production (self-sufficiency) and the maintenance of high added value products on piedmonts and mountain territories thanks to dairy production. 'High output farming systems' will remain diversified in terms of production systems and combinations of 'outputs' delivered. One of the challenges will be the maintenance of production systems combining maize silage and grass, with 'as much grazing as possible' in lowlands, thanks to a good field design, a good management of grass and clover pastures with very limited mineral N inputs. These systems should produce good quality milk with the 'right' fatty acids, and be efficient both on economic and environmental points of view.

References

Agreste (2013) *Primeur. Les exploitations laitières bovines en France métropolitaine.* Des territoires laitiers contrastés. N#308, 8 p.

Amiaud B., Chanséaume A. and Manneville V. (2014) *Un espace de biodiversité au service des productions herbivores, la prairie permanente.* Document Institut de l'Elevage, Université de Lorraine, CNIEL, 24p. Available at: http://tinyurl.com/k372kyp.

Autograssmilk (2012) *Innovative and sustainable systems combining automatic milking and precision grazing.* Available at: http://www.autograssmilk.eu.

Béchu T. (2013) *Etude des performances économiques et environnementales des exploitations bovins lait dans le nord-ouest de l'Europe.* Master thesis report. Université de Lorraine, Institut de l'Elevage, Dairyman. 43 p. Available at: http://tinyurl.com/l8r6bne.

Brunschwig P. and Perrot C. (2014) *L'alimentation des vaches laitières et l'autonomie des principaux systèmes spécialisés laitiers français.* Communication for the seminar « Autonomie Alimentaire: Quels enjeux pour la filière laitière après quota ?», CNIEL, Paris, France, 03/07/2014.

Clergue B., Amiaud B., Pervanchon F., Lasserre-Joulin F. and Plantureux S. (2005) Biodiversity: function and assessment in agricultural areas. A review. *Agronomy for Sustainable Development* 25(1), 1-15.

CNIEL-Idele 2012. *Observatoire de l'alimentation des vaches laitières.* Available at: http://tinyurl.com/l86axmb.

De Vries M., Debruyne L. and Aarts F. (2013) *Sustainability of dairy farming and the implementation of EU environmental directives in the northwest of Europe.* Dairyman final report. Available at: www.interregdairyman.eu.

Dollé J.B., Moreau S. and Foray S. (2013) *Combiner production et environnement, un défi pour la filière laitière.* Collection l'Essentiel, Institut de l'Élevage, 16 p.

Dossier Economie de l'Elevage (2013) *L'élevage d'herbivores au Recensement Agricole 2010. N#440-441.* Document Institut de l'Elevage, 100 p. Available at: www.idele.fr

Elluin G., Brunschwig P. and Le Doaré C. (2014) *L'autonomie alimentaire dans les principaux pays laitiers.* Institut de l'Elevage – Cniel.

FAO, IDF and IFCN (2014) *World mapping of animal feeding systems in the dairy sector.* FAO, Rome, Italy, 177 p. Available at: http://tinyurl.com/kgofuv6.

Foray S., Beguin E., Ferrand M., Perrot C., Dolle J.B., Bechu T., Hennart S., Boonen J., Tirard S., Morin C. and Castellan E. (2013) La durabilité des exploitations laitières du Nord-Ouest de l'Europe. *Rencontres autour des Recherches sur les Ruminants* 20, 217-220.

FranceAgriMer (2014) *Évolution des structures de production laitière en France.* 44p. Available at: www.franceagrimer.fr.

Huygues C., Peyraud J.L., Brocard V. and Van den Pol-van Dasselaar A. (2014) Appreciation of the functions of grassland by French stakeholders. *Grassland Science in Europe* 19, 807-809.

IFCN (2013, 2014). *IFCN Dairy report.* 207 p. Available at: www.ifcndairy.org.

Paccard P., Capitain M. and Farrugia A. (2003) Autonomie alimentaire des élevages bovins laitiers. *Rencontres autour des Recherches sur les Ruminants* 10, 89-92.

Perrot C., Reuillon J.-L., Capitain M. and Cassez M. (2008). Forces et faiblesses des exploitations laitières françaises de montagne dans la perspective d'un desserrement de la contrainte des quotas laitiers. *Rencontres autour des Recherches sur les Ruminants* 15, 243-246.

Perrot C. (2010) Projection du nombre d'exploitations bovines laitières ou allaitantes françaises. Une approche par modélisation démographique intégrant des effets territoriaux. *Rencontres autour des Recherches sur les Ruminants* 17, 211-214.

Perrot C., Bataille J.F., Bossis N., Caillaud D., Gallot S., Morhain B., Morin E., Roguet C. and Sarzeaud P. (2013) Diversité de l'élevage français et dynamiques territoriales. Les enseignements des recensements agricoles. *Rencontres autour des Recherches sur les Ruminants* 20, 341-344.

Perrot C., Caillaud D., Chatellier V., Ennifar M. and You G. (2014) La diversité des exploitations et des territoires laitiers français face à la fin des quotas. *Rencontres autour des Recherches sur les Ruminants* 21, 203-210.

Réseaux d'Elevage, 2012. *Synthèse annuelle des données des Réseaux d'Elevage. Bovins lait 2011.* Doc. Institut de l'Elevage-Chambres d'Agriculture, 52 p., available at: www.idele.fr.

Rieutort L, Ryschawy J., Doreau A. and Guinot C. (2014) *Atlas de l'élevage herbivore en France. Filières innovantes, territoires vivants.* Editions Autrement, 96 p.

Rouillé B., Devun J. and Brunschwig P. (2014) L'autonomie alimentaire des élevages bovins français. *Oilseeds and fats, Crops and Lipids* 21(4), D404.

Ryschawy J., Disenhaus C., Bertrand S., Allaire G., Aubert C., Aznar O., Guinot C., Josien E., Lasseur J., Perrot C., Plantureux S., Tchakerian E. and Tichit, M. (2013). Evaluer les services rendus par l'élevage dans les territoires: une première quantification sur le cas français. *Rencontres autour des Recherches sur les Ruminants* 20, 303-306.

SAFER (2014) *L'essentiel des marchés fonciers ruraux en 2013. Le prix des terres/La synthèse – mai 2014.* Document FNSAFER, 12 p., available aat: http://www.le-prix-des-terres.fr.

Dairy farming systems and development paths in Slovenia

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Abstract

The aim of this article is to describe the status of the dairy sector and future development paths of the various cattle farming segments in Slovenia. Agriculture is carried out under very diverse circumstances. About 73% of agricultural land is defined as 'less favoured areas'. The agricultural area (472,918 ha) consists of 58% of permanent grassland and 36% of arable land, mostly used for production of feed. Cattle husbandry on family farms, of which there are 7,000 dairy farms, is the most important agricultural activity. Three farming systems can be observed: summer grazing with the dual-purpose breeds in the mountains; grazing with suckler cows in the hills; and intensive dairy farming in the valleys. These farming systems were characterised on the basis of 1,346 questionnaires collected in 2007. Farmers of the local Cika breed were interested in protecting nature elements and in organic farming. Dairy farmers expressed a more economical attitude towards the farm business. Of the developing dairy farmers, more than half looked for specialisation and less than half for diversification. Management of grassland was ranked as of relatively high importance. Regular contact with some Western European institutes resulted in lowland areas receiving high N applications around the turn of the century. Land fragmentation is a huge problem. In a recent 'life long learning' project with Poland, Lithuania and the Netherlands, dairy farmer strategies were analysed. Of the participating 365 Slovenian dairy farmers, 40% applied grazing and the average farm had 30 separate parcels of land. Farmers in the Eastern European countries (n=1,028) were more concerned about the market and abolition of milk quota than were the farmers in the Netherlands. Farmers in Slovenia were more consumer-oriented. A challenge for Slovenia is to utilize the existing consumer orientation of farmers for direct selling or agro-business purposes, as well as a strengtening of the dairy-chain structure to gain better access to the international milk market.

Keywords: dairy farms, production systems, grassland, Slovenia

Dairy farming in Slovenia

Slovenian agriculture is characterised by small family farms. This has been influenced by historical reasons. Until 1991, private farmers were allowed to have only a maxium of 10 ha of agricultural land. Largely due to the mountainous and hilly terrain, almost 75% of the utilised agricultural area is characterised as having 'less favourable area' status. Forestry is also of considerable importance in Slovenia. These days, family farms account for 93% of the land and agricultural enterprises. The composition of the agricultural area is dominated by meadows and pastures, which represent 58% of all land, while arable land and horticulture, vineyards, and extensive orchards utilize respectively 36.0, 3.2 and 1.5% of the land (SURS, 2012). Maintenance of grassland and development of cattle production for both milk and meat is of strategic importance. Grassland is a suitable use of the land, in particular in the less favoured areas where alternative usage is quite limited. Indeed, the maintenance of livestock production and grasslands are important factors in preservation of the cultural landscape and of settlement in rural areas, reducing the likelihood of abandonment and the land becoming overgrown. Milk production is the predominant agricultural activity in the country, accounting for 16.2% of the Gross Agricultural Output (GAO) in 2013 (Table 1), which places Slovenia close to the EU average (KIS, 2011). The fluctuations in contribution of the sector to the GAO can be partly explained by the changes in milk prices and by fluctuations in GAO of crop products. In some years, crop production has been strongly affected by

	2007	2008	2009	2010	2011	2012	2013
Total GAO (€ mill.)	1,509	1,551	1,410	1,439	1,610	1,585	1,588
Share of animal production in GAO (%)	45.2	47.3	46.6	44.5	45.1	46.3	48.0
Share of milk production in GAO (%)	14.6	16.1	13.9	13.6	14.5	14.6	16.2
Share of beef/veal production in GAO (%)	12.1	11.6	13.1	12.4	12.8	14.0	12.8

Source: EUROSTAT, Economic Accounts for Agriculture; KIS, 2011.

bad weather conditions (droughts, storms, floods). Suckler cow farming on the grasslands with beef as a production goal is also a major activity in Slovenia. This large group of farms, whose work is often combined with off-farm employment, is characterised by very small herds.

Structure of dairy farming

Since the mid-1990s, the milk sector in Slovenia has gone through a period of rapid structural changes including a continuous decrease in the number of producers and an increasing herd size per holding (Figure 1). In 1985, there were 161,875 dairy cows reared on 58,194 agricultural holdings. Total raw milk production amounted to 379,800 Mg, of which 80% was delivered to the milk collection stations and the rest was used or sold on farm. In 2013, 99,664 dairy cows were reared on 6,573 dairy farms with a total milk production of about 595,000 Mg. However, the structural changes slowed down after 2004, when quotas were introduced, although the national quota of Slovenia has not been fully used (MAFF, 2014). According to the recent farm structure survey (SURS, 2012), the average number of dairy cows per holding is 15.2 and the average farm size is 11 ha. In Slovenia, more than 43% of the dairy holdings have fewer than 10 cows, 34% of dairy farms have between 10 and 20 cows and 23% of farms have more than 20 dairy cows; this last group accounts for more than half of the national herd. The abolition of milk quota will likely speed up the restructuring process, although the milk price may be a better indicator for this.

More than 60% of dairy cows are housed on farms situated within less favoured areas: in mountain, hilly, karst, Natura 2000 and water-protected areas (Figure 2). The structural development of the sector did not
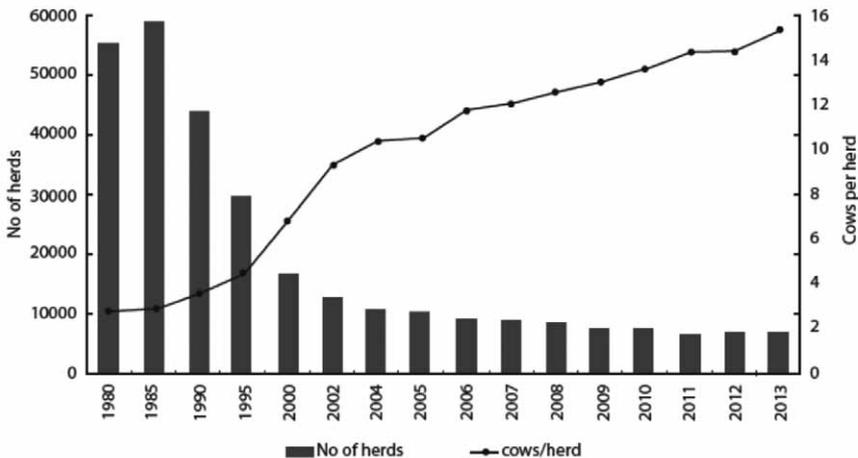
Figure 1. Changes in numbers of milk suppliers (number of dairy herds) and average number of dairy cows per herd.

differ very much in relation to the different farming conditions, and this may be regarded as unexpected. For instance, the percentage of cows and farms in the mountainous and hilly areas stayed about the same during the last 10 years (Figure 2). Apparently, there is greater competition to obtain land between the agricultural sectors and other sectors – human settlements and industry in the valleys. Indeed, very high prices for land are paid in the lowlands (from €30,000-60,000 ha^{-1}) and lower prices in less favoured areas (€20,000-30,000 ha^{-1}).

Milk market

Slovenia has a well-developed operating system for milk collection. It is largely organised through cooperatives but in some cases the dairies themselves collect the milk. In 2014, there were 94 registered and approved purchasers of milk of which 82 were cooperatives. There are seven domestic dairies that are members of the Chamber of Commerce and Industry of Slovenia and the Slovene Dairy Association. The self-sufficiency rate of milk production is over 115%, which makes Slovenia a net exporter of milk. Before accession to the EU, milk was purchased only by domestic dairies, but afterwards some cooperatives reoriented their sales of raw milk to foreign processors. In 2014, there were 517,000 Mg of milk delivered for processing, of which around 37% was sold and transported to Italian companies (SURS, 2015). Slovenia exports approximately 20% of its dairy products, so the export market is important for our dairies. The main export markets are, besides Italy, the countries of the former Yugoslavia, in particular Bosnia and Herzegovina, Croatia, and Kosovo (Bogovič, 2012). Slovenia has a series of EU-certified milk and meat PDO products, like Nanos and Tolminc cheese and Kranjska sausage (EC, 2015). In general, Slovenian milk prices follow the trend in the EU, but at a lower level, and are significantly lower than in Italy (Figure 3).

Performance at farm level

In recent years, dairy husbandry has seen a change in the breed structure, with dairy cow breeds increasing and the combined-purpose breeds (for milk and meat) decreasing (Figure 4).

This, together with technological advances in breeding and nutrition, has led to higher average milk yields and improved quality of milk. During the last twenty years, milk yield per cow has doubled. However, when comparing the milk yields with the EU-average, a relatively low technical efficiency of Slovenian dairy farming is indicated. The Slovenian average of 5,514 kg per cow in 2012 was at a level of 82% of the EU-27 average of 6,692 kg. Part of the explanation of the moderate average yields in Slovenia will be the low share of Holstein-Friesian cows in the national dairy herd (35% in 2013) and the large share of dairy
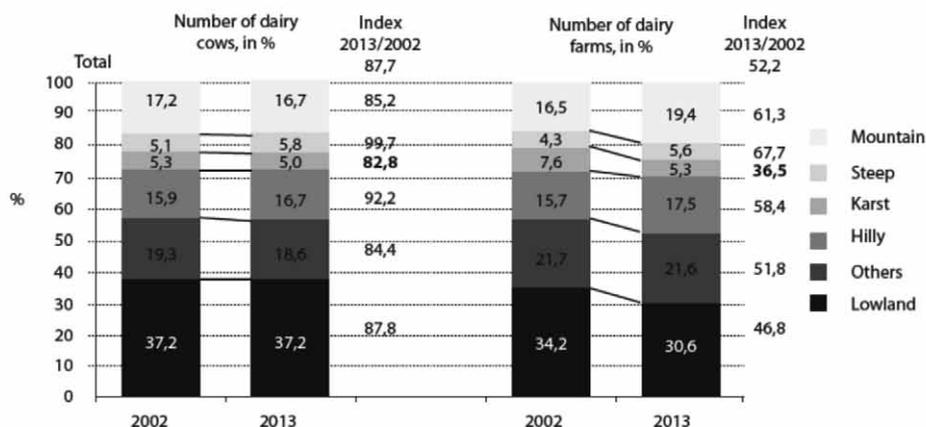
Figure 2. Number of dairy cows and farms in six different farming conditions in years 2013 and 2002 (in percentages of total).
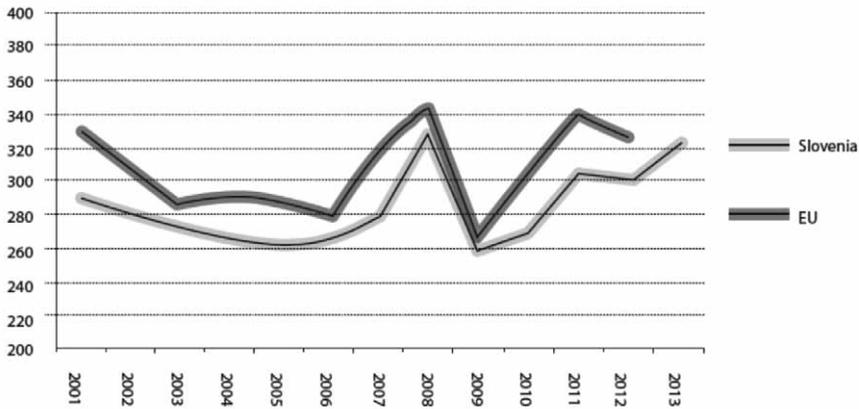
Figure 3. Trends in milk prices on farm gate (in € Mg^{-1}): comparison Slovenia vs EU (Volk, 2014).
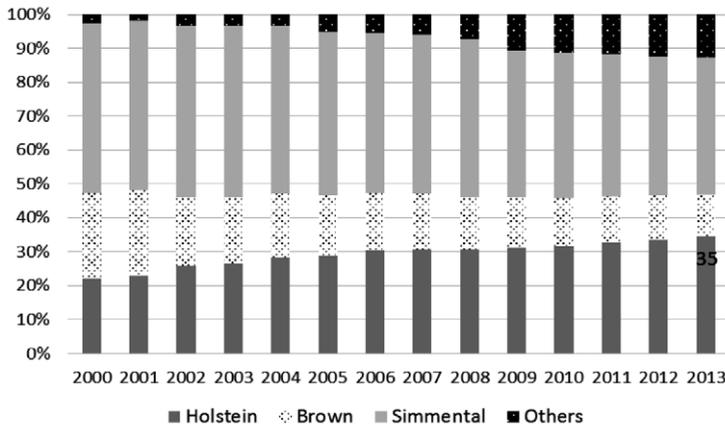
Figure 4. Breed structure of dairy cows over time (Volk, 2014).

farms functioning in the less favoured areas, where forage production is limited mostly to grasslands. About 40% of the Slovenian dairy herd is Simmental type and another 12% is Brown Swiss (Figure 4). These breeds of cows are more suitable for combined milk and beef production, which is the farming system that dominates on the smaller farms in the less-favoured hilly areas. The milk yield on farms with official milk recording, which covers about 80% of all dairy cows in Slovenia, increased to 6,328 kg in 2014. This ranges from 5,490 kg milk for Simmental cows to 7,414 kg milk for Holstein-Friesian cows. The quality of raw milk in recent years is for 92% classified in the extra-quality class, and additionally, 6% in the first-quality grade.

Application of manure and mineral fertilizer

Cattle and pig production are strongly developing in particular areas, like in the North East and in the North West, and less in the traditional livestock areas of the country. The ratio between number of livestock and manure production and available agricultural land in these regions is no longer in balance.

Use of organic fertilizers, especially livestock manure, sewage sludge and compost, is extensively regulated. About 80% of all agricultural holdings use manure or slurry to fertilize their agricultural areas including permanent grasslands. The other farmers have no animals and no manure. About 20% of arable

land, which varies from year to year, has crop cover during the winter. These crops are subsequently incorporated as green manure (MAFF, 2012). The maximum yearly-allowed application rate per hectare is based on the major nutrients – not more than 170 kg N ha^{-1} and 120 kg P_2O_5 ha^{-1} and 300 kg K_2O ha^{-1}. These amounts correspond to 2.5 LU (livestock unit) of cattle (ruminants) or 2.0 LU of pigs or poultry per ha. Nitrogen is commonly the limiting nutrient in manure, except in the case of poultry manure where the high phosphate content often limits the amount that can be applied. If a farm produces manure surpluses relative to its agricultural land available for manure application, the surpluses must be transported elsewhere upon receipt (to neighbouring farmers, through the market or, as a last solution, to the approved waste disposal service). The application of slurry is prohibited during wintertime, between 15 November and 15 February, if the arable soils are bare (i.e. without vegetative cover) during this period. It is prohibited to use organic fertilizers on soils that are flooded, deeply covered by snow (>10 cm), frozen, on slopes where surface runoff is possible, in swamps, marshes or in natural forests. Mineral fertilizers are typically used as additional fertilizer. When added to the organic fertilizer, this results in an average use of 140-150 kg N, 65-75 kg P_2O_5, and 130-150 kg K_2O per ha and year (Mihelič *et al.,* 2006).

The consumption of mineral fertilisers/nutrients (N, P_2O_5, K_2O) in the period 1992 to 2010 was reduced by 24% from 135 to 103 kg ha^{-1} utilised agricultural area (Figure 5). In this period, on average, 63 kg N, 30 kg P_2O_5, and 37 kg K_2O per hectare were used (ARSO, 2011). In 2012, 64% of the total agricultural area was fertilised. The estimated average consumption of nutrients by the total fertilised land area was 146 kg ha^{-1} – 78 kg N, 32 kg P_2O_5 and 36 kg K_2O (STAT, 2013). The plant nutrients from fertilisers were mostly used for cereals (39%), permanent grassland (32%) and green fodder (16%).

The Agricultural Advisory Service plays an important role in performing soil analysis and in the preparation of rotation plans and soil fertilisation plans. An innovation in this area has been the implementation of the agri-environmental programme. Farmers can ask for financial support from this programme only on the basis of measured nutrients in the soil and a well prepared fertiliser plan (MAFF, 2012).

Studies of development paths of cattle farmers in Slovenia

The development of the cattle sectors, as seen from the viewpoints of the farmers, was studied in the periods 2005-2007 and 2011-2012 as part of European projects. In the first study the entire focus was on Slovenia, and in addition to the dairy sector, farmers with the autochthonous Cika breed and a group of suckler cow farmers were also included. The second more recent study also concerned dairy farmers in Poland, Lithuania, Slovenia and the Netherlands.
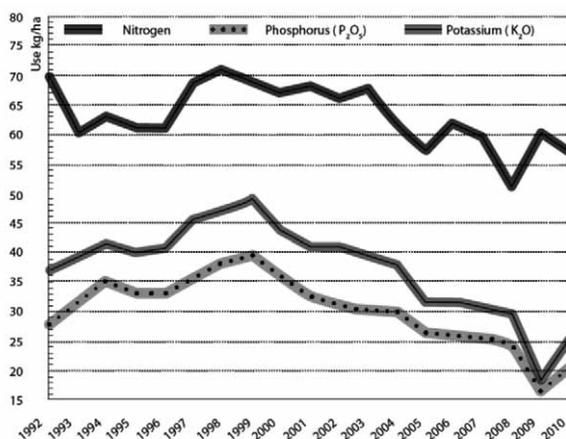
Figure 5. Consumption of plant nutrients (N, P_2O_5, K_2O) in kg per hectare of utilised agricultural area (UAA) in period 1992 to 2010 in Slovenia (ARSO, 2012).

Study of future plans and info exchange in years 2005-2007

The study was part of the EU-Twinning project 'Farming with quota' – SI SI04-AG-06. Two research questions of this particular activity of the project are adressed here (Klopčič *et al.*, 2010):

- How do farmers think about future plans to react to the EU policies?
- What interest do farmers have in information exchange and different tasks of farming?

Material and methods

A questionnaire was developed for Cika farmers, suckler-cow farmers and dairy farmers. The anonymously distributed questionnaire was identical for Cika and suckler-cow farmers, while the questionnaire for dairy farmers had some questions that were differently formulated. The Cika is an endangered breed and is part of the National programme for conservation of the Slovenian indigenous breeds. It is a dual-purpose breed, used for milk production or as a suckler cow. The milk is often processed into local dairy products. We find these cattle often in mountainous regions.

The number of returned questionnaires from the dairy, suckler-cow and Cika farmers were, respectively, 1,114, 121 and 111. The response rates were 22, 24 and 41%, respectively. About 40% of Cika farmers participated in the questionnaire, while only a small proportion of suckler-cow farmers took part in the questionnaire. More than 10% of the 10,000 Slovenian dairy farmers in that period participated in the study.

Results and discussion

Dairy farms participating in the survey had a larger land area than the other groups of farmers. The Cika farms appeared to be much smaller than suckler-cow and dairy farms (Table 2). The majority of Cika and suckler-cow farms were located in hilly and mountain regions. Less than half of the Cika farms' herds had purebred cattle. Cika and suckler-cow farmers in this study were more often employed outside agriculture (61-64%) than dairy farmers (32%), while the average age did not differ between the three groups. Suckler-cow farmers seemed to have a somewhat higher education than the other two groups of farmers. The proportion of farmers said to have a successor varied from 55% of the Cika farmers to 69% of the dairy farmers.

The thoughts about future planning of the farm business are rather similar between Cika and suckler-cow farmers (Table 3). On average, they more often choose consolidation rather than expansion, while dairy farmers act the opposite way. The relatively small number of Cika and suckler-cow farms studied that indicated they do wish to develop further, choose mostly to develop by diversification; in other words a combination of cattle and another activity. Of these second activities, agro-tourism is most popular choice (26-32%), while there is a significant interest in organic farming (43-44%), which is completely opposite to the preference of the questioned dairy farmers: only 6% of them show interest in the organic farming system.

The three farmer groups were asked to express their interest in different activities that are part of the farming job. They could choose between 'high', 'average' and 'low' interest. Dairy and Cika farmers scored high on interest in animal health and fertility and feeding, but also higher on a sound environment

Table 2. Characteristics of the farms participating in the survey.

Variable (answer)	Cika farmers	Suckler-cow farmers	Dairy farmers
Number of farms	111	121	1,114
Average no. of cows farm^{-1}	3.8	11.1	19.1
Agricultural land in use (ha)	8.8	12.1	17.1

Table 3. Future plans of Cika, suckler cow and dairy farmers (%) (Klopčič *et al.,* 2010, 2014).

Future plans	Dairy farmer, % n=1,114	Suckler cow, % n=121	Cika, % n=111
No future plans/stop farming or hobby farm	10	14	20
Keep the farm as it is now	41	55	46
Develop the farm further	49	31	34
Further development	**n=541**	**n=37**	**n=38**
by increasing number of cows	64[1]	38[1]	76[1]
by starting/increasing with a new activity	54[1]	70[1]	82[1]
horses	6	23	16
agro-tourism	5	26	32
local products	2	14	15
changing to organic farming	6	43	44

[1] A combination of an increase of number of cows and starting new branch was possible.

(Table 4). Nature protection, especially, was much more highly rated by the local-breed farmers, thereby expressing a close tie to the environment they live in. Dairy and suckler-cow farmers expressed a more economically oriented attitude towards the farm business and its environment in this study. For these two groups, management of meadows and pastures, and farming in an economical way (to be entrepreneurial) were key factors for success. For dairy farmers, the organisation of work was also considered to be important for running the business in an efficient way.

In addition, the dairy farmers were asked from which organisations they received information about farm management practices. In those years, 69% of the farmers said they received information from the extension service, 31% from the veterinarian, 28% from the farmers' cooperative, 15% from the feed company, 6% from the university and 2% from private consultants. The national extension service clearly fulfils a major role in providing the farmers with know-how. The task of the extension service is to combine information about government programmes with transfer of more technical farm or herd data. The regulatory tasks ask an increasing part of the labour capacity.

Table 4. Farmers with high interest (in %) in different tasks of farming (choice was high, average or low interest); it was possible to give multiple answers (Klopčič *et al.*, 2010, 2014).

Tasks	Cika farmers	Farmers with suckler cows	Dairy farmers
Care for animal health and fertility	72	48	77
Feeding of cattle	59	49	75
Management of meadows and pasture	47	60	63
Organisation of work/labour input	47	43	63
Farming in economical way/entrepreneurship	37	52	61
Animal breeding work	51	38	60
Working on sound environment (use of fertilisers, manure, etc.)	54	32	51
Protecting nature elements on farm	44	17	26

Study of development paths in 2011-2012

This study was part of the CEE project of Wageningen UR in combination with a Life Long Learning-Leonardo da Vinci project, involving four countries: Slovenia, Poland and Lithuania. The research questions reported here are (Klopčič *et al.,* 2014):

1. Which farm development paths do dairy farmers in Slovenia choose?
2. Which economic and social factors influence this? Factors studied were perceived internal strengths and weaknesses, and external opportunities and threats.

Material and methods

A questionnaire was used. The questionnaire had 49 main questions and, in total, 225 sub-questions which dealt with the following topics: farm and farmers' features; development direction; farming goals; availability of resources; opportunities and threats. The study was based on 1,038 questionnaires. 1,028 farmers completed the questions about strategic goals: 339 from Lithuania, 334 from Poland and 365 from Slovenia. The questionnaires were collected in 2011/2012, either (in Lithuania and Poland) by extension workers visiting the farmers or (in Slovenia) by instructing the farmers in group meetings during extension activities; these farmers returned the questionnaires by official post.

Farmers were asked to indicate in a list of 10 strategies what their first, second and third most important strategies were for the development of their farm in the next five years. Then a Principal Component Analysis (PCA) was conducted to see whether these answers could be summarized. Five components explained 67% of the variance in the answers (wait-and-see, move, diversify, cooperate or independent, and chain integration). Next a cluster analyses was performed to find segments of farmers with a similar combination of strategies. Also, farmers were asked to indicate the availability of resources and their opinion towards a series of opportunities and threats. They indicated the availability of resources on a 7-point Likert scale anchored by 1 'very difficult to obtain' to 7 'very easy to obtain'. The same procedure was followed for opportunities and threats, anchored by -3 'big threat' to +3 'a big opportunity'. Then a PCA was conducted to see whether these answers could be summarized.

Results and discussion

The different sizes of the seven segments of surveyed Slovenian dairy farmers are presented in Table 5. Each segment illustrates a certain development direction (path) of the farm. Farmers in Slovenia seemed to be more cooperation-oriented and have a larger interest in diversification than their colleagues in Lithuania and Poland. The group of cooperating diversifiers is quite unique for Slovenia. The cooperation

Table 5. Seven farmer segments in Slovenia in % of total number of farms (n=365) and characteritiscs of those farms per segment.

Farmer segments	Farmers who 'wait and see'	New starters	Cooperating specializers	Independent specializers	Chain integration	Cooperating diversifiers	Independent diversifiers
% of total farmers	10	7	16	31	14	12	10
Quota in kg	125,326	231,273	225,562	227,328	245,168	165,962	171,273
Total agr. area in ha	22	34	31	34	39	30	29
Milk yield/cow in kg	6,118	7,218	7,172	6,853	6,695	6,643	6,301
% of farms applying pasturing in summer	41	37	37	39	22	44	47
% of farms with unfavourable land	86	65	68	68	79	73	75
Pieces of land	25	44	32	33	28	25	28

in Slovenia is based on a large number of agricultural cooperatives (more than 100) of which 82 also act as intermediaries for milk: the cooperative buys and markets the milk to a processor or elsewhere.

Some characteristics of the farmer segments are also presented in Table 5. Farmers who expressed preference to chain integration have, on average, the largest milk quota (245,000 kg of milk) and they cultivated on average 39 ha of agricultural land (owned plus rented land). Also, the group of farmers who want to reallocate their farm to another location (mostly they want to move outside the village), and the independent and cooperating specializers have above 200,000 kg of milk. Farmers who prefer to diversify also have a somewhat lower milk quota. The lowest quota (125,000 kg of milk) has the group of farmers who do not know in which direction they will develop – the so-called 'wait-and-see' group of farmers. This group also cultivates the lowest area of agricultural land (22 ha). Average production of milk per cow varies from 6,118 kg for the 'wait-and-see' segment to around 7,000 kg for the reallocators and specialisers. These differences in milk production also depend on the breed. The diversifying farmers, especially, more often have dual-purpose breeds like Brown and Simmental cows. The rate of applying pasturing in summer differs between 22% for the 'chain-integration' group of farmers, to 44-47% for the diversifying farmers. The low percentage of grazing during the summer results mainly from the fragmented land situation on the farms. The various segments of farmers work, on average, with between 25 and 44 individual parcels of land. Some farmers are farming on more than 100 parcels of land, which are sometimes located far from the farm. This implies that Slovenian farmers spend a lot of time travelling from one plot of land to another, and this also explains the high tractor density in the country.

The link between development paths and availability of resources for the four countries is described in Table 6. In 2013, results of a similar questionnaire to that used in the other countries, but with fewer questions, was received from 102 Dutch farmers. These farmers were randomly selected to receive a postal questionnaire. The results are included here. The following resources are considered: land (rent, buy), labour, money (subsidies, credit), milk quota and knowledge (extension, private). It appears that land and labour availability are the biggest problems in all four countries. The availability of resources ranks almost the same among all four countries. Farmers in Poland, however, are clearly more optimistic about the availability of resources than the farmers in Slovenia and Lithuania. It appeared that quota and information (know-how) scored lower by the group of farmers classed as 'cooperating diversifiers' in Slovenia. This group seems to need additional attention, perhaps because resources and know-how do not fit easily into the expectations of this farmers' segment.

The perceptions of Slovenian, Lithuanian, Polish and Netherlands farmers regarding a series of opportunities and threats are presented in Table 7. Slovenian and Polish farmers consider the abolition of the milk quota and, to a lesser degree, the international milk market, as a threat; whereas, in contrast, Netherlands farmers see these changes as an opportunity. The orientation on the consumer is strongest in Slovenia, as well as appreciation for the certifying organisations. Farmers in the Netherlands show more fear regarding the regulations concerning environment and animal welfare.

Table 6. Available resources for each country according to respondents; factor scores are listed (1=very difficult available to 7=very easy available).

Resources	Slovenia	Lithuania	Poland	the Netherlands
Land	2.5	2.5	2.9	2.6
Labour	2.9	2.6	2.6	4.2
Money	3.8	4.6	5.2	3.7
Quota	3.9	4.7	5.2	5.5
Knowledge	4.6	5.6	5.7	5.6

Table 7. Opportunities and threats as experienced by Slovenian, Polish, Lithuanian and Dutch farmers expressed by scores between -3 and + 3 (-3=big threat to +3 =big opportunity).

Opportunities/threats	Slovenia	Poland	Lithuania	the Netherlands
Abolition of milk quota	−1.4	−0.9	+0.1	+0.8
EU subsidies	+1.1	+1.4	+2.2	+0.2
International milk market	−0.3	−0.2	+0.3	+1.2
Certifying organisations	+0.6	+0.3	+0.4	+0.1
Regulations on manure and fertilizer	0	0	+0.4	−0.8
Regulations concerning animal welfare	+0.4	0	+0.6	−0.4
Consumer concerns	+0.5	+0.9	+0.7	−0.1
Consumer orientation	+1.9	+0.6	+1.0	+0.5

Conclusions

The conclusions below refer to Slovenia:

- In Slovenia the spatial distribution of production is relatively stable: the process of structural change is rather similar in both the flat areas and the hilly/mountaneous areas; during the milk-quota era, restructuring of the sector is occurring relatively slowly.
- The milk price is low when compared to the old EU member states; this stimulates the sale and transport of raw milk to Italy.
- Dual-purpose breeds fulfill an important role in Slovenia, although the percentage of dairy breeds is increasing.
- The national extension service still fulfils a major role in know-how transfer.
- Dairy farmers and beef farmers are more economically oriented than Cika cow farmers; Dairy farmers also give a high priority to the management of grassland; Cika farmers are more nature-minded.
- For Slovenian dairy farmers, cooperation among the farmers, and in the chain and diversification, are also important development paths besides specialisation in dairying.
- Interest in organic farming is lower than expected.
- Land and labour availability and land fragmentation are the biggest problems for all segments of farmers.
- Utilization of the existing consumer-orientation of farmers for direct selling or agro-business purposes is a possible route for the future, as well as a strengthening of the dairy chain structure to gain a better access to the international milk market.

References

ARSO (2011 and 2012) *Environmental indicators in Slovenia.* Available at: http://tinyurl.com/qyq7ax8.

Bogovič F. (2012) *Minister Bogovič on World Dairy Forum EDA Annual Congress 2012.* Available at: http://tinyurl.com/p4dz8dt.

EC (2015) *Geographical indications and traditional specialities.* Availbale at: http://tinyurl.com/dngwtj.

KIS (2011) *Poročilo o stanju kmetijstva, živilstva in gozdarstva v letu 2010.* Agricultural Institute of Slovenia. http://www.kis.si/pls/kis/!kis.web?m=36&j=SI.

Klopčič M., Glavač J. and Kuipers A. (2010) Communication and future plans under EU policies. In: Kuipers, A., Verbič, M., Glavač, J., Kos-Skubic, M., Klopčič, M. (eds.) *Producers and consumers' choices regarding cattle farming systems and products: surveys in Slovenia.* Ministry of Agriculture, Forestry and Food, Ljubljana, Slovenia, pp. 23-29.

Klopčič M., Verhees F., Kuipers A. and Koops W.J. (2014) Study of development paths of dairy farmers in Slovenia. In: Kuipers A., Rozstalnyy A. and Keane G. (eds) *Cattle husbandry in Eastern Europe and China: structure, development paths and optimisation.* EAAP publication, no. 135, Wageningen Academic publishers, Wageningen, the Netherlands, pp. 85-98.

MAFF (2012) Report on the State of agriculture, agri-food sectors, forestry and fisheries in 2011 (*Poročilo o stanju kmetijstva, živilstva, gozdarstva in ribištva v letu 2011*). Ministry of Agriculture and Environment (MAE) and Agricultural Institute of Slovenia, 166 p.

MAFF (2014) *Situation and perspectives in the milk sector in the European Union.* Milk Conference 'Expectation and opportunities of milk production and milk processing in Slovenia', Ljubljana, March 7th, 2014. Available at: http://tinyurl.com/nk6qlzs.

Mihelič R., J. Sušin, A. Jagodic and Leskošek M. (2006) Slovene guidelines for expert based fertilization in a light of cross compliance rules. *Acta agriculturae Slovenica* 87, 109-119.

STAT (2013) Consumption of mineral fertilizers by agricultural crops, Slovenia, 2012 – final data. Available at: http://www.stat.si/eng/novica_prikazi.aspx?id=5817.

SURS (2012) Agricultural Census, Slovenia, 2010 – Final data. Available at: http://www.stat.si/eng/novica_prikazi.aspx?id=4594.

SURS (2015) Statistical Yearbook of the Republic of Slovenia, 2014.

Volk T. (2014) *Stanje v mlečni verigi v Sloveniji (primarna pridelava)* [Situation in milk chain in Slovenia (primary production)]. Milk Conference 'Expectation and opportunities of milk production and milk processing in Slovenia', Ljubljana, March 7th, 2014. Available at: http://tinyurl.com/nbajeje.

Dairy production systems in Finland

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Abstract

In Finland milk and beef contribute 50% of the agricultural gross return. The growing season is short, 125-180 days, and therefore the indoor period plays a major role relative to the grazing season. This leads to high capital costs for production (winter-proof housing systems, forage and slurry storage, harvesting machinery). Thus, production demand per animal is high and Finnish cows produce ca. 8,000 kg energy corrected milk per cow per year. Milk production is mostly located in central and northern parts of Finland where climate and geology restrict other agricultural land use options. Finnish dairy farms and herds have been small, but there has been a continuous increase in herd size, currently averaging 33 cows per herd. Grass silage contributes 55-60% of the dietary dry matter. Hard winter conditions limit the choice of forage species; the most important are timothy, meadow fescue and red clover. Potential annual grass yield is 9-12 Mg ha^{-1}, typically harvested 2 or 3 times per season. Silage is mostly pre-wilted and additives are commonly used. Concentrates typically include barley, oats and rapeseed meal. Grassland covers 32% of the agricultural land and therefore the forage production practices have strong environmental impacts.

Keywords: milk production, grassland, cattle, farm economy, animal welfare, dairy cow

Introduction

Milk production is the most important agricultural sector in Finland. It is based on family-owned farms that are small in area but managed at high intensity. All the production systems are based on highly digestible grass silage supplemented with relatively high amounts of concentrate feeds. The short summer season leads to a long indoor period with high demand for conserved feeds and production of large amounts of slurry. Requirements for infrastructure (cow house, silage and slurry storages) and machinery are high, causing large costs for production. The administrative demand for slurry storage capacity is one year.

There are two different dairy production systems in Finland: farms are either managed conventionally or organically, but the latter contribute only 2.5% of Finnish milk production. Further differences among systems are mostly due to the level on production intensity.

In this paper we will describe dairy systems generally and the reasons behind its evolution. We start with effects of geology and climate that form the physical basis of production. We continue by describing the cows and their welfare issues, typical diets, forage production, environmental issues and farm economy, and finally ending with a consideration of the most important future challenges.

Geography, climate and land use

The topography in Finland is relatively flat and the soils are naturally acidic (Peltovuori, 2006; Soil Atlas of Europe, 2005). Finnish soils are young and weakly developed because of the effects of the last glacial period, which ended ca. 10,000 year ago. During the melting of ice, clay soils formed on the low-lying coastland areas, resulting in large and uniform fertile cambisols (WBR classification). Inland,

the agricultural soils are typically formed of coarser materials (silt, sand) and their existence is more fragmented. Mineral soils are mainly podsols and organic soils (peat) histosols.

The agricultural area occupies a lower proportion of the total land area (9%) than in most European countries (OFS, 2015). The area occupied by lakes and water courses is high (10%). These water bodies are poor in nutrients, which makes them vulnerable to nutrient loads from agricultural activities. Cereal farms occupy most of the agricultural land, and their share is increasing. Dairy farms occupy approximately 25% of the agricultural land, and their share is decreasing. Mainly this is due to high labour demand of dairy production compared to the cereal production and the opportunity to get extra income from working outside of the farm.

Almost all Finnish agricultural land is located above latitude 60° N. The climate is under a mixture of continental and maritime influences due to the location between the Eurasian continent and the Atlantic Ocean (Kersalo and Pirinen, 2009). The dairy production area is characterized by a short growing season. The temperature sum is low and the snow cover period is long compared with the main dairy production areas of Europe (Table 1). Snow cover has important consequences: it provides a very effective protection against the effects of low temperatures during winter (Belanger *et al.,* 2002) and provides ample melt-water for the plants in spring (Pulli, 1980). It also affects strongly the surface run off and leaching (Saarijärvi, 2008) and even affects gaseous emissions (Maljanen *et al.,* 2009; Virkajärvi *et al.,* 2010).

The Finnish climate is better suited for grass than cereal production. Perennial grasses and legumes are able to utilize the long days with ample solar radiation, temperature and abundant water supply of the early summer. During midsummer the water deficit may occasionally restrict herbage productivity. In late summer, development slows down due to shorter days, lower solar radiation and falling temperatures as the winter approaches. Together with larger night/day temperature differences, these are environmental signals for perennial forages to prepare for the winter (Pulli, 1980). Night frosts occur frequently, except in July (Kersalo and Pirinen, 2009); this narrows the choice of suitable forage species and may further hamper the growth processes of forages during spring.

Cattle

The most common dairy breed is the Nordic Red, which was previously known as the Finnish Ayrshire but is currently bred as a single population with the red breeds from Sweden and Denmark. The other major breed is the Holstein, and its proportion is slowly increasing. The native Finncattle breed comprises three distinct types and has barely been saved from becoming extinct. The major characteristics of the breeds are presented in Table 2.

Table1. Climatic comparison: Kuopio and other important dairy production locations in Europe (ECA&D; 2015EEA 2015).

Parameter	Finland Kuopio	Estonia Voru	France Paris	Netherlands De Bilt	Ireland Birr	Denmark Copenhagen	Poland Warsaw
Growing season (d)	160	193	321	302	329	250	231
Annual mean temp (°C)	3.1	6.0	12.1	10.0	9.7	9.2	8.4
Growing[1] DD °C	1,418	1,833	3,064	2,418	2,168	2,207	2,255
Annual precipitation (mm)	608	648	632	817	828	637	542
Days with snow cover (y^{-1})	150	120	30	30	n.a.[2]	30	60

[1] DD = degree days, base temperature 0 °C.

[2] n.a. = not available.

Table 2. Major characteristics of the dairy breeds in Finland. Data from the milk recorded herds in 2013 collected by ProAgria Rural Advisory Services.

Breed	Nordic Red	Holstein	Finncattle (3 types)
Milk production, kg year^{-1}	8,640	9,520	6,120
Milk protein, g kg^{-1}	34.1	32.9	34.4
Milk fat, g kg^{-1}	42.7	39.6	44.2
Milk solids kg year^{-1}	664	690	481
Live weight, kg	597	645	527
Proportion of all cows, %	59	39.5	1.2

Development of dairy farms and milk production

There has been strong structural change across the whole agricultural sector, including dairy production, during the last decades. The number of dairy farms in Finland peaked in the 1960s, when it was in excess of 300,000 farms with a total of 1.1 million dairy cows, mostly native Finncattle. Since then the average farm size has been increasing both in surface area and in average herd size, reaching 56 ha and 33 cows in 2012. The herd size is still increasing and the largest dairy farms in Finland now have more than 300 cows. During the last ten years the total amount of dairy cows has declined by almost 20% to 284,000 in 2013. However, at the same time the total amount of milk produced has declined by a smaller amount, less than 8%, due to increased average production per cow, which reached almost 8,000 l in 2012 (Table 3). Although in the European context the production intensity per cow is high, the intensity per ha is relatively low. The annual milk production is only 4,350 kg ha^{-1}, whereas in the Netherlands it is 10,000-12,000 kg ha^{-1} and in Sweden 6,600-6,900 kg ha^{-1} (Virtanen and Nousiainen, 2005). In addition to climatic factors (short growing season), Finnish dairy production is strictly limited by administration. The whole country is classified as a nitrate vulnerable zone and thus N fertilization of grassland is restricted to 250 kg N ha^{-1}, when biological optimum would be 330-350 kg N ha^{-1} (Salo *et al.*, 2013).

Simultaneously with the structural changes in farm and herd size, there has been a shift in the geographic location of dairy production within Finland. In the 1960s milk production was relatively evenly distributed throughout the country, but nowadays over half of the dairy cows and milk production is located in central Finland, especially in the North Savo and Ostrobothia regions (Figure 1). This is partly due to environmental conditions: in the south and west coastal zones there are plenty of choices for production in addition to dairying, but in inland areas the fields are more suitable for forage production than arable cropping.

Table 3. The development of dairy production in Finland from 1980 to 2012 (OFS, 2015).

Year	Number of dairy farms (×1000)	Number of dairy cows (×1000)	Average milk production, l cow^{-1}	Arable land, ha farm^{-1}	Dairy cows farm^{-1}	Dairy cows ha^{-1}	Total milk production (million litres y^{-1})
1980	91.3	719	4,478	n.a.[1]	11.5	n.a.	3,170
1990	45.5	496	5,547	19.3	13.0	0.67	2,730
2000	22.2	364	6,786	32.6	15.2	0.47	2,450
2012	9.6	284	7,876	56.4	33.1	0.59	2,230

[1] n.a. = not available.
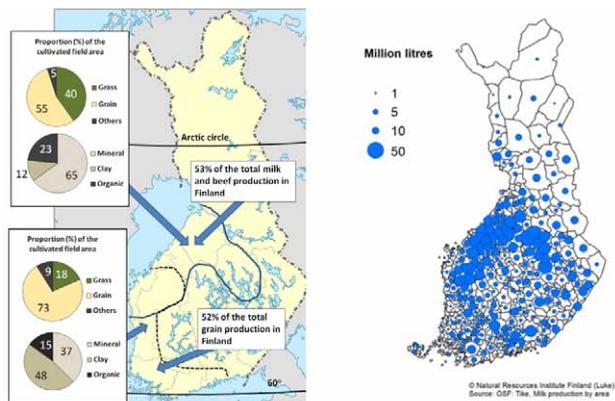
Figure 1. Regional differences in soil properties and crop production in main agricultural area and detailed distribution of milk production in counties in Finland 2013-2014 (OSF, 2015).

In addition, the Finnish subsidy system provides higher subsidies in the northern areas compared to southern areas. Historical reasons have resulted in land ownership becoming fragmented and, because of geographical reasons, agricultural land is distributed in small and often unevenly shaped parcels. The average distance of a hectare from the farm was 2.3 km in 2009 (Niskanen and Heikkilä, 2015). The main milk production regions are the most fragmented in the country. This presents challenges for feed and manure management.

Most of the dairy barns are tie stalls (71%), but as they are on average smaller than loose-housing systems, half of Finnish cows are kept in loose-housing systems. The new investments are most typically based on automatic milking systems (AMS) and have either 60 cows (one AMS unit) or 120 cows (two AMS units). The number of farms with AMS has increased from two in 2000 to 818 (with a total of 1,094 AMS units) in 2013, and the number keeps increasing steadily (65-111 new AMS farms per each year in the years 2008-2013). Today ca. 25% of milk produced in Finland comes from AMS farms (Manninen, 2013, and E. Manninen, personal communication).

Animal health and welfare

The average productive lifetime (4.9 years) of Finnish dairy cows has remained almost unchanged over the last fifteen years. The average replacement rate was 34% in 2010 (Heikkilä, 2013). The list of the main reasons for involuntary culling (50% of all cullings) reflects also the major health issues: mastitis (21%) and fertility (19%) (Heikkilä, 2013). Finland is free from the major infectious cattle diseases, such as enzootic bovine leucosis, brucellosis, bovine tuberculosis, infectious bovine rhinotracheitis, parafilaria, strongylus, trichomoniasis and bovine viral diarrhoea. The prevalence of infections like *Salmonella*, EHEC, trichophytosis, paratuberculosis and *Mycoplasma bovis* is also very low. Regular vaccinations are not needed on cattle farms.

The shift from tie stalls to loose housing can be regarded as a factor promoting animal welfare. On the other hand, the concomitant increase in herd sizes reduces the opportunities to arrange grazing (see below). Both loose housing and grazing opportunity are regarded to be important for the welfare of dairy cows from a behavioural point of view (Welfare Quality 2009). The adoption of technology for monitoring production, health and welfare of cows is tightly connected to the adoption of AMSs, the main extra features being systems for automatic mastitis control and heat detection. Also some farms with traditional milking parlours have acquired automatic heat detection systems.

Feed evaluation system

The feed evaluation system in Finland is maintained by the Natural Resources Institute Finland (Luke). It is presented in a web-based service by Luke (2015). The energy value is based on metabolizable energy (MAFF, 1975) and presented as megajoules. The protein system is based on the amino acids absorbed from the small intestine and protein balance in the rumen (AAT/PBV system) originally developed as a Nordic cooperation (Madsen *et al.,* 1995), but with a number of national modifications. The feeding value of ensiled grass is typically analysed by NIRS in practice. The NIRS method includes all silage quality components: chemical composition, energy, protein and ensiling quality.

The ration formulation for dairy cows in Finland is based on static feed values, but new elements have been taken into use in practical ration formulation through the program CowCompass, which is run by the experts of the ProAgria Rural Advisory Service. The ration optimization of CowCompass is based on published empirical relationships of feed composition, feed intake (Huhtanen *et al.,* 2007, 2008, 2010), associative effects in digestion (Huhtanen *et al.,* 2009) and milk production responses (Huhtanen and Nousiainen, 2012). Rations can be optimized based on least-cost ration or maximum milk income minus feed cost. Nowadays the milk price is still relatively high compared to feeding costs, which leads to high feeding intensity. High intensity means using high digestibility grass silage simultaneously with large amounts of concentrate supplementation. In many cases the risks of acidosis and hoof disorders become limiting factors in milk production. However, these health factors overrule economic optimization within the program, resulting in reduced diet intensity (usually lower amount of concentrates) compared to the economic optimum.

Feed production

Grass silage and cereals are typically produced on-farm and commercial feeds comprise on average 29% of the total dry matter (DM) consumed by cows (Huhtamäki, 2014). The DM yield of grass is about double that of cereal grains and the digestibility of grass organic matter is high despite of its high neutral detergent fibre content. High grass yield per ha combined with reasonably high digestibility makes grass production an economically profitable way to produce milk in Nordic circumstances, where maize is not an option. The use of high digestibility grass also makes diet rationing relatively easy and safe because cows can compensate for random variation in the concentrate supplementation by adapting their grass silage intake.

The rations are likely to change based on the relative prices of commercial feeds, but the best possible utilization of on-farm produced forages is generally targeted. The feed consumption statistics collected by ProAgria Rural Advisory Services in 2013 showed that grass silage comprised, on average, 48% of dairy cow DM intake and the proportion of grazed grass was 6%. The concentrate proportion was thus 46%; this amount has slightly increased during recent years (Huhtamäki, 2014). Rapeseed-based protein supplements are commonly used and very little soybean meal is used in dairy cow diets in Finland. The farms aiming at production exceeding 10,000 kg ECM cow^{-1} y^{-1} use up to 60% of dietary DM as concentrates in order to achieve this goal. In more extensive production systems, larger proportions of grass silage in the diet are used.

Approximately one third of arable land is used for grass, which is mainly used as feed for dairy cows (Figure 2; OFS, 2015). Due to the short growing season, great emphasis has been put on developing ensiling and knowledge-transfer actions within forage production and preservation in Finland (see e.g. Huhtanen *et al.,* 2012), which have contributed to the generally good nutritional and fermentation quality of Finnish grass silage. Salo *et al.* (2014) reported results based on over 110,000 farm silage samples collected during 1998-2012, showing that the average D-value (digestible organic matter in DM) was 674 g kg^{-1} DM, DM concentration 321 g kg^{-1}, crude protein concentration 147 g kg^{-1}, pH 4.2 and
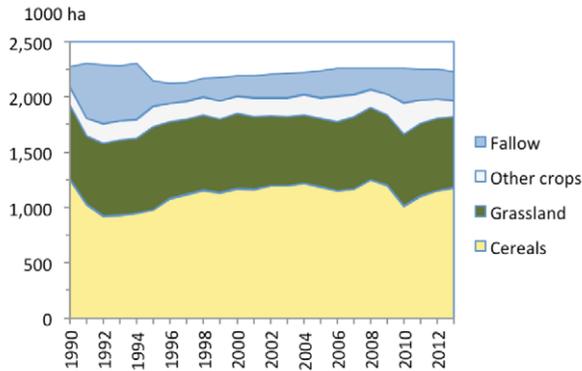
Figure 2. Cultivated area of different arable crops in Finland during years 1990-2013 (OFS, 2015).

ammonium N in total N was 44 g kg^{-1} N. These numbers demonstrate the high ambitions and abilities of the Finnish forage farmers.

Ensiling technologies develop fast and several methodological options are available depending on the particular circumstances and needs of the farms. On larger dairy farms it is very common to use precision chopping of moderately pre-wilted grass and ensile it into bunker silos using formic acid-based or biological additives. The relatively low inherent water soluble carbohydrate content of the Finnish silage raw material, which is due to the species used and environmental conditions, support the use of silage additives. Round bales are also used.

Grazing contributes approximately 6% of the annual feed DM intake of cows. This low proportion is partly due to the short grazing season and partly due to the lack of suitable grazing paddocks near the dairy barn, and also difficulties in combining grazing with automatic milking systems. The majority (77.6%) of cows still graze during the summer time. Mostly used grazing methods are rotational and strip grazing. Recommended pasture area is low (0.17-0.2 ha cow^{-1}) during early summer and increases to 0.3-0.45 ha cow^{-1} in later summer when grass growth decreases (Virkajärvi, 2005). Grazing is a compulsory part of the summer feeding regime in organic milk production, but because organic farms comprise only a small proportion of total farms it has only a minor impact in terms of overall grazing intensity.

Forage species and management

Permanent grassland in Finland occupies only 4% of the grassland area, which is a low proportion compared to most European grasslands (OFS, 2015). Instead, most Finnish silage production is based on rotational ley farming, i.e. the perennial swards are a part of the crop rotation. Based on the Field Parcels Registry (ProAgria Rural Advisory Services), the mean age of leys before new establishment is 4.4 years (Niemeläinen, 2015: personal communication). The main reason for frequent re-establishment of leys is the clear decrease in the productivity of swards over time (Figure 3). This decrease is mainly caused by winter damage, and consequential invasion by weeds that are of low productivity (Nissinen and Hakkola, 1994). The proportion of annual swards is minor. Swards are established typically using cereals as cover crops, or whole crop silage. Larger and more intensive farms are establishing more leys directly after the previous ley (Niemeläinen, 2015: personal communication). One possibility is to improve grassland productivity by reseeding grass (or legume) seed directly into the existing grassland. This technique is more popular among farms that have high animal density per hectare, thereby concentrating on grass farming and purchasing concentrates from outside the farm.
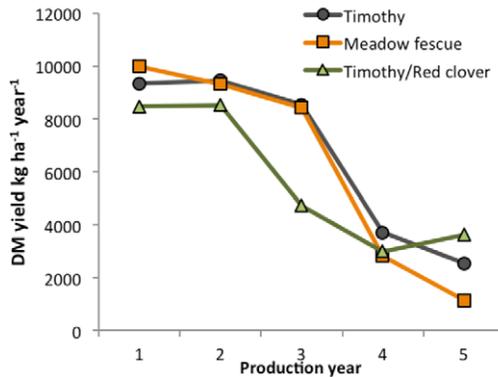
Figure 3. An example of typical dry matter decrease in three species during successive years after establishment (Modified from Nissinen and Hakkola, 1994).

The most important forage species are timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). These are preferred because of their combination of good winter tolerance, reasonably high yield capacity and high nutritive value under Finnish conditions and management guidelines. They are most commonly used in mixtures. The proportions of seeds used in mixtures vary according to the planned use and soil type. There has also been increasing interest in tall fescue (*F. arundinacea* Schreb.) because of its tolerance of water shortages and good regrowth ability (Virkajärvi *et al.,* 2012). In addition there is much interest in festulolium (*Festuca × Lolium*) cultivars but most currently available cultivars do not tolerate winter conditions sufficiently. Cocksfoot (*Dactylis glomerata* L.) and smooth meadow grass (*Poa pratensis* L.) are much less used. The winter tolerance of perennial ryegrass (*Lolium perenne* L.) is still poor.

Due to the climatic conditions the spring growth of swards is vigorous, reaching 270 kg DM ha^{-1} d^{-1} (Virkajärvi *et al.,* 2003). Because of the short summer and long days (up to 20 h daylight in summer solstice in North Savo) there is very little variation in heading date among cultivars of the species. For example there is only 3 days difference in the heading date between earliest and latest timothy cultivars (Kangas *et al.,* 2006). Therefore there is no grouping of cultivars into early or late types. In all, this leads to a relatively narrow time window for optimum harvest in the first cut (Kuoppala, 2010; Rinne and Nykänen, 2000) and consequently, this leads to high investment demand on harvesting machinery. It would be beneficial to find such forage species or cultivars or systems that would increase the time span for harvesting high digestible silage in the first cut. In the following cuts the rate of changes in forage amount and digestibility is clearly slower (Kuoppala, 2010; Pulli, 1980).

Among forage legume species, red clover (*Trifolium pratense* L.) is still the most important (Halling, 2002; Riesinger, 2010) and it is mainly used in seed mixtures with timothy and fescues. White clover is not well suited for inclusion in tall growing (up to 70-80 cm) Finnish silage leys (Virkajärvi and Järvenranta, 2001; Halling, 2002). Its performance under grazing without N fertilizer has been fairly good when compared with N-fertilized grass pasture (Saarijärvi, 2008). However, as pasture comprises a low proportion of the total grassland area, the role of white clover is also minor. The performance of lucerne (*Medicago sativa* L.) has been shown to be clearly lower than that of red clover, mainly because of poor winter tolerance and the low pH of Finnish soils (Halling *et al.,* 2002).

In practice, there is hardly any maize silage production in Finland. In plot experiments the productivity of maize may be up to 20 Mg DM ha^{-1} but variation in yield level is extremely high (Saarinen *et al.,* 2013).

Nutrient use, fertilization, manure and nutrient balances

Fertilization of N and P are regulated by the Nitrate Directive that is applied across the whole country without exceptions, and by the voluntary Finnish Agri-Environmental Scheme that covers over 90% of Finnish farms. There is a concern that with increasing restrictions in the new scheme (2015-2022) the popularity of voluntary membership in the Agri-Environmental Scheme might diminish, but this remains to be seen. Fertilization guidelines are based on soil analyses of main nutrients, analysed with acidic ammonium acetate (Vuorinen and Mäkitie, 1955). Guidelines for N-fertilization have been based on soil type and cultivation zone, but from 2015 onwards the concentration of soil organic matter will be the basis for this. In addition, the number of cuts and purpose of the grassland has to be taken into account (pasture, silage, hay). Generally the amounts of N, P and K used are clearly less than the recommended maximum values (Table 4).

Nitrogen has the largest effect on grass DM yield. The current maximum N rates for silage production are well below the biological maximum yield responses 330-350 kg N ha^{-1} achieved in experiments (Salo *et al.,* 2013).

In addition to the environmental restriction of N-use, there is also an increased risk of winter damage. Potassium (K) has the second largest influence on DM yield of grass, but the effect is related to the mineral composition of soil material and is well explained by concentration of acid soluble K (K_{HCl}; Virkajärvi *et al.,* 2014). In a recent meta-analysis across 37 studies in Finland the overall response of grass DM yields to P fertilization (mean 50 kg P ha^{-1}) was 13% over the control (Valkama *et al.,* 2015) and the response diminished by increasing soil P concentration. An important feature of Finnish grassland management is that fertilizers are often applied as commercial compound fertilizers (NPKS) with varying composition (N, NS, NK etc.) and nutrient ratios. This means that targeted changes in nutrient ratios can only be made at paddock level.

In experiments, annual grass yields are between 9,000-12,000 kg ha^{-1}, typically achieved with an annual N rate of 200-250 kg ha^{-1} and harvested 2 or 3 times per season. On farms the yield level is clearly lower, the median being 5,500 kg DM ha^{-1} year^{-1}, but the fertilization intensity is also lower on commercial farms (i.e. 155 kg N ha^{-1} year^{-1}; Field Parcel Registry of ProAgria Rural Advisory Services). However, there is substantial variation among farms and among paddocks on farms: for example, in a grass production competition by Yara Ltd. the winning farm had a mean yield of 13,200 kg DM ha^{-1} year^{-1} in the year 2012 (Luomaperä and Artjoki, 2012). The system of area-based subsidies and regulations concerning the area required for manure spreading per LU both lead to there being an excess field area (i.e. a low LU ha^{-1}) compared to biological maximum of LU ha^{-1} that could be achieved. On the other hand, this provides flexibility for the production system, and decreases the fertilization demand relative to the maximum figures (Regina *et al.,* 2014).

Animal manure

Animal manure has received a lot of attention during the last decades, mainly because of its large potential environmental impact. Many research reports have been published about best practices and new technologies in the spreading and transportation of manure, and life cycle analysis to estimate

Table 4. Annual nutrient use (total nutrients, kg ha^{-1}) in fertilizer for grassland cut for silage (2-3 cuts year^{-1})

	Nitrogen	Phosphorus	Potassium	Source
Maximum	160-240	0-46	0-170	Finnish Agri-Environmental Scheme 2015 (draft)
In farm surveys	150-160	15	66	ProAgria Field Parcel registry 2014, n=16,100 parcels in years 2005-2012

environmental effects (see e.g. Luostarinen *et al.*, 2011). However, the general problem still remains: low DM (and nutrient) concentration in slurry makes it expensive to transport over long distances. On the other hand, farmyard manure (FYM) is not used effectively in modern grass-dominated crop rotations.

In Finland the livestock unit (LU) density on dairy farms is relatively low and it seems that the problem of local concentration of manure and nutrients is less challenging on dairy farms than on pig and poultry farms. This is mainly due to the use of grass-silage-based diets on dairy farms, which ensure the low LU density per ha and, consequently, enables the slurry spreading area to be large enough for the amount of slurry produced. Typical amounts applied are in the range 20-40 Mg ha^{-1} year^{-1} in one or two applications. As manure contains 3.0 g N, 0.5 g P and 2.9 g K kg^{-1} of fresh weight (Viljavuuspalvelu, 2015), the amounts of nutrients are in the ranges of 60-120 kg N, 10-20 kg P and 58-116 kg K ha^{-1}. The proportion of farms using slurry systems is 63% and FYM is 36% (Grönroos *et al.,* 2009). Data obtained from a small number of farm surveys show that the soil P status is not exceptionally high on dairy farms, nor is it high in the most typical dairy production areas (Viljavuuspalvelu, 2015).

Dairy production and environment

Environmental impacts caused by dairy farming in Finland include nutrient losses in surface runoff and by leaching, and gaseous emissions from fields and farms. Gaseous losses from agriculture (5.7 Mt CO_2-eq) are about 9% of the total of all greenhouse gas (GHG) emissions (2012 data) in Finland (Statistics Finland, 2014). In 2008 milk production contributed 28% of the total GHG emissions from agriculture. The largest source of GHG emissions is agricultural soils, especially organic soils, which contributed 61% of the total emissions from agriculture. The proportion is high compared to other EU countries (Leip *et al.*, 2010). Thus, it is almost impossible to mitigate GHG emissions significantly without measures that affect the management and area of organic soils. Mitigation of gaseous losses is an important issue as there is a national Intergovernmental Panel on Climate Change (IPCC) reduction target to be met (-13%, 0.76 Mt CO_2-eq of the emissions in 2005 reduced in 2020, Regina *et al.,* 2014). The average CO_2-eq emissions from milk production are ca. 0.5 kg of CO_2-eq kg^{-1} milk higher than the average emissions in EU countries (1.4 kg of CO_2-eq kg^{-1} milk on EU average; Leip *et al.*, 2010) this difference being mainly due to the forage production on organic soils. Agriculture contributes over 90% of total ammonia emissions in Finland, being 30,000 Mg y^{-1}. Most of this (60%) originates from manure. Dairy production accounts for approximately one-third of the total amount of ammonia emissions from agriculture (Grönroos *et al.,* 2009).

Unlike GHG emissions, the impacts of water-soluble nutrient losses are mostly local. In the most important dairy production areas about half the annual precipitation falls as snow, and snowmelt causes large pulses of runoff in springtime. Lakes are fairly shallow with complex spatial structures including small closed bay areas. Phosphorus is the main cause of eutrophication of surface waters. As large part of dairy production is located in proximity to inland lakes and rivers, the P load from surrounding fields can be substantial. The ecological quality of surface waters in the main milk production regions of the North-Savo and Ostrobothnia river area is below average (Aakkula and Leppänen, 2014). However, only a minor part of dairy production is located in areas that affect the most polluted part of the Baltic Sea, the Finnish Archipelago.

It has been proven that grasslands reduce erosion and, consequently, the transfer of particulate P from land to water. However, the concentration of dissolved P in surface runoff from grasslands can be high (Turtola and Kemppainen, 1998). There are several reasons for this. Freezing temperatures may damage the plant and microbial cells, which then release dissolved nutrients to the soil. Decomposing dung pats on pastures and surface-applied slurry and fertilizers are also known to increase the risk for dissolved P losses. Snow-melt water is effective in its ability to carry nutrients in solution, and as the amount of melt

water is high this may also increase the losses (Järvenranta *et al.,* 2014). Räty *et al.* (2012) measured the total P-load from a grassland-based dairy production area in central Finland and found that it was slightly lower than the Finnish reference value from agricultural production in general (Vuorenmaa *et al.,* 2002). However, the proportion of dissolved P was much higher compared to the reference value and there was a great variation in the proportion of the dissolved P of the total P (from 8 to 93%). Losses of total N from dairy production area were 67% higher than the Finnish reference value from agricultural land. As expected, the losses of total solids were low compared to arable land (Puustinen *et al.,* 2007).

Surface-applied slurry causes a risk of P accumulation in the surface soil, which increases the risk for P losses in surface runoff after heavy rain or when soil is waterlogged or frozen. Average losses of 0.5-1.5 kg total P ha^{-1} y^{-1} have been measured from grasslands fertilized with surface-application of slurry. Surface-runoff losses of P can be minimized by using slurry-injection techniques, the use of which is quite common practice in Finland. The slurry is injected to 3-7 cm depth from the soil surface and P is adsorbed on to soil particles. This can decrease losses up to 80% (Uusi-Kämppä and Heinonen-Tanski, 2010).

In contrast to the surface run-off losses of P, losses of N by leaching are much more important than N losses in surface runoff. Most of the N-leaching from grasslands occurs in spring, but changing climate over recent years has resulted in increased autumn and winter losses. Nitrogen loss in surface runoff (mostly in the form of NH_4-N) is small and of minor importance. Winter conditions change the N dynamics in soil compared to areas where soil does not freeze. Microbial activity slows down, but still continues even at temperatures below zero (Maljanen *et al.,* 2009). Freezing prevents most water movement in soil and NO_3-N accumulates in the soil. Nitrate discharges in spring through leaching and gaseous losses when the soil thaws and snow cover (often containing over 130 mm water) melts. Sward renewal is the critical point of the N cycle in short-term leys. A mineralization pulse causes large N losses especially from pastures (60 kg N ha^{-1}) through leaching (Saarijärvi, 2008).

In Finland it is a common practice to use slurry as a fertilizer for the second cut of grass and again in autumn to empty the slurry storage before winter. In warm and dry conditions after the first cut, up to 20% of the surface-applied (broadcast) slurry total N may be lost through NH_3 volatilization. However, the injection technique almost fully prevents NH_3 volatilization (Uusi-Kämppä and Mattila, 2010). The leaching losses of N are more likely to occur in autumn and spring than during summer months and up to 40 kg year^{-1} total N leaching losses have been measured after spreading slurry twice during the growing season (summer and autumn; Virkajärvi, unpublished). After several years of repeated slurry applications to the grassland, as is usual in dairy farming, the risk for N leaching increases (Saarijärvi, 2008; Uusi-Kämppä and Mattila, 2010).

According a dairy farm survey (Virtanen and Nousiainen, 2005) the typical N and P farmgate balances in Finland were 109 (±41) and 12 (±7.2) kg ha^{-1} respectively. The most significant inputs into the system were fertilizers (100 and 9 kg ha^{-1} for N and P respectively) and concentrates (39 and 7 kg ha^{-1} for N and P, respectively) and the most important outputs were nutrients in milk exported from the farm (23 and 7 kg ha^{-1} for N and P, respectively).

Profitability and market environment

During the past century the Finnish dairy sector has been able to maintain a relatively stable and high price for milk. Between 2000 and 2013, the average producer price has been 22% higher than the average of EU-15 countries. The high producer price is the result of the co-operative structure of the dairy industry and high added value for the products. The durability of the co-operative chain became clearly visible during the world market price crisis in 2008, when profitability fell more in many other countries than it did in Finland (Jansik *et al.* 2014). Profitability of milk production has stayed below the EU-27

average, but remained relatively stable. During 2006-2012 the profitability ratio has varied between 0.40-0.67, while in EU-27 the average has been 15% higher, varying between 0.49-0.73 (Profitability ratio of 1.0 indicates that all production costs including country specific interest demand for capital and costs of family factors have been covered).

Self-sufficiency in milk products (primary equivalent, excluding butter) was 102% in 2011 (FAOSTAT, 2015). The total consumption of milk products has slightly increased in the past years. According to FAO (2007) the per capita consumption of milk in Finland is the highest in the world (361 kg year^{-1}). However, demand for domestic products has remained stagnant and the increased demand has been filled mainly by imports. The value of imported milk products tripled between 2002 and 2013, to M€ 377. For example, over the years 2002-2013, the proportion of cheese that was provided by imports increased from less than 20% to 51% of total consumption (Jansik *et al.,* 2014). Measured by value, the biggest suppliers of imports in 2013 were Sweden (34%), Germany (32%) and Denmark (9%). The location of Finland offers some geographical border protection for fresh dairy products, which are not easily transportable; therefore imports of fresh milk have stayed at a much more modest level compared to cheese and yoghurts (Jansik *et al.,* 2014). However, abolition of milk quotas is expected to increase European milk production, which may increase imports by Finland as well.

Export markets provided 20% of the dairy industry sales in 2012 (Jansik *et al.,* 2014). In 2013 Finland exported milk products mainly to Russia (48% of the total export value) and Sweden (19%). The volume of exports has increased by 45% over the years 2002-2013, while the export value increased by 60%. The greater increase of value, relative to volume, shows that so far exports have been able to concentrate more on high value products. The dairy industry has invested in better utilization of milk components and focused on high-value products like functional foods. A significant part of the fat-component of the milk is used in products that are exported, while protein is demanded domestically.

In 2013 the trade value balance of dairy products was positive by 162 M€ (Finnish Customs, 2014) which was achieved by exports higher value compared to lower value imports. The positive value balance, if compared directly to annual milk production, was 13.6 cents per litre (2,200 million l). Restrictions in trade with Russia, which were put in place in 2014, have seriously hit the Finnish milk industry.

Production cost

According to Finnish Farm Accountancy Data Network (FADN) results, the costs of purchased and produced feed account for one third of the total production cost of milk (Table 7), labour has the second biggest share, and the third is the animal cost, consisting mostly of replacement costs. Housing costs and related maintenance costs are also significant, because of small farm size and northern conditions, which require more farm buildings than is often the case in southern European countries. Fully comparable FADN-based calculations are not available for competing countries but, for example, according to International Farm Comparison Network (IFCN) farm comparisons, among European countries the production cost is higher only in Switzerland for average sized farms (Hemme *et al.,* 2014). According to Ovaska and Heikkilä (2014), the most significant cost disadvantages compared to competing countries were machinery, labour and other miscellaneous costs. Labour input per cow was 207 h year^{-1} cow[-1] in the research period. For example in Denmark and the Netherlands, this figure ranged from 34 to 52 h year^{-1} cow[-1]. The high production cost is also partly compensated by support payments, such as nationally paid northern aid. It is paid on a per-litre basis, and the support is higher in northern regions. The average of litre-based direct payments was 7.47 cents per litre in 2013. In southern Finland, after 2015 support is to be paid on a per-head basis.

Table 7. Unit cost structure of milk per litre in 2013, all farm sizes (Luke, EconomyDoctor 2015)

	Cents per litre	Proportion
Feed (purchased and self-produced)	25.2	33%
Animal cost	12.8	17%
Fuel and electricity	2.9	4%
Maintenance of buildings and machinery	5	7%
Insurance, rents and other costs	6.1	8%
Machinery depreciation and interest	4.6	6%
Building depreciation and interest	5.2	7%
Other interests (debt)	1.2	2%
Labour	13.3	17%
Total cost per litre	76.3	100%

Due to relatively high labour costs and the strenuous nature of the work, construction of new barns is capital-intensive; for example, adopting an automatic milking system is usual. The production cost varies according to farm size and efficiency. The best farms can produce milk with costs of 68-74 cents per litre, while the average of all farms was 80 cents per litre (Latukka and Vilja, 2014). Only costs were accounted for in the calculation. Because the profitability ratio was 52% in 2013, only a proportion of the unit cost of labour and interest costs are realized. If accounted for, area payments would also lower the net production costs of self-produced feeds.

Future challenges

Maintaining profitability of dairy farms in the future is one of the main challenges. Increasing production in Europe after quota abolition in 2015 may increase the supply of imported milk products to the domestic market and make it more difficult to maintain the high producer price. Previously, the price of milk has been above EU-27 average, which has compensated for the high production costs associated with northern conditions. Profitability is connected to farm efficiency, which is further related to the unit cost of milk. Increasing the farm size has been shown to increase productivity; therefore investment subsidies are justified. However, growth should be sustainable and should not lead to over-indebtedness, or slow down the total factor productivity growth by excessive capital costs. Profitability is also connected to the abilities for investing in new technology, which might improve, for example, animal welfare and improve the working conditions of the farmers. Poor profitability is also related to farmland degradation, which may increase environmental load.

Finnish farms are usually family farms, where ownerships are changed by generational shifts. In the past years, low profitability has had a negative impact on the attractiveness of farming as a profession. Heavy structural change is partly due to the unsatisfactory wage, in relation to the workload on a dairy farm. However, lower rates of return are often accepted in agricultural enterprises. Rural areas may not offer many options for full-time work and milk production may offer relatively high living standards compared to other options in the region. The inspiring examples of young farmers investing successfully, the support of local authorities and the attitude of local banks have strong influences that can explain why milk production may increase, or decline, even in neighbouring municipalities (Jansik *et al.,* 2014).

The domestic dairy market is mature, but fluctuations in demand and diet trends are becoming more common. Growing supply within EU internal markets will also increase the sensitivity of the Finnish dairy chain to world market disorders.

A very general challenge is to combine economically viable production with environmental and ethical demands, often referred to as sustainable intensification or resource-efficient production. Work has to be done to find the most cost-effective measures, e.g. for water protection and reducing gaseous emissions from dairy production. Often these measures must be especially tailored for dairy farms (dissolved P, NH_3 emissions, etc.). Slurry injection techniques can solve some of the manure-related problems but more technological innovations are needed to solve other problems, e.g. the logistic problems of large farms with scattered farm structures. The most difficult part is to keep the cost of such solutions at a reasonable level.

One challenge is to fulfil the protein demand of high producing dairy cows with domestic protein sources. Faba bean (*Vicia faba* L.) may provide one alternative for protein production in addition to the commonly used rape seed (*Brassica rapa* var. *oleifera* DC; *B. napus* var. *oleifera* DC), but it will need favourable growing conditions. Soybean (*Glycine max* L) is currently not an option in Finland due to the climatic conditions; however, these might change and become more favourable for lucerne and faba bean due to climate change.

The effects of projected future climate change provide both threats and opportunities. Increasing variability in weather conditions will force farmers to have buffers in their forage production, which will increase their production costs. On the other hand, Finnish dairy production will most likely benefit from climate changes that lead to an extended growing season and the possibility of adopting new protein and forage species. Full utilization of these projected positive climate changes may require some upward adjustment of the current nutrient-use regulations, which is very much against the current trend.

Finland has many strengths in its milk production chain such as well functioning infrastructures, ample water resources, animals of high genetic quality, top quality milk and, first and foremost, dedicated and highly qualified professional dairy farmers. The estimated impacts of climate change show that the feed production conditions may even improve in northern Europe, which may improve the relative competitiveness of the Finnish dairy industry in the global context. The key factor is to improve the economic efficiency of dairy farming by keeping in mind the occupational health of the dairy farmers, product quality, animal welfare and environmental constraints.

References

Aakkula J. and Leppänen J. (eds.) (2014) *Maatalouden ympäristötuen vaikuttavuuden seurantatutkimus (MYTVAS 3). Loppuraportti.* [The effectiveness of environmental subsidies. Follow-up study. (MYTVAS 3) Final Report] Maa-ja metsätalousministeriö 3/2014. 265 s. [In Finnish].

Bélanger G., Rochette P., Castonguay Y., Bootsma A., Mongrain D. and Ryan D.A.J. (2002) Climate change and winter survival of perennial forage crops in Eastern Canada. *Agronomy Journal* 94, 1120-1130.

EEA (2015) *Annual number of days with snow cover over European land areas 1961-1990 and projected change for 2071-2100.* Available at: http://tinyurl.com/n5xs5hx.

ECA&D (2015) Country info. Available at: http://tinyurl.com/ovkoxdu.

FAO (2007) *Current worldwide total milk consumption per capita.* Available at: http://chartsbin.com/view/1491.

FAO (2010) *Greenhouse gas emissions from the dairy sector a life cycle assessment.* Food and Agriculture Organization of the United Nations Animal Production and Health Division, Rome, Italy. 98p.

FAOSTAT (2015). Food Balance Sheets. FAO Statistics Division, Rome, Italy. Available at: http://faostat3.fao.org.

Finnish Customs (2014) Foreign trade statistics. Available at: http://www.tulli.fi/en/finnish_customs/statistics/index.jsp.

Grönroos J., Mattila P., Regina K., Nousiainen J., Perälä P., Saarinen K and Mikkola-Pusa J. (2009) *Development of the ammonia emission inventory in Finland.* The Finnish Environment 8, 63p.

Halling M., Paul C., Soether U., Nissinen O., Tuori M., Hopkins A., Lister S. and Doyle C.J. (2002) Production and nutritive quality of forage legumes for silage. In: Wilkins, R.J. *Low-input animal production based on forage legumes for silage (LEGSIL)*. Final report. IGER, UK, pp. 26-104.

Heikkilä A.-M. (2013*)* Replacement decisions on Finnish dairy farms: toward better economic performance with novel technology and sustainable herds. *MTT Science* 22. MTT, Helsinki, Finland, 38 p.

Hemme T. (2014) The IFCN Dairy Report 2014. For a better understanding of the dairy world, IFCN Dairy Research Center.

Huhtamäki T. (2014) Ruokinnan teemavuodesta nuorkarjan teemavuoteen [Results from on-farm feed consumption results] Available at: http://www.proagria.fi/sites/default/files/attachment/tuse-lehmien_rehunkulutus2013_paivitetty_tilaseosten_osalta_heinak2014.pdf.

Huhtanen P., Rinne M. and Nousiainen J. (2007) Evaluation of the factors affecting silage intake of dairy cows: a revision of the relative silage dry-matter intake index. *Animal* 1, 758-770.

Huhtanen P., Rinne M., and Nousiainen J. (2008) Evaluation of concentrate factors affecting silage intake of dairy cows: a development of the relative total diet intake index. *Animal* 2, 942-935.

Huhtanen P., Rinne M. and Nousiainen, J. (2009) A meta-analysis of feed digestion in dairy cows. 2. The effects of feeding level and diet composition on digestibility. *Journal of Dairy Science* 92,5031-5042.

Huhtanen P., Rinne M., Mäntysaari P. and Nousiainen J. (2010) Integration of the effects of animal and dietary factors on total dry matter intake of dairy cows. *Animal* 5, 691-702.

Huhtanen P. and Nousiainen J. (2012) Production responses of lactating dairy cows fed silage-based diets to changes in nutrient supply. *Livestock Science* 148, 146-158.

Huhtanen P., Jaakkola S. and Nousiainen J. (2012) An overview of silage research in Finland: from ensiling innovation to advances in dairy cow feeding. In: Kuoppala K., Rinne M. and Vanhatalo A. (eds.) *Proceedings of the XVI International Silage Conference*, Hämeenlinna, Finland, 2-4 July 2012. MTT Agrifood Research Finland, University of Helsinki, Finland, pp. 16-33.

Höglind M., Thorsen S.M. and Semenov M.A. (2013) Assessing uncertainties in impact of climate change on grass production in Northern Europe using ensembles of global climate models. *Agricultural and Forest Meteorology* 170, 103-113.

Jansik C., Irz X. and Kuosmanen N. (2014) *Competitiveness of Northern European dairy chains*. Publication 116. MTT Economic Research, Agrifood Research Finland, Helsinki, Finland.

Järvenranta K., Virkajärvi P. and Heinonen-Tanski H. (2014) The flows and balances of P, K, Ca and Mg on intensively managed Borel high input grass and low input grass-clover pastures. *Agricultural and Food Science* 23, 106-117.

Kersalo J. and Pirinen P. (2009) *Suomen maakuntien ilmasto* [The climate of Finnish regions]. Finnish Meteorological Institute, Report 2009:8. 185 pp. [In Finnish with English abstract].

Kangas A., Laine A., Niskanen M., Salo Y., Vuorinen M., Jauhiainen, L. and Nikander H. (2006) Results of official variety trials. MTT:n Selvityksiä 105. 210p. [In Finnish]

Latukka A. and Vilja M. (2014) What a litre of milk costs: knowing the production costs helps to develop profitability. In: Niemi, J. and Ahlsted, J. (eds) *Finnish agriculture and rural industries*. MTT, Helsinki, Finland, pp. 64-65.

Leip A., Weiss F., Wassenaar T., Perez I., Fellmann T., Loudjani P., Tubiello F., Grandgirard D., Monni S. and Biala K. (2010) *Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) – final report*. European Commission, Joint Research Centre.

Luke (2014) *Feed tables and feeding recommendations*. Available at: www.mtt.fi/feedtables.

Luke (2015) *Economy doctor*. Available at: https://portal.mtt.fi/portal/page/portal/economydoctor.

Luomaperä S. and Artjoki H. (2012) Nurmen satokilpailun tulokset 2012 [Results of yield competition 2012]. *Leipä Leveämmäksi* 3/2012, 28-29. [In Finnish].

Luostarinen S. LogrénJ. Grönroos J., Lehtonen H., Paavola T., Rankinen K., Rintala J. Salo T. Ylivainio K. and Järvenpää M. (2011) *Sustainable utilization of manure*. MTT report 21. MTT Jokioinen, Finland, 164 p.

Madsen J., Hvelplund T., Weisbjerg M.R., Bertilsson J., Spörndly R., Olsson I., Harstad O.M., Volden H., Tuori M., Varvikko T., Huhtanen R. and Olafsson B.L. (1995) The AAT/PBV protein evaluation system for ruminants. A revision. *Norwegian Journal of Agricultural Science Supplement* 19, 1-37.

MAFF (1975) *Energy allowances and feeding systems for ruminants*. Technical Bulletin 33. Her Majesty's Stationery Office, London, UK. 79 p

Maljanen M., Virkajärvi P., Hytönen J., Öquist M., Sparrman T. and Martikainen P.J. (2009) Nitrous oxide production in boreal soils with variable organic matter content at low temperature – snow manipulation experiment. *Biogeosciences* 6, 2461-2473.

Manninen E. (2013) Automaattilypsy jatkaa kasvuaan. *Maito ja me* 3/2013, 48. [In Finnish].

MMM (2000) VnA 931/2000. Valtioneuvoston asetus maataloudesta peräisin olevien nitraattien vesiin pääsyn rajoittamisesta. Available at: http://www.finlex.fi/fi/laki/alkup/2000/20000931. [In Finnish].

Niskanen O. and Heikkilä A-M. (2014) Selvitys parsinavettojen taloudellisesta merkityksestä nautasektorilla. In: Raussi S. (ed.) [*Well-being- and economic effects of cattle stalls types*]. Eläinten hyvinvointikeskus, Helsinki, Finland, pp. 22-39. [In Finnish].

Niskanen O. and Heikkilä A-M. (2015) The impact of parcel structure on the efficiency of Finnish dairy farms. *Agricultural and Resource Economics Review* 44/1 (*in press*).

Nissinen O. and Hakkola H. (1994) *The effect of the harvesting method and plant species on the grassland productivity in North Finland.* Maatalouden tutkimuskeskus, Tiedote 19/1994. 48 p. [In Finnish with English summary].

OSF (2015) Official Statistics Finland. Information centre of the Ministry of Agriculture and Forestry. Available at: http://tinyurl.com/ncjbe2t.

Ovaska S. and Heikkilä A.-M. 2012. *Suomen maitotilojen rakennekehitys ja kilpailukyky IFCN-tyyppitilatarkastelu 2001-2011.* MTT raportti 126. MTT, Helsinki, Finland. [In Finnish]

Peltovuori T. (2006) *Phosphorus in agricultural soils of Finland – characterization of reserves and retention in mineral soils.* Doctoral dissertation, Univ. Helsinki, Finland, 69 p.

Pulli S. (1980). Growth factors and management technique used in relation to the developmental rhythm and yield formation pattern of a pure grass stand. *Journal of Scientific Agricultural Society of Finland* 52, 281-330.

Puustinen M., Tattari S., Koskiaho J. and Linjama J. (2007) Influence of seasonal and annual hydrological variations on erosion and phosphorus transport from arable areas in Finland. *Soil and Tillage Research* 93, 44-55.

Regina K, Lehtonen H., Palosuo T. and Ahvenjärvi S. (2014) *Maatalouden kasvihuonekaasupäästöt ja niiden vähentäminen.* MTT Raportti 127. 43 p. [In Finnish with English summary].

Riesinger P (2010) *Agronomc challenges for organic crop husbandry.* Doctoral dissertation, Univ. Helsinki, Finland, 412 p.

Räty M. Saarijärvi K, Virkajärvi P. Saarijärvi E. and Kröger H. (2014) *Jatkuvatoiminen ravinnekuormituksen seurantaverkosto Kirmanjärven valuma-alueella.* [Nutrient load from Kirmanjärvi catchment area measured by continuous monitoring system.] Suomen Maataloustieteellisen Seuran Tiedote No 30. 7 p. [In Finnish].

Saarijärvi K. (2008) *Nitrogen cycling on intensively managed boreal dairy pastures.* Doctoral dissertation. Agrifood Research Reports 134. MTT Agrifood Research Finland, Jokionen, Finland,134 p.

Saarinen E, Virkajärvi P., Hyrkäs M., Suomela R., Niskanen M., Salo K. and Huuskonen A. (2012) Maissin soveltuvuus rehukasviksi Keski-Suomessa. [Suitability of maize as fodder crop in Central Finland]. In: Huuskonen A. (ed.) *Novel crop options for cattle.* MTT report 77. MTT, Jokioinen, 75 p.

Salo T., Eurola M., Rinne M., Seppälä A., Kaseva J. and Kousa T. (2014) *The effect of nitrogen and phosphorus concentrations on nutrient balances of cereals and silage grass.* MTT Report 147. MTT, Jokioinen, Finland. 36 p.

Soil Atlas of Europe (2005) Soil Bureau Network, European Commission, Office for official publications of the European Communities, Luxembourg, Luxembourg, 128 p.

Statistics Finland (2014) *Greenhouse gas emissions in Finland 1990-2012.* National Inventory Report under the UNFCCC and the Kyoto Protocol 15.4.2014. Available at: http://www.stat.fi/greenhousegases.

Turtola E. and Kemppainen E. (1998) Nitrogen and phosphorus losses in surface runoff and drainage water after application of slurry and mineral fertilizer to perennial grass ley. *Agricultural and Food Science in Finland* 7, 569-581.

Uusi-Kämppä J. and Heinonen-Tanski H. (2008) Evaluating slurry broadcasting and injection to ley for phosphorus losses and fecal microorganisms in surface runoff. *Journal of Environmental Quality* 37, 2339-2350.

Uusi-Kämppä J. and Mattila P.K. (2010) Nitrogen losses from grass ley after slurry application-surface broadcasting vs. injection. *Agricultural and Food Science*, 19, 327-340.

Valkama E. Uusitalo R., Ylivainio K. Virkajärvi P. and Turtola, E. (2009) Phosphorus fertilization: a meta-analysis of 80-year research in Finland. *Agriculture, Ecosystems & Environment* 130, 75-85.

Viljavuuspalvelu (2015) Lantatilasto 2005-2009. Available at: http://tinyurl.com/ohbmqax. [In Finnish].

Virkajärvi P. (2005) Milk production on pasture in Finland. *Grønn Kunnskap* 9: 58-62.

Virkajärvi P. and Järvenranta K. (2001) Leaf dynamics of timothy and meadow fescue under Nordic conditions. *Grass and Forage Science* 56, 294-304.

Virkajärvi P., Sairanen A. and Nousiainen J. (2003) Sward and milk production response to early turnout of dairy cows to pasture in Finland. *Agricultural and Food Science in Finland* 12: 21-34.

Virkajärvi P., Kykkänen S., Räty M., Hyrkäs M., Järvenranta K., Isolahti M. and Kauppila R. (2014*) Potassium fertilization of grass in Finland. Use of soil acid-soluble potassium as a basis for potassium fertilization.* MTT raportti 165. MTT Jokioinen, Finland, 52 p.

Virkajärvi P., Maljanen M., Saarijärvi K., Haapala J. and Martikainen, P.J. (2010) N_2O emissions from boreal grass and grass-clover pasture soils. *Agriculture, Ecosystems & Environment* 137, 59-67.

Virkajärvi P., Pakarinen K., Hyrkäs M., Seppänen M. and Bélanger G. (2011) Tiller characteristics of timothy and tall fescue in relation to herbage mass accumulation. *Crop Science* 52, 970-980.

Virtanen H. and Nousiainen J. (2008) Nitrogen and phosphorus balances on Finnish dairy farms*. Agricultural and Food Science* 14, 166-180.

Vuorenmaa J., Rekolainen S., Lepistö A., Kenttämies K. and Kauppila P. (2002) Losses of nitrogen and phosphorus from agricultural and forest areas in Finland during the 1980s and 1990s. *Environmental Monitoring and Assessment* 76, 213-248.

Vuorinen J. and Mäkitie O. (1955) The method of soil testing in use in Finland. *Agrogeology Publication* 63, 1-44.

Welfare Quality® (2009). Welfare Quality® assessment protocol for cattle. Welfare Quality® Consortium, Lelystad, the Netherlands.

Forage production and use in the dairy farming systems of Northern Italy

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Abstract

In the Po river valley, which represents the largest plain area of Northern Italy, the two main dairy farming systems are associated with cheese production: one for Grana Padano (GP) cheese using silage as the main forage source, and the other for Parmigiano-Reggiano (PR) cheese using hay, where silage fodders are banned to prevent *Clostridium* contamination and potential swelling defects in the cheese with the lengthy seasoning times. Maize silage is the mainstay forage base for fresh milk and GP cheese forage systems. Farm forage self-sufficiency is not always possible, mainly due to dry seasons and/or the practice of maize monoculture. In addition to the difficulties arising from low quantity production, problems of fodder safety (e.g. mycotoxins contamination of maize grain) and nutritional value occur. Regulations in force for PR production set the minimum level of dry matter intake from hay at 50% of dairy cows' rations. Difficulties arise in optimizing nutritional values and dry-matter intake when poor quality forages are available. Research is ongoing to evaluate the optimal alfalfa-grass mix, investigating how to maximize forage nutritional value and digestibility. Moreover, both dairy farming systems are highly dependent on imported feedstuffs: soybean from overseas, maize and other starch grains. Ongoing research activities are seeking to establish whether maize or soybean can be partially replaced by other crops (e.g. sorghum, triticale, grains with high protein content, alfalfa and grain legumes).

Keywords: alfalfa, cereals, dairy, forage, maize, permanent meadows

Introduction

Italy has confirmed its position as the country with the highest number of PDO (protected designation of origin) and PGI (protected geographical indication) certifications granted by the European Union. As at 31 December 2014, Italy had 268 PDO and PGI products, cheese being particularly important with 47 certifications (MiPAAF, 2014).

Grana Padano (GP) and Parmigiano-Reggiano (PR) are the two main Italian PDO cheeses, using more than 40% of the milk produced in Northern Italy and most of the milk from the areas of origin: 32 provinces in Lombardy, Emilia-Romagna, Veneto, Piedmont and Trentino Alto-Adige in the case of GP, and the provinces of Parma, Reggio Emilia, Modena, part of Bologna in Emilia Romagna and part of Mantua in Lombardy for PR.

GP and PR are undoubtedly based on high output dairy farming systems: farms have average productivity of 30.7 kg milk cow^{-1} day^{-1} in GP and 23.7 kg milk cow^{-1} day^{-1} in PR (AIA, 2013).

Even though changes in agricultural systems over the twentieth century have led to high levels of milk production based on increasing inputs and specialization of farms and agricultural districts, both systems are still effectively integrated crop-livestock systems: mixed farming and territorial systems based on the simultaneous utilization of crops and animals, where the recycling of livestock manure as a fertilizer, even within the limits imposed by the Nitrates Directive (91/676/EEC), is the basic means of fertilizing crops. Forage crops represent a substantial share of farmland but a high input of feed concentrates (around 10 kg cow^{-1} day^{-1}) is typical.

The possibility of using silage to feed animals and the favourable climatic conditions have tied the GP production area, which is mainly north of the Po river, to maize silage. The PR production area, south of the Po river, is mainly characterised by alfalfa and grass utilised to produce hay. In fact, in the PR system, silage fodders are banned in order to prevent *Clostridium* contamination and potential swelling defects in the preservative-free cheese subjected to lengthy seasoning.

The objective of this work is to describe the forage systems associated with the GP and PR production, their special characteristics, strengths and weaknesses. This paper used data from representative dairy farms belonging to the two production areas, monitored by CRPA (the Research Centre on Animal Production) in the LIFE+ projects Climate ChangE-R (Reduction of greenhouse gases from agricultural systems of Emilia-Romagna, LIFE12 ENV/IT/000404) and AQUA (Achieving good water quality status in intensive animal production areas, LIFE09 ENV/IT/000208): 10 case studies from the GP system and 10 from the PR system.

CRPA's databases have been used for the description of forage crop characteristics, as well as the results of a number of agronomic experimental trials conducted to test the production responses and nutritional values of some crops whose whole above-ground biomass and/or grains can be used as livestock feed (trials financed by the Emilia-Romagna Region, Regional Law 28/98).

Climatic conditions and cropping systems

The Po valley has a continental climate with relatively hot and humid summers and relatively cold winters. Rainfall ranges from 500-600 mm year^{-1} in the eastern area, around the Po river delta, to 800-1000 mm year^{-1} in the western area and in the foothills, with much higher values in the Alps and the Apennines. The highest rainfall is recorded in autumn, but April and May also have quite high average rainfall which can have a negative effect on the hay harvest. Over recent years the area has experienced more rain and reduced snowfall.

Two factors that need to be taken into account when determining land production potential are irrigation availability and altitude. Water availability is greater north of the Po river, thanks to the presence of the Alps. Conditions are less favourable south of the Po, where the Apennines are not able to guarantee the same quantity of water resources. This explains why 80% of the agricultural land to the north of the Po is irrigated whereas in the south riverside a lesser area is irrigated.

The main cropping systems in Northern Italy are cereals and forages, generally with high yields and high nitrogen uptake. Cropping systems in the plains of Northern Italy are closely linked to livestock type: dairy cattle, beef cattle or pigs.

Maize (*Zea mays* L.) is the main crop, and is used for grain or for silage. In pig farms and in the PR cheese production area, maize is mainly cropped for grain.

Where the soil and other conditions are suitable, dairy farms develop a two-crops-per-year cropping system: maize for silage (early-medium maturing hybrids) in combination with Italian ryegrass (*Lolium multiflorum* Lam.) or winter cereals for silage production. Maize is also a key crop for manure utilisation, particularly before ploughing. Nevertheless, silage maize is increasingly used, in combination with cattle manure, to feed biogas plants producing methane via anaerobic digestion (Fabbri *et al.*, 2013). In the last decade the cultivation of sorghum (*Sorghum bicolor* L. Moench) and triticale (*Tritico secale*) has increased, having a 'plastic' use in both livestock farms and biogas plants.

Forage crops take up most of the land on dairy farms. The most commonly used forage crops are alfalfa (*Medicago sativa* L.), permanent meadows, autumn-winter grass such as Italian ryegrass, winter wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), triticale and summer grasses such as maize and sorghum.

Alfalfa production in Northern Italy represents an important resource for dairy cattle farms because of the amounts of protein and fibre it guarantees. Due to its resistance to drought, thanks to a deep root system, it is particularly suitable in the south riverside of the Po, where water availability is reduced. The most common rotation is made up of alfalfa for three to five years followed by a winter cereal (wheat or barley) or Italian ryegrass. The subsequent crop could be maize, tomatoes or another winter cereal. This rotation allows the use of livestock manure to fertilize soils: farmyard manure before ploughing and slurry before ploughing or as a top dressing.

The Grana Padano forage system

Maize silage is the mainstay forage for the production of either fresh milk or milk for GP cheese. Maize hybrids used for silage production are mainly late- or very late-maturing types (FAO 600 and 700). Where maize is cultivated in combination with Italian ryegrass (double annual crops), medium-late (FAO 500-600) or early (FAO 400-500) maturing maize hybrids are used and harvested for silage production. Maize production is usually high when water is not a limiting factor; silage production ranges between 21-25 Mg dry matter (DM) ha^{-1} (Table 1).

Heavy soils are ploughed in autumn, and other soil types in spring or autumn. Livestock manures are usually spread before soil tillage, to be incorporated into the soil. Mineral fertilizer distribution takes place just before or in combination with sowing (NPK fertilizer) and as top dressing (N). Dairy farms where manure is available apply mineral fertilisers (mainly urea) at a rate of about 100 kg N ha^{-1}. Farms relying strongly on manure fertilisation tend to skip mineral N and P fertilisation before sowing. Therefore, the total or the largest part of mineral N is applied to maize as top dressing.

Italian ryegrass is a forage crop which has traditionally played an important role in the GP forage system: production is about 5-7 Mg DM ha^{-1}, with N uptake of 75-105 kg ha^{-1}. The double-crop system is able to produce 23-27 Mg DM ha^{-1}, with total N uptake of 290-340 kg ha^{-1}.

Table 1. Average yield and N uptake for the main types of maize in the Italian northern plain (Source: unpublished data from Pioneer Hi-Bred Italia, modified by AGROSELVITER University of Turin. Reference years: 2004-2008).

	FAO class	Number of measurements	Average	1st quartile	Median	3rd quartile
Yield (Mg dry matter ha^{-1})						
Irrigated	(FAO 400-500)	82	22.1	20.4	22.1	23.6
	(FAO 600-700)	1,478	22.9	20.7	23.0	25.1
Not irrigated	(FAO 400-500)	11	18.9	18.1	20.1	20.7
	(FAO 600-700)	163	20.0	17.5	20.5	22.6
N uptake (kg ha^{-1})						
Irrigated	(FAO 400-500)	65	254	234	254	271
	(FAO 600-700)	1,007	266	241	267	292
Not irrigated	(FAO 400-500)	11	217	208	230	237
	(FAO 600-700)	163	243	212	249	274

On GP farms, the use of alfalfa is considerable, representing 34.4% of the total UAA (Utilised Agricultural Area) even though GP feed rations are mostly based on maize silage, which takes up 21.7% of crop area (Figure 1).

The Parmigiano-Reggiano forage system

On PR farms, alfalfa occupies about half the UAA (47.6%). The second-most common crop, with a share of 26.4%, is winter wheat (Figure 1), which is mostly sold for grain and has limited use as a forage.

Permanent meadows, which are still found on the less-intensive farms, are generally cultivated without irrigation in the hills and with surface irrigation in the plains. When irrigated, permanent meadows provide an average of 13 Mg DM ha^{-1}, well distributed over 5-6 cuts, while 2-3 cuts are common in non-irrigated meadows with an average production of 5-6 Mg DM ha^{-1}, which is concentrated in the spring. During the season the floristic composition varies: in spring cuts the forage mainly consists of grasses and in summer cuts it is mainly legumes. The forage is turned into hay or used in cowsheds as fresh green forage.

The permanent meadow area is declining to the benefit of alfalfa. The presence of meadows and annual grasses in the PR forage system increases its sustainability from the environmental point of view because such crops are able to make the best use of the nitrogen provided with manure, thus depleting nitrates in the soil and in the soil water (Mantovi *et al.*, 2007). In fact, the permanent meadow is usually fertilized
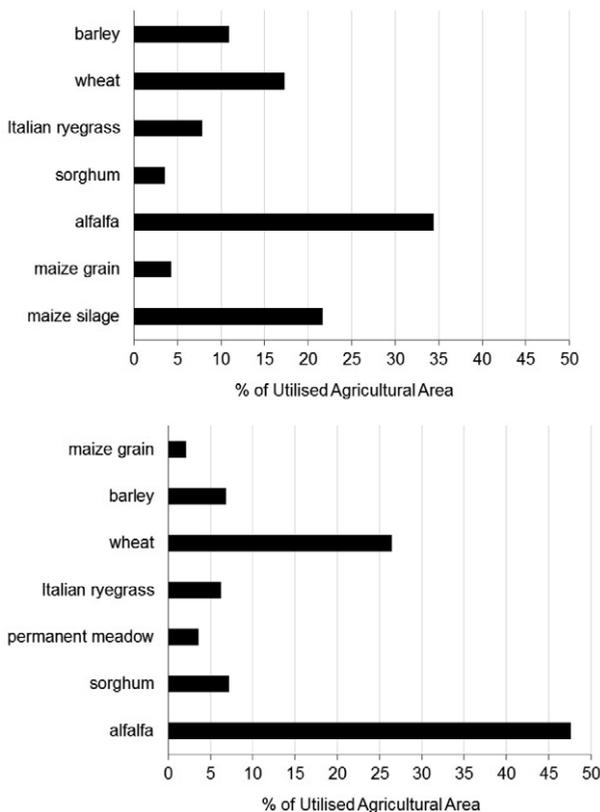
Figure 1. Area of crops in farms producing milk for Grana Padano (A) and Parmigiano-Reggiano (B), average values for representative dairy farms monitored by CRPA.

using farmyard manure, applied on the sward in the autumn-winter, and the liquid manure is applied throughout spring-summer after mowing.

These meadows have in many cases a long history (decades or centuries) and represent an important reservoir of biodiversity, holding a high number of plant species. Moreover, they represent a carbon sink since the soils accumulate organic matter. These are among the reasons of the CAP Greening criteria for preserving permanent meadows.

Alfalfa (*Medicago sativa* L.) is the mainstay crop in the PR cheese area, contributing to sustainable agriculture as a result of its productivity of feed protein per unit area, which is the highest among forage and grain legumes (Huyghe, 2003).

On the plain, alfalfa is grown for about 4 years and then the land is ploughed during the summer and prepared for sowing in the autumn (for example, with common wheat or Italian ryegrass) or in the spring (e.g. with maize). In hilly areas, alfalfa stands generally last longer (up to even 6 or 7 years) and grasses tend to prevail over time. This helps to increase the sustainability of the system, limiting soil erosion and allowing the possibility of spreading manure.

In Northern Italy, 4 or more cuttings of alfalfa (up to 6 or 7 under irrigation) can be harvested annually. Alfalfa yield varies according to the age of the crop and the availability of water. As a general rule, alfalfa achieves its highest production levels in the second year of cultivation (Table 2).

Various studies have shown that forage quality is affected by the growth stage (Nordkvist and Åman, 1986; Yu *et al.*, 2003), the cultivar (Griffin *et al.*, 1994) and the growing conditions (e.g. rainfall, temperature, soil characteristics and treatments (Mathison *et al.*, 1996)). To obtain high forage quality, alfalfa should be cut at the beginning of the flowering phase when the ratio between dry matter, protein content and fibres quality are optimal (Tabaglio *et al.*, 2006). After this stage the Neutral Detergent Fibre (NDF) becomes quite high (Table 3).

Table 2. Average yield of alfalfa in the Italian northern plains and hills (source: Ligabue *et al.*, 2005).

	1st year	2nd year	3rd year	4th year
Plains (Mg dry matter ha^{-1})				
Irrigated	10-11	16-18	13-14	10-12
Not irrigated	7-9	13-15	11-13	9-11
Hills (Mg dry matter ha^{-1})				
Not irrigated	3-5	8-10	6-8	3-5

Table 3. Characteristics of an alfalfa stand cut at different stages during the third year of cultivation (source: unpublished data from CRPA/Prosementi, project QualeMedica, year 2012).[1]

Harvesting date	Phenological stage	Kalu and Fick (1981) score	Dry matter yield (Mg DM ha^{-1})	NDF (%)	Crude protein (%)	Crude protein yield (kg ha^{-1})
4 May	Late vegetative stage	2.2	5.8	38.1	19.1	1,108
10 May	Late vegetative stage	2.3	6.5	40.5	17.1	1,111
15 May	Early bud	2.7	6.4	41.5	16.8	1,075

[1] DM = dry matter; NDF = neutral detergent fibre.

Alfalfa is traditionally managed without the use of herbicides or by limiting their use to the first year. This management gives rise to the significant presence of grass species taking advantage of the moisture present in the soil, particularly in the first and second cut. Current trends towards more specialised forage crops tend to separate the production of alfalfa and grasses. As a consequence, alfalfa stands are treated with herbicide to ensure pure forage and high yields over time.

Haymaking, particularly in the spring cuttings when climatic conditions are often adverse (high rainfall), is the most critical stage of forage production. Losses can reach 30%, 40% or more of the protein produced in the field. The production of high-quality hay is dependent on the reduction of these losses and this can be achieved by low-temperature dehydration of wet harvested forage. The most widespread conservation technique, even today, is haymaking. Hay is stored in round or square bales of different weights.

As with the GP district, in the PR area the cultivation of wheat forage is gaining ground. In this case the biomass is usually cut for hay at the grain-milk stage and the hay is used to feed the more productive animals. When weather conditions prevent haymaking at the best vegetative stage for cutting the wheat, some farmers opt for grain production, often stored in the farm and used after crushing.

Grana Padano and Parmigiano-Reggiano ration characteristics

Maize silage, with an average administration of 23 kg cow^{-1} day^{-1}, is the forage basis of cattle feed rations in the GP system (Table 4). Alfalfa is the second-largest ingredient at 2 kg cow^{-1} day^{-1} of the first cut and 4.8 kg cow^{-1} day^{-1} of other cuts. The average dry matter intake for lactating cows is 23 kg DM cow^{-1} day^{-1}.

Table 4. Ingredients and nutrients in GP and PR typical TMR for dairy cows, average values for representative dairy farms monitored by CRPA.[1]

Ingredients (kg head^{-1} day^{-1})	GP	PR
Alfalfa hay (first cut)	2	4.5
Alfalfa hay (other cuts)	4.8	6.9
Maize silage	23	-
Lolium sp. silage	1	-
Sorghum silage	0.5	-
Triticale silage	0.5	-
Italian ryegrass hay	-	1
Permanent meadows hay	-	0.5
Wheat hay	-	0.6
Wheat silage	0.5	-
Concentrate	9.5	11
Dry matter intake	23.0	22.5
Nutrients		
Crude protein (%DM)	14.0	14.8
Starch (%DM)	21.3	26.4
Sugar (%DM)	4.8	6.1
NDF (%DM)	36.0	31.8
dNDF (24 hours) (%NDF)	46.5	44.8
ADF (%DM)	22.3	22.9
ADL (%DM)	3.6	3.8
Net energy of lactation (Mcal kg^{-1} DM)	1.63	1.63
Ash (%DM)	7.5	8.5

[1] ADF = acid detergent fibre; ADL = acid detergent lignin; NDF = neutral detergent fibre; DM = dry matter.

The PR farms rely heavily on alfalfa hay in the rations, including the use of the first cut (with the presence of grasses), in amounts of more than 11 kg cow^{-1} day^{-1}.

The significant difference between the diets adopted in the two systems is represented by the presence of silage in GP, particularly maize silage. The production costs per hectare of maize silage are higher than for other forage crops; however, the former is able to provide a high yield harvested and made into silage in a single operation.

Production costs for GP rations have been estimated at 0.144 Euro per litre of milk produced, as compared with 0.177 Euro for the litre of milk used for PR (Santini and Ottolini, 2012).

TMR (Total Mixed Ration) composition analysed using the NIRS predictive technique identified significant differences in the starch content of the rations (21.3% DM in GP vs 26.4%DM in PR) mainly due to the different use of concentrates. The high quantity of maize silage in the GP rations has a significant bearing on the NDF (36.0% DM in GP vs 31.8% DM in PR) and digestibility over 24 h (46.5% DM in GP vs 44.8% DM in PR). The higher use of hay results in a difference in ash contents: greater in the PR rations (7.5% DM in GP vs 8.5% DM in PR).

Table 5 sets out the average characteristics of the maize silage and alfalfa hay. Maize silage achieves good quality levels with starch content over 32% DM and NDF digestibility at 24 hours around 50% NDF. The first alfalfa cut includes grasses. For this reason, crude protein content is higher in other cuts (11.0% DM first cut vs 17.3% DM other cuts) as well as NDF digestibility at 24 hours (39.1% NDF first cut vs 34.9% NDF at other cuts).

The forage quality confirms that it would be desirable to organise haymaking of alfalfa on a more rational basis, anticipating the cut up to the green flowering bud stage. Regarding concentrate feed, with maize as the main amilaceous component and soybean as the source of protein, both GP and PR forage systems have a limited self-sufficiency.

Problems and opportunities

The degree of fodder self-sufficiency is sometimes a problem for the milk production systems of Northern Italy, mainly due to dry seasons and the maize monoculture which, in addition to low yields, has also caused problems of fodder safety and nutritional quality.

Table 5. Qualitative parameters of forages (source: unpublished data from CRPA, three-year-period from 2012 to 2014).

Nutrients[1]	Maize silage (370 samples)	Alfalfa first cut (175 samples)	Alfalfa other cuts (280 samples)
Crude protein (%DM)	7.8	11.0	17.3
Starch (%DM)	32.1	1.9	1.5
Sugar (%DM)	0.8	7.6	7.0
NDF (%DM)	37.7	54.0	42.1
dNDF (24 hours) (%NDF)	50.2	39.1	34.9
ADF (%DM)	23.8	39.7	35.9
ADL (%DM)	2.7	6.6	7.7
Net energy for lactation (Mcal kg^{-1} DM)	1.71	1.17	1.28

[1] ADF = acid detergent fibre; ADL = acid detergent lignin; NDF = neutral detergent fibre; DM = dry matter.

Mycotoxin contamination of maize grain

The contamination with aflatoxin of a large part of maize produced in those agricultural areas subjected to heat stress and drought, especially in the years 2003, 2013 and 2014, has created extremely severe problems for the feed industry and the milk-cheese production chain. In particular, the most-used components in livestock feed, maize grain and its derivatives (gluten, gluten bran, etc.), are among the raw materials at the highest risk of contamination.

It was necessary to obtain non-contaminated maize from both EU and extra-EU markets with a significant increase in production costs. The doubts over the quality of farm-produced maize has forced farmers to make unusual replacements and variations in rations at the expense of ruminal functionality and milk quality. In this situation, the replacement of maize starch with a source having similar nutritional characteristics, such as that of sorghum, has provided an alternative without risks in the composition of cattle rations.

Alfalfa and high crude protein grains

Alfalfa could be useful for a partial replacement of soy protein in dairy cattle diet. It is important to improve the haymaking by scheduling early cuts, which in addition to increasing crude protein contents have a better amino acid profile when managed properly (Table 6).

In addition to providing energy, some cereals are valuable for their protein content and their amino acid profiles. Wheat and barley grains contain a high protein level and greater contents of essential amino acids than maize (Lanzas *et al.*, 2007). NRC (2001), indicate lysine content of 0.27%DM for maize grains and levels of 0.34 and 0.46% DM for grains of winter wheat and barley respectively. Similar values have been reported by Sauvant *et al.* (2002): 0.27% DM for maize, 0.35% DM for winter wheat and 0.42% DM for barley.

Grains with high protein content were cultivated in experimental trials conducted by CRPA in 2014 within the PR production area, near Modena. Barley (11 cultivars), winter wheat (4 cultivars) and triticale (3 cultivars) were compared. Yield and quality characteristics for the three cereals are reported in Table 7. The average protein content for the 18 cultivars was 12.1% DM, with the highest values recorded for wheat and triticale cultivars (over 13%). The starch content for the same cultivars was also high, around 75% DM.

Table 6. Amino acid composition (g 100 g^{-1}) (source: tissue, milk and bacterial from Lanzas *et al.,* 2007. Soybean meal from Sauvant *et al.,* 2002 and alfalfa from Masoero *et al.,* 2015, personal communication, unpublished).

	Milk protein	Ruminal bacteria	Soybean meal	Alfalfa hay[1]
Methionine	2.71	2.68	0.83	1.45
Lysine	7.62	8.20	6.08	3.87
Arginine	3.40	6.96	7.96	4.25
Threonine	3.72	5.59	3.03	4.36
Leucine	9.18	7.51	6.13	6.78
Isoleucine	5.79	5.88	4.25	4.07
Valine	5.89	6.16	3.79	5.12
Histidine	2.74	2.69	2.27	2.84
Phenylanine	4.75	5.16	3.88	4.50
Tryptophan	1.51	1.63	1.64	3.11

[1] Average values from 60 samples from various cuts.

Table 7. Average yields and characteristics of grains with high protein content (source: unpublished data from CRPA, Specie e varietà project, reference year 2014).[1]

Cereals	Grain yield (Mg ha^{-1})	DM yield (Mg DM ha^{-1})	Crude protein (g kg^{-1} DM)	Starch (g kg^{-1} DM)	Crude fibre (g kg^{-1} DM)	Crude fats (g kg^{-1} DM)
Winter wheat	5.60	4.81	134	752	15.4	13.3
Barley	8.26	7.19	113	400	40.3	19.9
Triticale	7.10	6.16	134	765	13.6	11.9

[1] DM = dry matter.

It is important to note that the production of grain legumes has never taken off in the Po valley; neither for soybean nor for grain legumes such as field pea (*Pisum sativum*) or field bean (*Vicia faba minor*). The reason is mainly the low and unreliable productivity of grain legumes with respect to the profitability of other crops.

Silage and hay from cereals other than maize

Research is underway to investigate the possible partial replacement of maize silage, using sorghum, triticale and other winter cereals. Sorghum is becoming an important crop for silage because it adapts to conditions of limited water availability, allowing the production of fodder in areas where maize experiences dryness and mycotoxin contamination. Sorghum is a multi-purpose cereal of potential interest for several food and non-food uses (Piluzza *et al.*, 2013). Different types are distinguished with specific morphological characteristics: grain sorghum, fibre sorghum, sweet sorghum and others. Silage sorghum can reach the dry matter production of maize, with the content of structural carbohydrates (NDF) around 50% and the starch from few percent (fibre cultivars) up to 20-25% DM (in grain cultivars). Crude protein content is generally lower than in maize and varies between 5 and 6% DM, whereas ash contents are around 7-9% DM.

In particular for the PR forage system, research is being carried out to investigate the optimal use of alfalfa combined with good quality grasses. In this context the hay from winter cereals can be a valuable resource.

In experimental trials conducted by CRPA in 2014 within the PR area, 14 wheat forage cultivars were cut at different growth stages. Biomass yields varied from about 30 to 50 Mg ha^{-1}, with an average dry matter level of 32.7%. Dry matter yields varied from 9 to 15 Mg DM ha^{-1}, with higher values recorded for late cuts (soft dough growth stage). Although wheat is considered to be a forage crop that provides carbohydrates in the diets of dairy cows, the average level of protein was 11.9% DM at head emergence, rapidly decreasing to dough development in kernel (Table 8). Managed wisely and when unaffected by unfavourable weather conditions, the resulting forage production has very balanced carbohydrate components characterised by different fermentation speeds.

Table 8. Average yields and characteristics of wheat forage (source: unpublished data from CRPA, Specie e varietà project, reference year 2014).[1]

Growth stage	DM yield (Mg DM ha^{-1})	Protein (g kg^{-1} DM)	Starch (g kg^{-1} DM)	NDF (g kg^{-1} DM)	ADF (g kg^{-1} DM)
Head emergence	8.6	119	20.4	557	370
Milk development in kernel	12.8	88	26.3	532	377
Dough development in kernel	15.1	58	42.4	526	410

[1] ADF = acid detergent fibre; NDF = neutral detergent fibre; DM = dry matter.

Conclusions

Grana Padano and Parmigiano-Reggiano are the two main Italian PDO cheeses using more than 40% of the milk produced in Northern Italy and almost all the milk from the areas of origin. They are based on high-output dairy farming systems with high average productivity (30.7 kg milk cow^{-1} day^{-1} in GP and 23.7 kg milk cow^{-1} day^{-1} in PR; AIA, 2013).

In the GP system, based on maize silage which guarantees high production of forage with high energy value, problems such as forage self-sufficiency and safety are currently addressed by varying the monoculture through the use of other cereals (sorghum, triticale and other winter cereals). While they cannot guarantee the same high-energy value as maize, these cereals can have a role in the production of silage and protein-enriched grains.

In the PR system, where hay is the base of TMR because the regulations set at 50% the minimum level of dry matter to be obtained from hay (in the rations of dairy cows), the main problem is optimising the alfalfa-grass mix. For this reason, in recent years there has been a progressive specialisation of forage crops: alfalfa is increasingly cultivated in pure stands to obtain high quality protein forage while grasses, which provide the necessary fibre in the ration, come from permanent meadows or pure stands of Italian ryegrass or winter wheat.

In both systems, the production of grain legumes is not significant because of poor and unreliable productivity, meaning they are still highly dependent on soybean imports. Research activities are ongoing to improve the quality characteristics of crops, reducing as much as possible the energy use for soil tillage while adapting the systems to climate change.

References

AIA (2014) Associazione Italiana Allevatori. Available at: www.aia.it.

Fabbri C., Labartino N., Manfredini S. and Piccinini S. (2013) Biogas, il settore è strutturato e continua a crescere. *L'informatore agrario* 11, 11-18.

Griffin T.S., Cassida K.A., Hesterman O.B. and Rust S.R. (1994) Alfalfa maturity and cultivar effects on chemical and in situ estimates of protein degradability. *Crop Science* 34, 1654-1661.

Huyghe C. (2003) Les fourrages et la production de protéines. *Fourrages* 174, 145-162.

Kalu B.A. and Fick G.W. (1981) Quantifying morphological development on alfalfa for studies of herbage quality. *Crop Science* 21, 267-271.

Lanzas C., Sniffen C.J., Seo S., Tedeschi L.O. and Fox D.G. (2007) A revised CNCPS feed carbohydrate fractionation scheme for formulating rations for ruminants. *Animal Feed Science and Technology* 136, 167-190.

Ligabue M., Tabaglio V. and Betti S. (2005) *La piante foraggere*. Edizioni L'Informatore Agrario, Verona, Italy.

Mantovi P., Ligabue M. and Tabaglio V. (2007) Nitrate content of soil water under forage crops fertilised with dairy slurry in nitrate vulnerable zone. In: De Vliegher, A. and Carlier L. (eds.) *Grassland science in Europe* 12, *Proceedings of the EGF2007, Ghent, Belgium*, pp. 347-350.

Mathison, R.D., Sheaffer C.C., Rabas D.L., Swanson D.R. and Halgerson J.H. (1996) Early spring clipping and herbicide treatments delay alfalfa maturity. *Journal of Production Agriculture* 9, 505-509.

MiPAAF (2014) Ministero delle Politiche Agricole e Forestali. Available at: http://www.politicheagricole.it.

NRC (2001) *Nutrient Requirements of dairy cattle*, 7th rev. National Academy Press, Washington, DC, USA.

Nordkvist E. and Åman P. (1986) Changes during growth in anatomical and chemical composition and *in vitro* degradability of lucerne. *Journal of the Science of Food and Agriculture* 37, 1-7.

Piluzza G., Sulas S. and Bullitta S. (2013). Tannins in forage plants and their role in animal husbandry and environmental sustainability: a review. *Grass and Forage Science* 69, 32-48.

Santini S. and Ottolini M. (2012) Alimentazione tutti i limiti dei due grana DOP. *Informatore Zootecnico* 3, 53-56.

Sauvant D., Perez J.-M. and Tran G. (2002) *Tables de composition et de valeur nutritive des matières premières destinées aux animaux d'élevage*. INRA editions, Paris, France, 301 pp.

Tabaglio V., Ligabue M. and Davoli M. (2006) Influenza dello sfalcio sul foraggio di medica. *L'Informatore Agrario* 20, 39-42.

Yu P., Christensen D.A., McKinnon J.J. and Markert J.D. (2003) Effect of variety and maturity stage on chemical composition, carbohydrate and protein subfractions, *in vitro* rumen degradability and energy values of timothy and alfalfa. *Canadian Journal of Animal Science* 83, 279-290.

The effect of decreased N and P applications on herbage quality in the Netherlands

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Abstract

In the Netherlands, the amounts per ha of nitrogen (N) and phosphorus (P) applied have been reduced by approximately 40% since 1996, due to legislative restrictions. However, as the reductions in N and P fertiliser application have not resulted in a reduction in the dry matter (DM) yield of grassland, we hypothesise that herbage quality is changing. We used a large database (n>350,000) with results of spring forage analyses from dairy farms in the Netherlands. In the period studied (1996-2013), crude protein (CP), crude ash, P, K, Fe, Zn, Mo, Cu and Co content all decreased. In the same period, an increasing content of energy, water-soluble carbohydrate (WSC) and selenium was found. The decreasing CP levels probably induced the increase in the WSC content of herbage. The increase in Se content can be explained by the increased use of Se containing fertilizers. In conclusion, almost all mineral contents in herbage seem to decrease because of the legislative restriction on N and P input. In order to maintain high animal production levels, farmers need to purchase high-protein feed and minerals for their rations to compensate for the decreasing CP and mineral contents in silage.

Keywords: herbage quality, nitrogen, yield

Introduction

In the Netherlands the applications of N and P have been reduced due to legislative restrictions. These restrictions are intended to minimize losses of N and P and thus improve ground- and surface-water quality. Application of N and P has declined by approximately 40% since 1996 (CBS, 2014). However, as the reduction in N and P fertiliser application has not resulted in the DM yield of grassland has not yet significantly changed (CBS, 2014). So the reduction of N and P applications has led to increased fertiliser-use efficiency in the Netherlands. However, since N application directly influences herbage quality (Tremblay, 2005), it is expected that there will be consequences for the herbage quality and animal performance. This paper summarises the changes in herbage quality in the Netherlands in relation to the reduced N and P applications. The results can indicate if the reduced N and P application might eventually affect animal performance in the near future.

Materials and methods

A huge database of commercial feed analyses from BLGG (www.blgg.nl) was used to perform this study. The database contains over 350,000 spring-cut forage analyses (grass silage) from Dutch dairy farms in the period 1996-2013. To evaluate the development of herbage quality, annual averages have been used. Besides the commercial analyses, the national mineral balances established by Statistics Netherlands (CBS, 2014) are used to correlate the changes to the reduced applications of N and P. The statistical analyses were performed with PSAW statistics 2013 using a simple linear regression model.

Results and discussion

Table 1 shows the development of the silage quality in the Netherlands over the years 1996 to 2013. The contents of ash, CP, K, P, Mn, Zn, Fe, Cu, Mo, and Co all decreased significantly. The decline in CP contents has a strong direct correlation with the reduced N input. However, the data from the CBS contain the average national N input by manure and fertilizer is for the Netherlands overall. Therefore, it

Table 1. Mean values (3 periods) of herbage quality characteristics and mineral input and DM yield in the Netherlands. Annual change (indicated by slope) and the regression coefficient indicates the mean change per year for the period 1996-2013.

Characteristics[a]		1996-2001	2002-2007	2008-2013	Slope[b]	R^2
DM	g kg^{-1}	448	448	455	n.s.	n.s.
VEM [c]	g kg DM^{-1}	886	888	912	2.3 *	0.51
Crude Ash	g kg DM^{-1}	119	108	102	-1,6 ***	0.58
CP [d]	g kg DM^{-1}	202	180	168	-2.9 ***	0.75
CF	g kg DM^{-1}	246	263	252	n.s.	n.s.
WSC	g kg DM^{-1}	79	84	99	1.8 [#]	0.19
Na	g kg DM^{-1}	2.4	2.5	2.4	n.s.	n.s.
K	g kg DM^{-1}	36	34	33	-0.3 ***	0.57
Mg	g kg DM^{-1}	2.3	2.3	2.3	n.s.	n.s.
Ca	g kg DM^{-1}	5.1	4.9	4.9	-0.0 *	0.23
P	g kg DM^{-1}	4,2	4.1	3.9	-0.0 *	0.32
S	g kg DM^{-1}	2,7	2,8	2.9	n.s.	n.s.
Mn	mg kg DM^{-1}	97	90	88	-0.7 *	0.23
Zn	mg kg DM^{-1}	44	40	40	-0.4 *	0.26
Fe	mg kg DM^{-1}	497	398	349	-13.4**	0.47
Cu	mg kg DM^{-1}	8.1	7.6	7.5	-0.1*	0.34
Mo	mg kg DM^{-1}	2.2	1.9	1.7	-0.0 **	0.53
Co	µg kg DM^{-1}	212	151	131	-7.0 ***	0.68
Se	µg kg DM^{-1}	46	75	95	3.6 ***	0.64
DM yield	kg ha^{-1}	10,540	10,408	10,928	n.s.	n.s.

[a.] DM = dry matter; CF = crude fibre; CP = crude protein; WSC = water-soluble carbohydrate.

[b] [#] $P<0.1$; * $P<0.05$; ** $P<0.01$; *** $P<0.001$; n.s. = not significant.

[c] VEM = Dutch energy unit. 1 VEM= 6,9 kJ net energy for lactation

[d] Crude Protein including NH_3-fraction.

includes more than just the dairy farmers. Nevertheless, over 50% of Dutch agricultural land consisted of grassland during the studied period (CBS, 2014). Figure 1 shows this correlation between the average N input ha^{-1} and the CP contents in silage. The decreasing CP content can be a challenge for the Dutch dairy sector since sufficient CP in the ration is necessary to maintain high milk yields (Broderick, 2003). The decreasing CP content in herbage will force dairy farmers to buy more high-protein feed. However, the
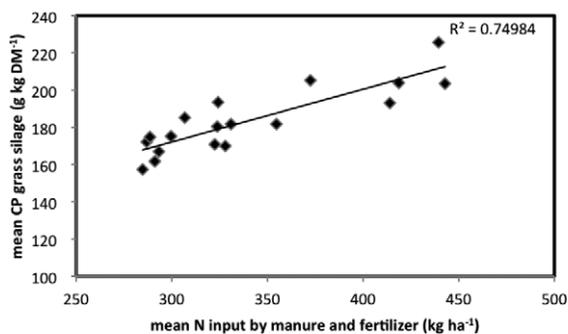
Figure 1. The relationship between the average N input ha^{-1} by animal manure and fertilizer and the mean CP content of spring-cut grass-silage in the Netherlands during 1996-2013.

content of VEM, WSC and Se tend to increase. The decreasing CP levels probably induced the increase in the WSC content of herbage (Tremblay, 2005; King, 2012). Silages with a higher WSC content will also contain more VEM which can be used for milk production. The increasing Se concentrations are possibly an effect of the increased use of fertilizers containing Se. This was also noted by Reijneveld (Reijneveld, 2014).

Conclusions

The reduced N and P inputs and the maintenance of the DM yield on grassland have resulted in a higher efficiency in terms of fertilisation. However, the lowering of manure and fertilizer inputs are resulting in a change of silage quality in the Netherlands. The decreasing CP and mineral contents are directly correlated to the reduced N input. In order to maintain high animal performance, dairy farmers will need to buy more high-protein feeds and minerals. Therefore, at farm level, the lower N input by fertilizers will be partly replaced by higher inputs of N present in the feed.

References

Broderick G.A. (2003). Effects of varying dietary protein and energy levels on the production of lactating dairy cows. *Journal of Dairy Science* 86, 1370-1381.

CBS (2014). Statistics. Available at: www.cbs.nl.

King C., McEniry J., Richardson M. and O'Kiely P. (2012). Yield and chemical composition of five common grassland species in response to nitrogen fertiliser application and phenological growth stage. *Acta Agriculturae Scandinavica Section B: Soil and Plant Science* 62, 644-658.

Reijneveld J., Abbink G.W., Termoshuizen A.J. and Oenema O. (2014). Relationships between soil fertility, herbage quality and manure composition on grassland-based dairy farms. *European Journal of Agronomy* 56, 9-18.

Tremblay G., Bélanger G. and Drapeau R. (2005). Nitrogen fertilizer application and developmental stage affect silage quality of timothy (*Phleum pratense* L.). *Grass and Forage Science* 60, 337-355.

The effects on performance of out-wintering replacement heifers in a high-output dairy system

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Abstract

Out-wintering replacement dairy heifers is commonly practised among low input pasture-based dairy systems, and is potentially an option to facilitate expansion for high output dairy farms. The effects on performance of Holstein dairy heifers out-wintered on perennial ryegrass, fodder beet, or housed during the winter of 2013/2014 in the UK were examined. Forty eight, 23-($\pm$2.8) month-old, in-calf heifers were randomly assigned to one of three treatments: out-wintered on perennial ryegrass and grass silage (G); out-wintered on fodder beet and grass silage (F); or housed and fed grass silage and concentrate (H). The study commenced in November 2013, with heifers continuing on their respective treatments for 13 weeks, before being housed for six weeks before parturition. Post-partum all animals received the same diet with performance measured for 12 weeks. Mean live weight (Lwt) and body condition score (BCS) during the winter was unaffected by treatment, but BCS of heifers that received G tended to be lower (P=0.090) at housing. Post-partum, mean Lwt was unaffected by treatment; however, mean BCS was lower (P=0.022) in animals that received G. Milk yield was not affected by treatment, but milk fat (g kg^{-1}) was lowest (P=0.027) and milk protein (g kg^{-1}) highest (P=0.026), in F. The results indicate that Holstein heifers can be successfully out-wintered without impacting on first lactation performance in a high output dairy system.

Keywords: heifer, out-wintering, forage crop, lactation

Introduction

Out-wintering is the practice of rearing cattle outside during the winter period (Barnes *et al.*, 2013). Out-wintering systems commonly use pasture or a forage crop, such as kale (*Brassica oleracea*) or fodder beet (*Beta vulgaris*) grazed *in-situ* (Atkins *et al.*, 2014). These systems have the perceived advantage of lower costs and improved animal health and welfare (Atkins *et al.*, 2014; Barnes *et al.*, 2013). Potential exists for herd expansion, without high capital expenditure in housing, by employing these systems to rear replacement dairy heifers. However, there are increased risks involved with outwintering cattle (Barnes *et al.*, 2013), in particular to the soil and environment, but also potentially to animal health, welfare and production, which could impact on dairy farm productivity. Reduced animal performance as a heifer through the winter has been reported to have negative effects on productivity and longevity (Le Cozler *et al.*, 2010). Previous research in intensively grazed spring-calving cows (Keogh *et al.*, 2009), and heifers (Kennedy *et al.*, 2012), has reported lactation performance from out-wintering systems similar to that from winter housing. However, the suitability of these systems for high output dairy systems, which require higher live weight gain as a heifer and greater milk production than spring-calving, grazed pasture-based herds, has not been studied. The objective of this study was to examine the effects on early lactation performance of Holstein dairy heifers out-wintered on perennial ryegrass, fodder beet, or housed during the winter of 2013/2014, in the UK.

Materials and methods

Forty eight, 23-($\pm$2.8) month-old-Holstein heifers, expected to calve between February and April 2014, were blocked according to their predicted transmitting ability (PTA), for milk, milk fat and protein PTA, calving date, live weight (Lwt), and body condition score (BCS), and randomly allocated to one of the

three treatments: out-wintered on strip-grazed fodder beet and bale silage (F), out-wintered on strip-grazed perennial ryegrass (*Lolium perenne*), and bale silage (G), or housed for the winter on bale silage and concentrate (H). During the final two weeks of the out-wintering period, G was offered 1.1 kg DM head^{-1} day^{-1} of concentrate due to continuing wet weather. The experiment commenced on 1 November 2013, with the out-wintered groups receiving a fresh strip of forage and 1/3 of dry matter intake as bale silage each morning from 8:00 am, and group H receiving daily concentrates and fresh forage as required. The animals remained on their respective treatments until approximately 6 weeks prior to their expected calving date and were then housed on dry cow total mixed ration (TMR) until calving. Post-partum the animals were housed in a cubicle shed and offered *ad libitum* TMR for the first 12 weeks of lactation. Through the out-wintering period, pre- and post-grazing herbage mass were measured weekly using five, 1×1 m and five 0.4×0.25 m quadrat cuts for fodder beet and perennial ryegrass respectively, and animals were weighed and body condition scored at intervals of two weeks until housed. Post-partum, animals were weighed and body condition scored within 24 hours of calving and at intervals of two weeks until week-12 of lactation, while milk yield was automatically recorded daily in the parlour and samples taken every two weeks for milk fat, protein and somatic cell count (SCC) analysis (NML, Wolverhampton, UK). Daily Lwt change for each animal was calculated by linear regression and data analysed by ANOVA in Genstat v.16.

Results and discussion

The mean herbage mass of fodder beet during the out-wintering period was 19.9 (±2.19) Mg DM ha^{-1} with mean utilisation of 81.3% (±14.0). Mean herbage mass in perennial ryegrass fields was 3,460 (±459) kg DM ha^{-1} pre-grazing and 1,960 (±389) kg DM ha^{-1} post-grazing. Calculated mean group intakes for F were 7.3 (±2.02) kg DM of fodder beet and 3.6 (±1.10) kg DM of silage; for G, 6.0 (±2.17) kg DM of perennial ryegrass and 4.5 (±1.12) kg DM of silage; and H, 8.5 (±1.85) kg DM of silage and 1.0 (±0.22) kg DM of concentrate per day.

The mean number of days spent on each treatment during the out-wintering period was 91 days, which did not differ between groups (*P*=0.928), nor was the number of days spent housed on transitional dry cow TMR different (*P*=0.633), at 44 days on average, close to the target of 6 weeks prior to calving. At parturition there was no difference in Lwt (*P*=0.390) between treatments (Figure 1); however, daily Lwt change was lower (*P*=0.001) during the out-wintering period for G than F or H; 1.24, 0.95 and 1.11 kg head^{-1} day^{-1} for F, G and H respectively. Body condition score tended to be lower in G at housing (*P*=0.090) and was lower (*P*=0.022) during lactation for G than F or H; 2.63, 2.44 and 2.61 BCS for F, G and H respectively. This was not reflected in lower milk yields, which were the same across all treatments
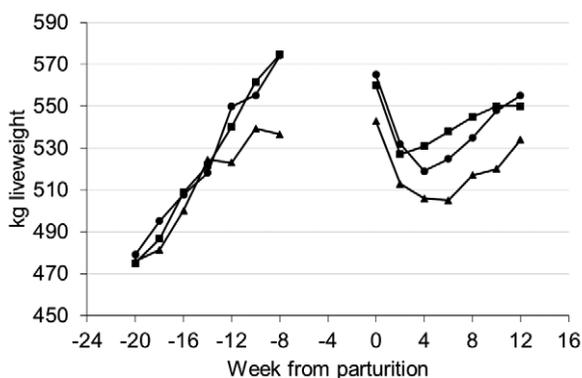
Figure 1. Live weight of Holstein heifers during 12 weeks of out-wintering on fodder beet (■), deferred grazing (▲), or housed for the winter (●), and in the first 12 weeks of lactation.

Table 1. Lactation performance of primiparous Holstein heifers in the first 12 weeks of lactation following out-wintering on fodder beet, deferred grazing, or housed for the winter.

	Fodder beet	Deferred grazing	Housed	s.e.d.[1]	Sig.[1]
Milk, kg	30.1	31.3	30.7	0.34	0.120
Fat, g kg^{-1}	35.4	37.1	37.9	0.40	0.027
Fat, kg day^{-1}	1.05	1.16	1.16	0.015	0.006
Protein, g kg^{-1}	32.1	31.2	31.6	0.17	0.026
Protein, kg day^{-1}	0.95	0.97	0.96	0.008	0.357
SCC log$_{10}$	1.73	1.52	1.66	0.024	0.014

[1] s.e.d. = standard error of difference; Sig. = significance.

(Table 1), although G had lower protein g kg^{-1} milk than F, with F having lower fat g kg^{-1} milk than both G and H, and lower SCC observed in G.

Conclusions

High animal performance is achievable from in-calf replacement Holstein dairy heifers outwintered on either fodder beet or deferred perennial ryegrass grazed *in-situ* during the winter in England. Winter performance in these systems is similar to housing with grass silage-based diets, although it may be more difficult to manage Lwt gain and BCS, particularly using deferred grazing. First-lactation milk yield in a high output dairy system was not affected by out-wintering, suggesting these systems can be used as a viable alternative to high capital cost winter housing.

References

Atkins N.E., Walley K., Bleach E.C.L. and Sinclair L.A. (2014) A survey of current practice among dairy farmers out-wintering replacement heifers in Great Britain. In: *Advances in Animal Biosciences.* Proceedings of the British Society of Animal Science, Cambridge University Press, Cambridge, UK, pp. 218.

Barnes A.P., McCalman H., Buckingham S. and Thomson S. (2013) Farmer decision-making and risk perceptions towards outwintering cattle. *Journal of Environmental Management* 129, 9-17.

Le Cozler Y., Peccatte J.R. and Delaby L. (2010) A comparative study of three growth profiles during rearing in dairy heifers: Effect of feeding intensity during two successive winters on performances and longevity. *Livestock Science* 127, 238-247.

Kennedy E., Coughlan F., Murphy J.P. and Fitzgerald S. (2012) The effect of winter diet on pre-partum weight gain and post-partum milk production of grazing primiparous animals. *Grassland Science in Europe* 17, 243-245.

Keogh B., French P., McGrath T., Storey T. and Mulligan F.J. (2009) Effect of three forages and two forage allowances offered to pregnant dry dairy cows in winter on periparturient performance and milk yield in early lactation. *Grass and Forage Science* 64, 292-303.

Development of a validity test for survey data on milk-from-grass from German dairy farms

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Abstract

Questionnaires are a frequently used instrument to analyse the productivity of farms. As surveys might include wrong or incorrect data, there is a need for validity testing. A validity test aims at generating an adjusted, reliable data-set with fewer outliers. Large data sets require an automated approach. We conducted a survey on 47 German dairy farms to evaluate the role of grassland in milk production. The farms are located all over Germany with a focus on Lower Saxony and Hesse. In a first step, we developed a generally applicable validity test for assessing the milk yield directly related to grassland. Several simple, directly measurable parameters were defined which correlate with important parameters with a high error rate. These relations were put into a formula and applied to the data set. We found that out of the 47 data sets three had to be excluded from further analysis because of large deviations from the defined confidence limits. The experience with the validity test did not only result in a more reliable data set, but helped to optimize the questionnaire for future surveys. The farms in this survey produced 4,916 l grassland-milk ha^{-1}.

Keywords: survey, validity test, grassland-milk, dairy

Introduction

For evaluating the productivity of farms, questionnaires are a frequently used instrument. However, with surveys there is always a high risk for misunderstandings and miscalculations. The validity and plausibility of the data for the most important parameters should be tested before a final analysis takes place. Ideally, this is done in a systematic way based on confidence limits and following a protocol. For extensive surveys, faulty data-sets are then excluded while for small surveys it can make sense to check doubtful data and eventually correct obvious mistakes by hand.

In order to determine the amount of milk based on grass (grassland-milk), 47 German dairy farmers were interviewed. We developed a protocol to test the validity and plausibility of answers to important parameters and applied it to the survey data. We hypothesize that this will improve data quality and the reliability of the following analysis.

Material and methods

In 2012 and 2013, 47 dairy farmers in Germany were interviewed by students from the Faculty of Agricultural Sciences of the Georg-August University Göttingen. Since it is not possible to ask directly for the amount of grassland-milk produced on the farm, this parameter has to be calculated from the following basic parameters which were provided by the farmers from farm records: amount of concentrates and maize in the ration; number of cows; milk yield per cow; and amount of grassland used for milk production. Some of these basic parameters were also used for the validity test. In a first step the data for these basic parameters have to fall within defined confidence limits and are then combined in a formula to calculate parameters that cannot directly be measured, e.g. the amount of grass (grass + grass-silage + hay) in the feed ration (Table 1). The results obtained from these formulas (final parameters) have to match previously defined confidence limits as well. Some additional parameters, which were not asked in the survey, were taken from the literature (Table 2). The overview of the protocol of the study is given in Table 3.

Table 1. Basic formulas for determining the final parameters and the amount of grassland-milk per hectare.

Calculation of the amount of grass in the daily ration of one cow
- Maintenance requirement per cow per day (MJ NEL) + energy requirement for lactation per cow per day (MJ NEL) = Energy requirement per cow per day (MJ NEL)
- Energy requirement per cow per day (MJ NEL) – energy from maize per cow per day (MJ NEL) – energy from concentrates per cow per day (MJ NEL) = Energy from grass (grass + grass-silage + hay) per cow per day (MJ NEL)
- Energy from grass per cow per day (MJ NEL) / energy content of silage (MJ NEL kg^{-1} DM) = Amount of grass in feed ration (kg DM per cow per day)

Calculation of the milk from grass per cow per year
- Milk yield per cow per day (l) / energy requirement per cow per day (MJ NEL) × energy from concentrates (MJ NEL) = Milk from concentrates per cow per day (l)
- Milk yield per cow per day (l) / energy requirement per cow per day (MJ NEL) × energy from maize (MJ NEL) = Milk from maize per cow per day (l)
- Milk yield per cow per day (l) – milk from maize per cow per day (l) – milk from concentrates per cow per day (l) × 305[a] = Milk from grass per cow per year (l)

Calculation of the milk from grass per ha grassland per year
- Milk (l) from grass per cow per year × cows per farm = Milk from grass per farm per year (l)
- Milk (l) from grass per farm per year per ha grassland per farm = Milk from grass per ha grassland per year (l)

Calculation of the yield of grass per ha grassland per year
- Amount of grass in feed ration (kg per cow per day) × cows per farm × 305 days of lactation = Need for grass (for milk production) per farm per year (kg DM)
- Need for grass (for milk production) per farm per year (kg DM) ha^{-1} grassland per farm = Yield of grass (for milk production) per ha per year (kg DM)
- Yield of grass (for milk production) per ha per year (kg DM) / 60%[b] = Total yield of grass per ha per year (kg DM)

[a] Lactation duration.
[b] Amount of grass yield ha^{-1} that is used for milk production.

Table 2. Basic parameters and final parameters which are needed for the validity test.

Basic parameters	Confidence limits	Source[1]
Amount of concentrates in the ration per cow per day	0-13 kg DM[a]	KTBL, 2009
Amount of maize in the ration per cow per day	0-13 kg DM[a]	KTBL, 2009
Milk-yield per cow per year	0-12,000 l[a]	KTBL, 2009
Energy content of roughage	4-7 MJ NEL kg^{-1} DM[a]	KTBL, 2009
Final parameters for validity test	**Confidence limits**	
Calculated amount of grass (grass + grass-silage + hay) in feed ration per cow per day	0-19 kg DM[c]	KTBL, 2009
Calculated dry matter intake per cow per day	15-24 kg[c]	KTBL, 2009
Calculated yield of grass per year ha^{-1}	0-11 Mg DM[c]	KTBL, 2009
Basic-parameters taken from literature	**Values**	
Live weight of a dairy cow	650 kg[c]	KTBL, 2009
Lactation duration	305 days[d]	Loeffler (2002)
Maintenance requirement per cow	37.7 MJ NEL day^{-1} [c]	KTBL, 2009
Power requirement per liter milk	3.28 MJ NEL[c]	KTBL, 2009
Energy density of maize	6.7 MJ NEL kg^{-1} DM[c]	KTBL, 2009
Energy density of concentrates	7.6 MJ NEL kg^{-1} DM[c]	KTBL, 2009
Amount of grass yield ha^{-1}, that is used for milk production	60%	_[2]

[1] Confidence limit based on the source.
[2] Assumption based on common agricultural knowledge of farming practice.

Table 3. Protocol for executing the validity test.

Extensive surveys	Small surveys
• Defining basic parameters and final parameters. Determining confidence limits for the parameters.	• Defining basic parameters and final parameters. Determining confidence limits for the parameters.
• Checking the basic parameters.	• Checking the basic parameters.
• Data-sets with one or several basic parameters that do not match the confidence limits are excluded.	• Data-sets with one or several basic parameters that do not match the confidence limits are marked.
• Applying the formulas for calculating the values of the final parameters.	• Applying the formulas for calculating the values of the final parameters.
• Data-sets with one or several final parameters that do not match the confidence limits are excluded.	• Data-sets, with one or several final parameters that do not match the confidence limits are marked.
	• Search for mistakes in marked data-sets. Eventually correction of the mistakes.
	• Exclusion of data-sets which do not pass the validity tests after correction.
• Final analysis of the data from the remaining data-sets.	• Final analysis of the data from the remaining data-sets.

Table 4. The effect of applying a validity test on some parameters for evaluating the importance of grassland for milk production.

	Before validity-testing (n=47)		After validity-testing (n=44)	
	Mean	SD	Mean	SD
Grassland used for milk production (ha)	64	47	54	36
Milking cows	95	70	98	71
ha grassland per cow	0.7	0.4	0.6	0.3
Milk yield per cow per year (l)	9,104	1,410	9,117	1,225
Grassland-milk ha^{-1} (kg)	4,206	4,442	4,916[a]	2,053[a]
Grassland-milk per cow per year	2,572	2,137	2,294	1,393
Calculated yield of grassland (t ha^{-1} per year) [b]	4.7	5.1	5.7	2.3
Calculated grass-intake (kg per cow per day) [b]	6.0	5.7	7.1	3.8

[a] Weighted mean.

[b] Parameter of validity test.

Results and discussion

In our survey of 47 dairy farms, the data sets from four farms did not match the basic parameters. Three of these had also not matched the final parameters. Besides these three, there were nine other data-sets which did not match the final parameters. In small surveys, it often makes sense to have a closer look at the faulty data sets to find out why they failed the test.

When we did that, mistakes in ten data-sets could be corrected, and they passed the test in a second run. Most errors were caused by a confusion of dry matter and fresh matter of feed or by miscalculating the grassland area. Three data-sets, that are three farms, did not pass the test even after an intensive search for mistakes and the correction. As it was not possible to contact the farmers for clarification, these data-sets had to be excluded from further analysis. Data from the remaining farms were then used for calculating the amount of grassland-milk. The validity testing did not lead to drastic changes of the means but resulted in much lower standard deviations. Before the test, standard deviations of grassland-milk ha^{-1}, grassland-milk per cow, grass intake per cow per day and of yield of grass ha^{-1} were in the range of the mean, but were reduced to 50% of the means after applying the test (Table 4).

References

Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL) (2009) *Faustzahlen für die Landwirtschaft* 14, Darmstadt (GER), pp. 382-404, 659-670.

Loeffler K. (2002) *Anatomie und Physiologie der Haustiere* 10, Ulmer, Stuttgart (GER), 340.

The effect of pasture allowance offered for different time durations on the dry matter intake of dairy cows

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Abstract

Milk quota abolition will increase herd size resulting in greater deficits in spring grass availability. 96 early lactation grazing dairy cows were assigned to one of four pasture allowances (PA; 60, 80, 100 and 120% of intake capacity) for either 2 or 6 weeks. All cows were allocated a 100% PA during the carryover period. Dry matter intake (DMI) was estimated during weeks 2, 6 and 13. During week 2, there was no difference in DMI between the 100 and 120% allowances (13.7 kg DM cow^{-1}) but their DMI was significantly greater than the 60 and 80% allowances (10.4 and 11.5 kg DM cow^{-1}, respectively), which were also significantly different to each other. During week 6, there was a significant interaction between PA and duration. Cows assigned to the 2-week treatment had similar DMI (13.9 kg DM cow^{-1}). The 120×6 treatment (14.6 kg DM cow^{-1}) was significantly different to the 60×6, 80×6 and 100×6 treatments (10.7, 12.3 and 13.3 kg DM cow^{-1}, respectively). There was no difference in DMI between the 80×6 and the 100×6 treatments (12.8 kg DM cow^{-1}), which were both different to the 60×6 treatment (10.7 kg DM cow^{-1}). During week 13, there was no effect of treatment on DMI (15.1 kg DM cow^{-1}). Differences in DMI were observed during the experimental period, but there was no effect of treatment on DMI during the carryover period. In conclusion, varying the PA of early lactation dairy cows from 60 to 120% of intake capacity for 2 or 6 weeks produced no carryover effects in terms of DMI.

Keywords: pasture allowance, early lactation dairy cows, dry matter intake, carryover period

Introduction

Grazed grass is the cheapest source of nutrition for dairy cows in Ireland (Finneran *et al.*, 2010), and along with grass silage can account for more than 80% of the diet of Irish dairy cows (Shalloo *et al.*, 2004). The 50% increase in milk production proposed in 'Food Harvest 2020' will be achieved by an earlier spring-calving date, higher stocking rates and increased milk yield per cow (Dillon, 2011). This will lead to increased demand for grass, especially in spring, and will result in greater nutritional deficits as grass supply at this time can be extremely variable (Ganche *et al.*, 2013). The objective of this experiment was to determine the dry matter intake (DMI) of early lactation grazing dairy cows allocated to one of four pasture allowances (PA) for either 2 or 6 weeks, and to establish if any carryover effects of treatments imposed during early lactation exist.

Materials and methods

This full lactation study took place at Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork from 25 March to 27 November 2014. 96 early lactation dairy cows (41 primiparous and 55 multiparous) were blocked by breed (Holstein-Friesian, n=52; Jersey × Holstein-Friesian, n=38; Norwegian Red, n=6), calving date (February 17 ± 15.5 days), parity (2.4±1.61), pre-experimental milk yield (22.6±4.20 kg), body weight (BW) (469±68.2 kg) and body condition score (BCS) (3.09±0.193) and from within block were randomly allocated to one of eight treatments in a randomised complete block design with a 4×2 factorial arrangement of treatments.

The cows were offered one of four PA (60, 80, 100 and 120% of intake capacity) for two durations of time (2 or 6 weeks). Cows were rotationally grazed on a perennial ryegrass (*Lolium perenne* L.) sward on a

full-time basis. All cows were offered a grass-only diet for 2 weeks prior to the start of the experiment. The cows in the 100% PA treatment were fed to 100% of their intake capacity and all other treatments were calculated from this (e.g. if the 100% herd were offered 15 kg DM cow^{-1} day^{-1} the 80% herd were offered 12 kg DM cow^{-1} day). Intake capacity was calculated according to the equation of Faverdin *et al.* (2011) and was dependent on age, parity, days in milk, stage of pregnancy, BW, BCS and potential milk yield.

Pasture allocation was measured using pre-grazing herbage mass (>3.5 cm) and area (m^2). Pre-grazing herbage mass was measured by cutting two strips (1.2×10 m) per paddock and per treatment area twice weekly, with an Etesia mower. Ten grass-height measurements were recorded before and after each cut strip using a folding plate meter (diameter 355 mm and 3.2 kg m^{-1}; Jenquip, Fielding, New Zealand). All mown herbage from each strip was collected, weighed and sampled. A sub-sample of 100 g fresh weight of the herbage sample was dried for 16 h at 90 °C for DM determination. Pre- and post-grazing sward heights were measured daily using a rising plate meter.

Cows assigned to the 2-week treatment were allocated a PA of 100% of intake capacity once the 2 weeks had elapsed (PA was the same as the 100×6 treatment); all 6-week cows were offered a 100% PA once 6 weeks of being allocated to their respective treatments elapsed. The cows were offered fresh grass after each milking during the experimental period and on a 24-hour basis during the carryover period. Grass DMI was estimated during weeks 2, 6 and 13 using the n-alkane technique (Mayes *et al.*, 1986; Dillon and Stakelum, 1989).

The data were analysed using covariate analysis and mixed models in SAS v9.3, with terms for allowance, duration, the interaction between allowance and duration and the appropriate pre-experimental covariate.

Results and discussion

The PA for the 100% treatment during week 1 of the experiment was 13.4 kg DM cow^{-1} day^{-1}; this increased to 15.5 kg DM cow^{-1} day^{-1} by week 7 (Table 1). During week 13 the PA was 16.0 kg DM cow^{-1} day^{-1} for all cows. During week 2 there was an effect of PA on DMI. The 100 and 120% allowances were similar (13.7 kg DM cow^{-1}) but their DMI was significantly greater than the 60 and 80% allowances (10.5 and 11.5 kg DM cow^{-1}, respectively), which were also significantly different to each other. Post-grazing sward heights (PGSH) across all treatments were significantly different during this period ($P<0.001$). The 120% treatment had a higher PGSH (4.3 cm) than the 100, 80 and 60% treatments which were also significantly different to each other (3.7, 3.1 and 2.5 cm, respectively). During week 6, there was a significant interaction between PA and duration ($P<0.01$). Cows assigned to the 2-week treatment were offered a 100% PA. They had similar DMI (13.9 kg DM cow^{-1}) to the 100×6 cows, but the DMI of these treatments was significantly different to the DMI of 120×6, 80×6 and 60×6 treatments. There were, therefore, no carryover effects in terms of DMI for cows on the 2-week treatment. A 2-week period of restriction or surplus PA had no impact on the DMI of cows 4 weeks later. This was reflected in their PGSH as the 100×6 and 2-week treatments had similar PGSH during this period (3.8 cm), which was different to the 60×6, 80×6 and 120×6 treatments (2.8, 3.3 and 4.3 cm, respectively; $P<0.001$). During week 6 the DMI of the 120×6 treatment (14.6 kg DM cow^{-1}) was significantly different to the 60×6, 80×6 and 100×6 treatments (10.7, 12.3 and 13.3 kg DM cow^{-1}, respectively). Differences in DMI between the 100×6 and 120×6 treatments resulted from the 20% higher PA offered to the 120×6 cows. These cows had a greater ability to select pasture which was higher in organic matter digestibility (OMD) and UFL (Unité Fourragère Lait) value, and lower in fill value, enabling a greater DMI. Although the 120×6 cows had a 20% higher PA compared to the 100×6 treatment they only had a 9% higher DMI. Providing a PA of 120% of intake capacity for 2 or 6 weeks resulted in poorer sward utilisation when compared to 100% (PGSH increase of 0.6 cm and 0.4 cm during weeks 2 and 6, respectively) which may have consequences for grass quality in subsequent rotations. There was no difference in DMI between

Table 1. Effect of pasture allowance offered for different time durations on the dry matter intake of early lactation dairy cows.[1]

	60×2	80×2	100×2	120×2	60×6	80×6	100×6	120×6	SED	PA	D	PA×D
Wk2	10.6	11.6	13.4	13.9	10.3	11.4	13.2	14.2	0.58	***	NS	NS
Wk6	14.2[ad]	14.1[ad]	13.4[ac]	13.8[ad]	10.7[b]	12.3[c]	13.3[ac]	14.6[d]	0.60	***	***	***
Wk13	15.2	16.1	14.6	14.5	14.6	15.4	14.8	15.8	0.67	NS	NS	NS

[1] SED = standard error of the difference; PA = pasture allowance; D = duration, PA×D = pasture allowance × duration, Wk = week; *** = P<0.001.

the 80×6 and 100×6 treatments (12.8 kg DM cow^{-1}) which were both different to the 60×6 treatment (10.7 kg DM cow^{-1}). During week 13, there was no effect of treatment on DMI (15.1 kg DM cow^{-1}) indicating that there was no carryover effect of treatment.

Conclusions

The quantity of pasture offered to dairy cows in early lactation significantly affected their DMI. However, when they returned to being offered 100% of their intake capacity no differences in DMI were observed indicating no carryover effects of previous treatments on this factor; however, there may be possible effects on body weight, behaviour, reproduction and milk production.

References

Dillon P. (2011) The Irish Dairy Industry – planning for 2020. In: Teagasc National Dairy Conference, Cork & Athlone, Ireland, pp. 1-24.

Dillon P. and Stakelum G. (1989) Herbage and dosed alkanes as a grass measurement technique for dairy cows. *Irish Journal of Agricultural Research* 28, 104.

Faverdin P., Baratte C., Delagarde R. and Peyraud J.L. (2011) GrazeIN: a model of herbage intake and milk production for grazing dairy cows. 1. Prediction of intake capacity, voluntary intake and milk production during lactation. *Grass and Forage Science* 66, 29-44.

Finneran E., Crossan P., O'Kiely P., Shalloo L., Forristal P.D. and Wallace M. (2010) Simulation modelling of the cost of production and utilizing feeds for ruminants on Irish farms. *Journal of Farm Management* 14, 95-116.

Ganche E., Delaby L., O'Donovan M., Boland T.M. and Kennedy E. (2013) Direct and carryover effect of post-grazing sward height on total lactation dairy cow performance. *Animal* 7, 1390-1400.

Mayes R., Lamb C. and Colgrove P.M. (1986) The use of dosed and herbage n-alkanes as markers for the determination of herbage intake. *Journal of Agricultural Science* 107, 161-170.

Shalloo L., Dillon P., O'Loughlin J., Rath M. and Wallace M. (2004) Comparison of a pasture-based system of milk production on a high rainfall, heavy-clay soil with that on a lower rainfall, free-draining soil. *Grass and Forage Science* 59, 157-168.

Models for predicting effects of management factors on per-cow and per-hectare pasture intake by grazing dairy cows

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Abstract

Robust modelling of pasture herbage intake by grazing dairy cows under a wide range of grazing and supplementary feeding strategies allows the better combination of high rates of pasture utilisation and nutrition management in dairy systems. The GrazeIn model has been developed from 10 years at INRA (France) from extensive literature review and large experimental databases, and then validated at European level. It allows prediction of the effects of animal characteristics, sward nutritive value, grazing management (grazing system, pasture allowance, pasture mass, daily access time) and supplementation (concentrates and/or forages), along with their interactions, on daily pasture dry matter intake by grazing dairy cows. Grazing management and sward structural characteristics are, however, often unknown on farm. For that reason, a simplified version of the model describing sward state and management through only pre-grazing and post-grazing sward heights has also been developed, allowing easier use of the model for advising or teaching. After a brief description of the two versions of the model, the relative effects of the main factors affecting pasture intake are compared on a per-cow and on a per-hectare basis.

Keywords: grazing, intake, dairy cow, modelling

Introduction

Increased efficiency of grazing systems for dairy cattle production requires a better estimation of cow intake and performance according to management practices. Grazing management factors (pasture allowance, pre- and post-grazing sward height, daily access time), mostly depending on the farmer's decisions, are known to affect daily intake at pasture, in interaction with cow characteristics, pasture nutritive value and supplementation strategy. As pasture herbage intake at grazing is always difficult to measure, accurate predictive models may be used to help decisions, such as GrazeIn (Delagarde *et al.*, 2011a; Faverdin *et al.*, 2011), provided the required input information is available. However, at farm level, precise description of sward state is not available, and simplified models may be needed. After describing the complete and simplified version of GrazeIn, this paper will focus on the main factors determining per-cow and per-hectare intake at pasture and its use-efficiency.

Materials and methods

GrazeIn predicts pasture herbage intake through two steps. Firstly, sub-models for animal intake capacity and requirements, forage feed value and substitution rate between forages and concentrates through iterative calculations allow the calculation of the voluntary dry matter (DM) intake at pasture (as if the grazed pasture herbage was cut and given *ad libitum* indoors). Secondly, the relative intake at grazing is calculated, as a proportion of voluntary intake, taking into account the effects of pasture herbage allowance and pasture mass under strip- or rotational grazing, sward surface height under set-stocking, and daily access time to pasture under all grazing systems. Pasture herbage allowance and pasture mass effects are combined through the calculation of the relative pasture allowance above 2 cm from ground level, which allows the simulation of the positive or negative effects of pasture mass on intake in relation to cutting height as found in the literature (Pérez-Prieto and Delagarde, 2012). External validation with several datasets from Europe showed an average mean prediction error for pasture herbage intake of 10 to 16%, with no source of bias identified for sward or grazing management factors at herd and paddock level, whatever the season (Delagarde *et al.*, 2011b; O'Neill *et al.*, 2013).

The simplified version of the model was developed with the objective to use pre- and post-grazing sward heights as the sole descriptors of pasture availability, avoiding the need for estimating pasture herbage mass and allowance. Empirical multiple regressions were calibrated from thousands of grazing and feeding situations by using the complete GrazeIn model, in order to predict successively pasture DM intake without supplementation, the substitution rate of any conserved forage given as supplement, and the concentrate substitution rate if cows are fed concentrates (Faverdin *et al.*, 2007). Required daily area or paddock residency time to achieve the post-grazing sward height are also predicted. A single spreadsheet calculator allows a rapid calculation of pasture herbage intake per cow and per hectare in relation to cows, pasture, management and supplementation characteristics.

Results and discussion

This section focuses on key messages about the known effects of management factors affecting per-cow and per-hectare pasture intake and milk production, derived from literature review and using both versions of the GrazeIn model. High pasture quality (leafy swards, high organic matter (OM) digestibility, presence of legumes) has a major impact on milk production per cow due to its cumulative effect on pasture energy concentration and voluntary intake. As an example, increasing OM digestibility from 0.7 to 0.8 increases daily net energy (NE) intake by 20-25%.

Grazing severity may be viewed as the degree of restriction of pasture intake (at grazing) when expressed as a proportion of voluntary intake (indoors with no restriction). Relationships between pasture allowance and pasture intake show that grazing management strategy may be defined as lax, severe and very severe for relative intake restrictions of 1.0, 0.9 and 0.8, respectively. Grazing is called lax when cow intake is not restricted because it is achieved with high area per cow and low number of grazing days per hectare. During one grazing rotation, a severe grazing enables 45% increase in grazing days and 30% increase in milk production per hectare, when compared to lax grazing. During a grazing season (cumulated rotations), it may be estimated that pasture intake and milk production per cow varies 8 times less per cow than per hectare when stocking rate is affected (McCarthy *et al.*, 2011; Peyraud and Delagarde, 2013). In the current range, pre-grazing sward height (or pasture mass) or post-grazing sward height considered alone are bad indicators of pasture intake. However, the relative post-grazing sward height, when expressed as a proportion of pre-grazing sward height, is well related to pasture allowance and intake. Relative post-grazing sward height of 0.5, 0.4 and 0.3 are indicative of lax, severe and very severe grazing, respectively.

From lax to very severe grazing management, substitution rate between pasture and concentrates normally ranges from 0.5 to 0.0, and substitution rate between pasture and a forage supplement ranges from 1.0 to 0.5. Recommendations of supplementation level when daily access time to pasture is limited may also be given (Peyraud and Delagarde, 2013).

The complete GrazeIn model is currently used in INRAtion (www.inration.educagri.fr), a commercially available software for formulating diets of ruminants, in commercial tools of the French institute of performance control, in an INRA whole-farm model, and will be used after some adaptations in Irish grazing management tools by Teagasc. The simplified model is partially used in a pasture simulation model in France, and in several French experimental farms to estimate pasture DM intake at year level when platemeter heights are measured. Both versions of the model are also used for teaching in France.

Conclusions

Prediction of pasture intake by grazing dairy cows needs models sensitive to grazing system and grazing management factors. Several validated models adapted to the available grazing management information exist and may be used for advising, teaching and thinking on impacts of grazing management strategies.

The relatively low variation of intake per cow compared to that of intake per hectare when grazing pressure is changed shows that increasing efficiency of dairy cattle grazing systems should focus on pasture-use efficiency rather than on individual cow performance or on grazing system or sward state. In all situations, the quality of pasture herbage is a primary factor enabling high per cow performance at low use of concentrates.

References

Delagarde R., Faverdin P., Baratte C. and Peyraud J.L. (2011a) GrazeIn: a model of herbage intake and milk production for grazing dairy cows. 2. Prediction of intake under rotational and continuously stocked grazing management. *Grass and Forage Science* 66, 45-60.

Delagarde R., Valk H., Mayne C.S., Rook A.J., Gonzalez-Rodriguez A., Baratte C., Faverdin P. and Peyraud J.L. (2011b) GrazeIn: a model of herbage intake and milk production for grazing dairy cows. 3. Simulations and external validation of the model. *Grass and Forage Science* 66, 61-77.

Faverdin P., Delagarde R., Delaby L. and Meschy F. (2007) Alimentation des vaches laitières. In: *Tables INRA 2007 – Alimentation des bovins, ovins et caprins*. Editions QUAE, Versailles, France, pp. 23-55.

Faverdin P., Baratte C., Delagarde R. and Peyraud J.L. (2011) GrazeIn: a model of herbage intake and milk production for grazing dairy cows. 1. Prediction of intake capacity, voluntary intake and milk production during lactation. *Grass and Forage Science* 66, 29-44.

McCarthy B., Delaby L., Pierce K.M., Journot F. and Horan B. (2011) Meta-analysis of the impact of stocking rate on the productivity of pasture-based milk production systems. *Animal* 5, 784-794.

O'Neill B.F., Lewis E., O'Donovan M., Shalloo L., Mulligan F.J., Boland T.M. and Delagarde R. (2013) Evaluation of the GrazeIn model of grass dry-matter intake and milk production prediction for dairy cows in temperate grass-based production systems. 1. Sward characteristics and grazing management factors. *Grass and Forage Science* 68, 504-523.

Pérez-Prieto L.A. and Delagarde R. (2012) Meta-analysis of the effect of pregrazing pasture mass on pasture intake, milk production, and grazing behavior of dairy cows strip-grazing temperate grasslands. *Journal of Dairy Science* 95, 5317-5330.

Peyraud J.L. and Delagarde R. (2013) Managing variations in dairy cow nutrient supply under grazing. *Animal* 7, supplement 1, 57-67.

Herbage and milk production from a grass-only sward and grass-white clover swards in an intensive grass-based system

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Abstract

White clover (*Trifolium repens* L.; clover) can increase the sustainability of grass-based dairy systems and has the potential to increase milk production. This experiment compared milk production from a perennial ryegrass (PRG) sward receiving 250 kg N ha^{-1} yr^{-1} (Gr250), a PRG-clover sward receiving 250 kg N ha^{-1} yr^{-1} (Cl250) and a PRG-clover sward receiving 150 kg N ha^{-1} yr^{-1} (Cl150) in a rotationally grazed system in 2013 and 2014. Three groups of cows were allocated to graze each sward in 2013 and 2014 (n=14 and 19, respectively). Clover inclusion into PRG swards had no effect on the total herbage production. There was a treatment×week interaction on sward clover content; Cl150 had greater clover content in the second half of the grazing year. Treatment had an effect on cumulative milk yield (MY) and milk solids (MS) production. The Cl150 had lower cumulative MY compared to Cl250 (6,055 and 6,343 kg milk cow^{-1}, respectively); there was no significant difference between Cl150 and Gr250 (6,055 and 5,912 kg milk cow^{-1}, respectively); and Cl250 had greater cumulative MY than Gr250 (6,343 and 5,912 kg milk cow^{-1}, respectively). The MS yield of the clover treatments were significantly greater than the Gr250 and were similar between both clover treatments.

Keywords: *Trifolium repens* L., nitrogen, dairy cow, milk production

Introduction

White clover (*Trifolium repens* L.; clover) can increase the sustainability of grass-based dairy systems by reducing nitrogen (N) fertiliser application and has the potential to increase milk production (Ledgard, 2002). Clover and perennial ryegrass (*Lolium perenne* L.; PRG) have different temperature responses and different seasonal growth patterns (Davies, 1992). Fertiliser N can compensate for lower herbage production on PRG-clover swards due to low clover growth rates in spring. High N-fertiliser application rates can reduce sward clover content (Harris *et al.*, 1996). Previous research has shown the benefit of clover over PRG for milk production, particularly in the second half of the year (July onwards) (Egan *et al.*, 2013; Riberio Filho *et al.*, 2003). The objective of the current study was to compare herbage production of and milk production from a PRG-only sward receiving 250 kg N ha^{-1} with PRG-clover swards receiving 150 or 250 kg N ha^{-1}.

Materials and methods

A farm systems experiment was established at Teagasc, Animal and Grassland Research Innovation Centre, Moorepark, Fermoy, Co. Cork Ireland (52°09'N; 8°16'W) in 2013. This experiment compared herbage and milk production from a PRG sward receiving 250 kg N ha^{-1} yr^{-1} (Gr250) and PRG-clover swards receiving 250 kg N ha^{-1} yr^{-1} (Cl250) or 150 kg N ha^{-1} yr^{-1} (Cl150) in an intensively grazed system over two grazing seasons (2013 and 2014). Spring-calving Holstein-Friesian dairy cows were blocked on calving date, pre-experimental milk yield (MY) and milk solids yield (MS) and parity, and randomly allocated to one of the three treatments (n=14 in 2013 and n=19 in 2014). All treatments were stocked at a whole-farm stocking rate of 2.74 cows ha^{-1}. Cows remained on their respective treatment for the entire grazing season. This was a farm systems experiment and annual fertiliser rates were applied across the whole farm. Fertiliser N was applied after each grazing; N application was similar on all treatments until late May, after which N was reduced on Cl150 for the remainder of the year. Herbage was allocated

daily to achieve a target post-grazing sward height of 4 cm. Pre-grazing herbage mass (>4 cm; HM) was determined twice weekly using an Etesia mower (Etesia UK Ltd., Warwick, UK). Sward clover content was estimated twice weekly as described by Egan *et al.* (2013). Milk yield was recorded daily and milk composition (fat and protein concentrations) was measured weekly. Milk solids yield was calculated as the sum of milk fat and protein yields. Data were analysed using a mixed model in SAS with terms for treatment, time (week or rotation), year and the associated interactions. Fixed terms were year, treatment and week or rotation, and random terms were cow and paddock.

Results and discussion

Treatment had no significant effect ($P>0.05$) on herbage production (Table 1). Year had a significant effect ($P<0.001$) on herbage production: it was greater in 2014 (15.5 Mg DM ha^{-1}) than in 2013 (12.8 Mg DM ha^{-1}). There was a treatment×week interaction ($P<0.01$) on sward clover content. Clover content was similar on both clover treatments in both years until early July. From July to the end of the year, clover content was greater on the Cl150 than the Cl250. This increase in clover content on the Cl150 treatment coincided with the reduction in N fertiliser application to Cl150, similar to that reported by Ledgard and Steele (1992). Year had a significant ($P<0.001$) effect on sward clover content; it was greater in 2014 (0.27 g kg^{-1} DM) than in 2013 (0.23 g kg^{-1} DM). Frame and Newbould (1986) reported that sward clover content increased in the second production year. There was a significant treatment×week interaction ($P<0.05$) on daily MY and daily fat content. All treatments had a similar MY until experimental week 21 (July), after which the Cl250 and Cl150 treatment had greater daily MY compared to the Gr250 treatment until week 27, and thereafter in weeks, 30, 35 and 39 the clover treatments had greater MY than Gr250. The Cl150 treatment had greater fat content in experimental weeks 2, 4, 17, 20, 28 and 32. Treatment had an effect on cumulative MY and cumulative MS ($P<0.001$; Table 1). The Cl150 treatment had lower ($P<0.05$) cumulative MY compared to Cl250 (6,055 and 6,343 kg milk cow^{-1}, respectively); there was no significant difference between Cl150 and Gr250 (6,055 and 5,912 kg milk cow^{-1}, respectively); and Cl250 had greater ($P<0.001$) cumulative MY than Gr250 (6,343 and 5,912 kg milk cow^{-1}, respectively). Treatment had a significant effect on daily and cumulative MS. The MS yield of the clover treatments was greater ($P<0.001$) than the Gr250 (Table 1; Figure 1) and was similar between both clover treatments.

Table 1. Daily and cumulative milk production and cumulative herbage production on grass only swards receiving 250 kg N ha^{-1} (Gr250) and grass clover swards receiving 150 kg N ha^{-1} and 250 kg N ha^{-1} (Cl150 and Cl250, respectively) and average sward clover content on Cl150 and Cl250.

	Cl150	Cl250	Gr250	S.E.[1]	TRT	Year	Week	TRT[2] × week	TRT × year
Milk yield (kg^{-1} cow^{-1} day^{-1})	21.13	22.05	20.62	0.44	0.001	NS[3]	0.001	0.05	NS
Milk solids (kg^{-1} cow^{-1} day^{-1})	1.69	1.70	1.58	0.03	0.001	NS	0.001	NS	NS
Milk fat (%)	4.58	4.47	4.43	0.26	NS	NS	0.001	0.05	NS
Milk protein (%)	3.61	3.58	3.62	0.05	NS	NS	0.001	NS	NS
Cumulative milk yield kg^{-1} cow^{-1} year^{-1})	6,055	6,343	5,912	126	0.001	NS	-	-	-
Cumulative milk solids (kg^{-1} cow^{-1} year^{-1}	485	489	454	2.85	0.001	NS	-	-	-
Annual herbage production (kg DM ha^{-1})	14,355	14,317	14,233	434	NS	0.001	-	-	-
Clover content (g kg^{-1} DM)	0.27	0.24	-	0.02	NS	0.001	0.001	0.01	NS

[1] S.E. = standard error.

[2] TRT = treatment.

[3] NS=not significant.
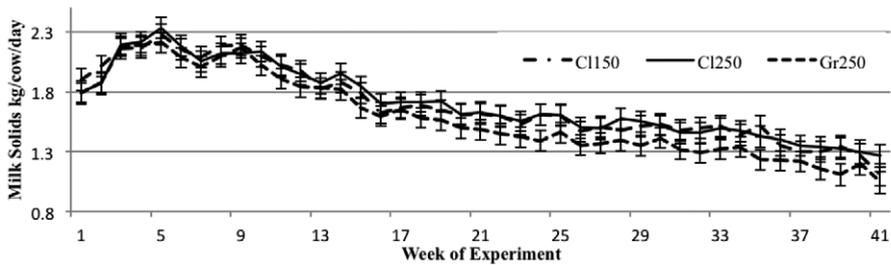
Figure 1. Effect of sward type on daily milk solids yield for cows grazing a grass-only sward receiving 250 kg N ha^{-1} (Gr250) and grass-clover swards receiving 150 kg N ha^{-1} and 250 kg N ha^{-1} (Cl150 and Cl250, respectively) for each week of experiment. Error Bars represent standard error.

Conclusions

Clover inclusion into PRG swards had no effect on the total herbage production. White clover had a positive effect on milk production (yield and solids) regardless of N fertiliser application rate in both production years. The greatest difference observed in both years was from July onwards when clover content was at its highest.

Acknowledgements

References

Davies, A. (1922) White clover. *Biologist* 39, 129-133.

Egan, M.J., Lynch, M.B. and Hennessy, D. (2013) The influence of white clover inclusion in perennial ryegrass swards on milk and herbage production in a high N fertiliser system. In: *Proceedings of the Agricultural Research Forum*, p. 81.

Harris, S.L., Clark D.A., Waugh, C.D and Clarkson, F.H. (1996) Nitrogen fertiliser effects on white clover in dairy pastures. In: *Agronomy Society of New Zealand Special Publication No. 11 / Grassland Research and Practice Series* No. 6, pp. 119-124.

Ledgard, S.F., (2001) Nitrogen cycling in low input legume-based agriculture, with emphasis on legume/grass pastures. *Plant and Soil* 228, 43-59.

Ledgard, S.F. and Steele, K.W. (1992) Biological nitrogen fixation in mixed legume/grass pastures. *Plant and Soil* 141, 137-153.

Riberio Filho H.M.N., Delagarde, R. and Peyraud, J.L. (2003) Inclusion of white clover in strip-grazed perennial ryegrass swards: herbage intake and milk yield of dairy cows at different ages of sward regrowth. *Animal Science* 77, 499-510.

Developing mixed farming systems at regional level: examples from intensive dairy farming

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Abstract

Improving agricultural sustainability through innovative mixed farming systems (MFS) is the scope of the EU project CANTOGETHER. MFS may refer to activities on a single farm and/or to cooperation between farms (e.g. animal and crop production). Combining agricultural production with biodiversity and environmental goals may also be involved. To design such systems, participatory methods were used. This paper discusses two regional case studies dominated by intensive dairy farming that aim to reduce N losses. The first case study concerns the region of Winterswijk (NL), where intensive dairy farming is combined with nature conservation areas to maintain an attractive landscape and improve water quality. In cooperation with the District Water Board, practices to reduce both N and P losses have been implemented. The second case study concerns the Lieue de Grève catchment (F), where dairy farmers aim to reduce nitrate leaching by implementing, at regional and farm levels, a set of systemic indicators for N inputs and stocking rates per ha of grassland. Here the aim is to guide production systems towards better agro-ecological performance. Reduction in farm losses have been scaled up to the regional level using simple calculations for the Winterswijk region and the CASIMOD'N model for the Lieue de Grève region. For the region of Winterswijk, application of the practices to all suitable fields would reduce potential losses of N by 123 Mg and of P_2O_5 by 72 Mg, amounting to 8-9% of the N applied in the area as manure and chemical fertilisers and 19-20% of the P_2O_5 applied. In the Lieue de Grève catchment, increasing the percentage of grassland in the agricultural area (by 25 percentage points) would maintain milk production and decrease nitrate-N losses by about 30% (-8 mg NO_3^- l^{-1}). Conditions for implementing changes at the regional level are mentioned.

Keywords: mixed farming systems, dairy farms, N and P losses, CASIMOD'N model

Introduction

Improving agricultural sustainability through innovative mixed farming systems (MFS) is the scope of the EU project CANTOGETHER (Crops and Animals Together). Innovations in MFS are targeted at improving nutrient use and reducing nutrient losses. We studied intensive dairy farms that aim to reduce N and/or P losses, working closely with regional stakeholders to preserve the landscape. The case studies are located in the region of Winterswijk (139 km^2, the Netherlands) and in the Lieue de Grève catchment (120 km^2, France; Moreau *et al.*, 2013). For the design of MFS in CANTOGETHER, use is made of a participatory method. For both regions, the type of integration is identified as 'territorial synergy' (Moraine *et al.,* 2014).

Materials and methods

For both case studies, MFS at the regional level may result from cooperation between stakeholders and consideration of regional characteristics (Figure 1). The Winterswijk region is characterised by a 'coulissen' landscape, a mosaic of agricultural lands, hedgerows and woodlots, dominated by intensive dairy farming. The area comprises 8,000 ha of agricultural area (AA). Most dairy farms in the region have been granted a derogation (till 2013 based on 70% grass and 30% maize in each farm's AA) that gives them higher manure-application limits. Thirteen dairy farms agreed to take measures to improve water
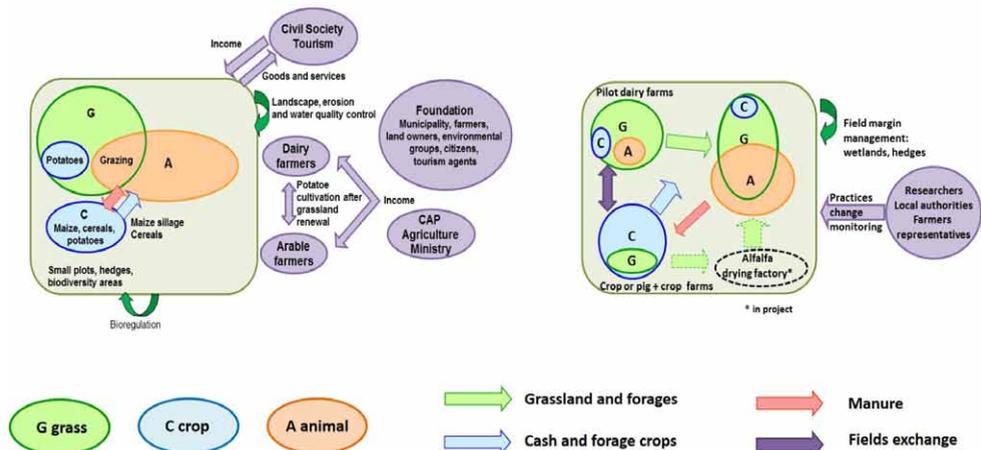
Figure 1. Regional development of mixed farming systems in the case studies Winterswijk (left) and Lieue de Grève (right).

quality. For each practice, the reductions in losses of N and P_2O_5 achieved were calculated from analyses of crop and soil samples. In workshops and telephone interviews, farmers were asked to evaluate the ease of implementation and economics of the practices. Using data on the area of each land use in the region and farmers' evaluations, potential reductions in N and P losses for the Winterswijk region as a whole was quantified (Den Boer and De Haas, 2013).

The Lieue de Grève catchment, 65% of which is AA, comprises 170 farmers, mostly dairy and/or beef producers (some specialized) who aim to reduce nitrate leaching drastically by implementing at the regional and, as far as possible, farm level, a set of co-built systemic indicators of N inputs and stocking rates per ha of grassland. The aim is to guide production systems towards better agro-ecological performance. A working group of stakeholders (1) worked with eight pilot dairy farms that modified their practices or production systems to implement the indicators, and (2) extrapolated the changes to all farms in the catchment with the CASIMOD'N model, which included farmers' main decision rules concerning land use and manure management (Moreau *et al.*, 2013).

Results and discussion

In the Winterswijk region, the farms implemented over 10 agricultural practices during a 2-year period. Application of the practices to all suitable fields in the region would reduce potential losses of N by 123 Mg and of P_2O_5 by 72 Mg. This amounts to 8-9% of the N applied in the area as manure and chemical fertilisers and 19-20% of the P_2O_5 applied. Promising practices for reducing N and P are 'application of manure in the row (maize)', 'no manure if soil P is high', and 'use of a nitrification retarder (with mineral fertiliser)'. The farmers identified the practices 'green crops' and 'raising pH' as economically attractive. They considered that not applying manure if soil P is high was not economically viable, since extra mineral P_2O_5 fertiliser would be required and farmers would have to pay for manure disposal.

In the Lieue de Grève catchment, two types of results were compared: (1) observed changes in farm practices and certain N fluxes in the eight pilot dairy farms between initial (2007) and final (2011-2013) states, and (2) predicted N fluxes at the catchment level if all cattle farmers achieved target values of indicators (stocking rate: ≤1.4 livestock units (LU) ha^{-1} grassland, N input: ≤100 kg N ha^{-1}). Most dairy farms in the catchment chose to maintain or increase milk production (from a mean of 370 to 430 Mg year^{-1} farm^{-1} for the eight pilot farms), became more grass-based, and decreased bull fattening and maize or cereal area. The percentage of grasslands increased from 53 and 54% of AA in pilot farms

and the catchment, respectively, to 65 and 68%. Mean values of indicators moved toward target values, decreasing for the pilot farms from 2.5 to 2.0 LU ha^{-1} grassland and from 91 to 68 kg N ha^{-1}. Simulating attainment of target values by all dairy farms at the catchment level predicted a strong decrease in nitrate concentration in water at the outlet (from 28 mg NO_3^- l^{-1} in 2007 to 20 in 2020), still far from the target value of 10 mg NO_3^- l^{-1}. Results also show that soil N balances of pilot farms were higher than the mean soil N balance predicted at the catchment level.

Conclusions

Intensive dairy farms that undertake practices to maintain landscape quality and improve water quality can be regarded as a specific type of MFS. The technical results of the case studies in Winterswijk and the Lieue de Grève catchment are promising. Adjusting the management of intensive dairy farms to maintain nature values and abiotic ecosystem boundaries of the regional landscape resulted in a wide range of practices. Some of these practices were economically viable, while others were not. Payments for specific ecosystem services, regionally devised by stakeholders, could stimulate farmers to implement these practices. For further development of the MFS studied, ecological intensification applied at the regional level is advocated. For this, networks for knowledge exchange and collective design and trials of innovative practices should be organized to move towards more integrated systems.

Acknowledgements

References

Den Boer D.J. and De Haas M.J.G. (2013) *Prospects for mixed farming systems and minimising N and P losses in the Winterswijk region* [Mogelijkheden gemengde bedrijfssystemen en beperken N- en P-verliezen in de regio Winterswijk]. Report 1425.N.12, Nutrient Management Institute, Wageningen, the Netherlands. For a summary in English, visit http://www.fp7cantogether.eu/publications.

Moraine M., Duru M., Nicholas P., Leterme P. and Therond O. (2014) Farming system design for innovative crop-livestock integration in Europe. *Animal* 8, 1204-1217.

Moreau P., Ruiz L., Vertès F., Baratte C., Delaby L., Faverdin P., Gascuel-Odoux C., Piquemal B., Ramat E., Salmon-Monviola J. and Durand P. (2013) CASIMOD'N: An agro-hydrological distributed model of catchment-scale nitrogen dynamics integrating farming system decisions. *Agricultural Systems* 118, 41-51.

Comparison of feeding time in barn and pasture under a given grass allowance in a system with robotic milking and strip grazing by using collected sensor data

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Abstract

In the Autograssmilk project funded by the EU-FP7 programme an experiment was conducted with the objective to study the potential of using new technologies for the optimisation and integration of automatic milking with cow grazing. Data were collected during the 2014 grazing season from a 60-cow herd. The herd was kept in the barn during the night (16:00-6:00) where 8.4 kg dry matter (DM) per cow per day of conserved forage was fed. During the day (6:00-16:00) the herd had access to a strip of grass with approximately 8 kg DM per cow per day. Cows were free to return to the barn for visiting the milking robot. Automatic milking-system visits and milk yields were collected per cow. The average milk yield was 26.1 kg milk per cow per day. Feeding time was measured with a sensor attached to the neck of each cow. The cows spent an average of 346 minutes per day for feeding/grazing. For forage fed in the barn, cows spent an average of 6.7 minutes feeding time per kg of milk, while for grazing 8.8 minutes per kg of milk was spent. Older cows were significantly more efficient than heifers in their feeding time in the barn, whereas for grazing the differences were smaller.

Keywords: grazing, sensor, feeding, milking robot

Introduction

Partly due to the increased use of automatic milking systems in the dairy sector of the EU, grazing of cows is decreasing (Van den Pol-van Dasselaar *et al.*, 2008). However, it is seen as desirable by both society and science that cows spend the summer in the pasture, as this increases animal health, improving, for example, hoof and leg condition (Autograssmilk, 2014). Additionally, cows can express normal behaviour on pasture which also increases their welfare. The EU-supported Autograssmilk project has the overall aim to stop the decline in grazing. For this purpose this project also pays attention to possibilities of new technologies on behalf of animal and grassland management when combining automatic milking and grazing. In this paper the main focus will be on feeding information collected with a commercial sensor; the objective is to study the effect of lactation number and lactation stage on feeding time and efficiency. If effects are clear, a next step could be the implementation of sensor techniques in daily grassland management.

Materials and methods

On the 'Dairy Campus' experimental farm in Leeuwarden, the Netherland, milking, feeding and grazing information was gathered for a herd of 60 cows. This herd was milked with a DeLaval automatic milking system located in a barn with cubicles, feeding fence and concentrates feeding station. The herd was kept in the barn during the night (16:00 till 6:00) and fed with 8.4 kg dry matter (DM) of conserved forage (mixture of 30% grass and 70% maize silage on DM basis) per cow per day. In the milking robot or in a concentrate feeding station located in the barn, cows received additional concentrates on an individual basis. The herd had access to a pasture between 6:00 and 16:00. Starting from 6:00, cows that were recently milked could leave the barn to graze. Cows in the pasture were free to return to the barn for visiting the milking robot, concentrate feeder or water trough. At 12:00, cows that not returned to the

barn voluntarily were then fetched. The cycle was repeated for an afternoon grazing session. Cows still in the pasture at 16:00 were fetched to the barn.

In the pasture a strip of grass was made available for grazing twice a day (in the morning and afternoon). The size of the strips was attuned to the grass height and the number of cows so that about 8 kg of DM were available per cow and per day.

Individual cow data regarding milk production (yield and frequency) were collected at the automatic milking system. Feeding information was collected by a sensor (Nedap, 2014) on the neck of each animal. The sensor determines feeding (grazing) time in 15-min periods.

Milking and feeding data collected during the experiment were summarized for further processing in terms of average values per cow and per week of lactation. For analysing the feeding efficiency, feeding time was expressed in minutes per kg of produced milk. Data originate from a total of 68 cows (22 in 1st, 17 in 2nd and 29 in 3rd or higher lactation) and 657 weeks of lactation (approximately 10 weeks of lactation per cow). The effects of the fixed interaction terms 'lactation number' and 'lactation stage' on milk and feeding parameters were analysed by the REML algorithm using GenStat® Release 13 (Payne *et al.,* 2013). Cow number and week of year were used as random model terms.

Results and discussion

The predicted mean milk yield was 26.1 (standard error (s.e.) 0.90) kg per cow per day. As could be expected, milk yields differed between lactation numbers and lactation stages (Table 1). In automatic milking, daily milking frequencies could potentially affect milk yields. In this research milking frequencies did not differ between lactation numbers. Nevertheless, milking frequencies were, across all lactation numbers, significantly lower with advancing lactation stage. The predicted mean for total feeding time was 346 (s.e. 9.2) minutes per cow per day; for feeding time during the day (grazing) and feeding time during the night (in the barn) these figures were respectively 198 (s.e. 6.7) and 149 (s.e. 5.2) minutes per cow per day. Table 1 shows that total feeding time and feeding time at night in the barn were in general significantly shorter for older cows (in 3rd or higher lactation). The effects of lactation stage on total feeding time were small. Differences in grazing times (pasture) between lactation stages and lactation numbers were even smaller.

On average, cows needed 15.5 (se. 0.70) minutes feeding time per kg of milk. In the barn where conserved forages were fed, cows spent, on average, 6.7 minutes feeding time per kg of milk, while for grazing they spent 8.8 minutes per kg of milk. In all the lactation stages the older cows (3rd or higher lactation) were significantly more efficient than younger cows. Differences in feeding time per kg of milk between heifers and older cows were larger in the barn, where a silage mixture was fed, than with grazing in the pasture. In the barn the feeding time per kg of milk for the older cows was about 50% of the heifer feeding time; in the pasture the grazing time for the older cows amounted 60% of the heifer grazing time.

Conclusions

Especially for the high yielding dairy cows, grazing requires greater effort to provide sufficient feed for a high production. This research demonstrated that it is easier for the cows to consume food at the feeding gate rather than gathering their feed by grazing. In grazing, cows needed about 30% more time for feeding.

Table 1. Predicted means for effects of lactation number and lactation stage on feeding and milking parameters of cows in a strip-grazing regime.

Parameter	Lactation number[1]	Lactation stage (d)[2]		
		<100	100-200	200-300
Milk yield (kg per day)	1st	22.3[A]	21.3[A]	20.1[A]
	2nd	28.6[Ba]	27.0[Ba]	23.54[Ab]
	3rd or higher	32.8[Ca]	30.2[Bb]	29.4[Bb]
Total feeding time (minutes per day)	1st	348[Aa]	361[Aab]	373[Ab]
	2nd	359[A]	371[A]	365[AB]
	3rd or higher	298[Ba]	306[Ba]	336[Bb]
Feeding time day (grazing) (minutes per day)	1st	186[a]	193[ABab]	212[b]
	2nd	195	216[A]	215
	3rd or higher	177[a]	184[Ba]	203[b]
Feeding time night (barn) (minutes per day)	1st	163[A]	169[A]	163[A]
	2nd	161[A]	157[A]	152[AB]
	3rd or higher	122[Ba]	122[Ba]	134[Bb]
Total feeding time per kg milk (minutes per day)	1st	16.37[Aa]	19.89[Ab]	23.09[Ac]
	2nd	13.24[Aa]	13.81[Ba]	20.42[Ab]
	3rd or higher	9.45[Ba]	10.65[Ca]	12.52[Ba]
Feeding time day per kg milk (minutes per kg)	1st	8.80[Aa]	10.69[Ab]	13.09[Ac]
	2nd	7.25[ABa]	7.85[Ba]	12.17[Ab]
	3rd or higher	5.57[Ba]	6.30[Bb]	7.46[Bb]
Feeding time night per kg milk (minutes per kg)	1st	7.58[Aa]	9.14[Ab]	9.95[Ab]
	2nd	5.95[Ba]	6.00[Ba]	8.20[Bb]
	3rd or higher	3.91[Ca]	4.30[Ca]	4.94[Cb]

[1] Different uppercase letters within the same parameter column mean a significant difference ($P<0.05$).

[2] Different lowercase letters within the same parameter row mean a significant difference ($P<0.05$).

Acknowledgements

References

AUTOGRASSMILK (2014) Project homepage. Available at: http://www.autograssmilk.eu/Start.htm.

NEDAP (2014) Homepage. Available at: http://tinyurl.com/nva8u8x.

Payne R., Welham, S. and Harding, S. (2013) A guide to REML in GenStat® (16th edition). VSN International, Hemel Hempstead, UK.

Van den Pol-van Dasselaar A., Vellinga T.V., Johansen A. and Kennedy E. (2008) To graze or not to graze, that's the question. *Grassland Science in Europe* 13, 706-716.

Milk production in relation to farm organization

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Abstract

In recent years, dairy production has been considered to be the most profitable farming activity in Poland. This study focuses on a sample of 40 randomly selected dairy farms from the north-eastern part of the Lublin province and compares their technical results. The research was completed in 2012 with a questionnaire containing 18 questions sent to the farm managers. The farms were classified into five production groups according to their annual milk sales. The largest research group accounted for 37.5% of farms; this group produced 100-250,000 litres of milk, with the average of 47 ha and the average number of 30 cows. A large share of permanent grassland as a proportion of the agricultural area, and high stocking density on grasslands in the north-eastern Lublin province, indicate a change in the direction of grassland management.

Keywords: milk production, farm, barn type

Introduction

Poland is a country with a large number of dairy farms. The main source of success in this type of production is the right organization and management (Jankowski *et al.*, 2013). The effectiveness of milk production depends primarily on the direct costs and the milk-selling price. In addition, high dairy production results in the use of modern feeding systems (Jankowski *et al.,* 2014; Sosnowski *et al.*, 2014). The aim of this study is to evaluate the organization and management of dairy farms in relation to the production volume.

Materials and methods

The study was conducted in 40 farms located in the Lublin region in 2012. The farm owners answered a questionnaire containing 15 questions. The research subject was the volume of milk production per farm, the farm size and the available resources. Based on the average annual milk production per farm, the sample was divided into five groups: (1) producing less than 50,000 litres (15% of farms); (2) 50-100,000 litres (22.5%); (3) 100-250,000 litres (37.5%); (4) 250-500,000 litres (12.5%); and (5) above 500,000 litres (12.5%).

Results

In the studied farms, the average agricultural and grassland areas increased with the increase in milk production (Table 1). In the feeding of dairy cows, fodders produced on permanent grassland were essential. On farms that produced up to 250,000 litres of milk the grazing system was only used, while on those with more than 250,000 litres of milk the cow-shed feeding system was mainly applied.

Stalls for cows (Table 2) in the studied dairy farms were not fully utilized; therefore, there was a possibility of increasing the number of cattle and milk production. It was observed that with the increase in annual milk sales, the number of stalls used also increased. Some stalls were not fully used so as not to exceed milk quotas. In all farms with up to 250,000 litres of milk, the barns were in a good condition (Table 3) while farms with annual sales of over 250,000 litres of milk had a barn in a very good condition; these

Table 1. Relationship between the farm and grassland area and the annual sales of milk.

Specification	Annual sales of milk in thousand litres				
	<50	50-100	100-250	250-500	Above 500
Average agricultural area of farm (ha)	24	33	47	74	102
Average area of grassland (ha)	10	13	23	27	50

Table 2. Relationship between the number of cows and the annual sales of milk.

Specification	Annual sales of milk in thousand litres				
	To<50	50-100	100-250	250-500	Above 500
Average number of stalls used	17	23	30	57	86
Average number of unused stalls	2	4	10	20	32
Stocking density (LU per 100 ha of grassland)	170	177	130	211	172

Table 3. Number of farms in relation to the cowshed state and the annual sales of milk.

Cowshed state	Annual sales of milk in thousand litres				
	<50	50-100	100-250	250-500	Above 500
Very good	0	0	3	4	5
Good	6	9	12	1	0

were newly built and automated barns. Farms with a smaller milk production did not have modern and large cowsheds. The number of supporting buildings increased with the increase of milk production.

In the bigger farms the number of existing silage silos and slurry tanks increased (Table 4). The predominant type of barn in the studied farms is the tie-up type on shallow litter (Table 5). Farms with different amounts of annual milk sales had different types of barn. In large barns technical installations were operated by different automatic devices. In farms with up to 50,000 litres of milk all milking was done at a bucket parlour (Table 6). In farms in the range 250-500,000 litres of milk and above 500,000 litres of milk milking machines, such as 'herringbone' parlour were used (Table 6).

Conclusions

Large dairy farms have unoccupied stalls, which indicates a possibility for increasing the milk production. Milk production is dependent on many factors, including the herd size and the milk yield per cow. Most farmers benefit from European funds, enabling farms to modernize with new equipment. Grasslands provide roughage, such as hay, silage or haylage, but do not supply all the nutritional needs of the animals.

Table 4. Additional buildings in farms in relation to the annual sales of milk.

Additional buildings	Annual sales of milk in thousand litres				
	<50	50-100	100-250	250-500	Above 500
Tank for liquid manure	6	8	14	3	1
Slurry tank	0	1	2	3	4
Farmyard manure plate	6	9	13	5	5
Silage/grain silo	1	1	5	4	5

Table 5. Number of farms in relation to barn functional type and annual sales of milk.

Barn type	Annual sales of milk in thousand litres				
	<50	50-100	100-250	250-500	Above 500
Tie-up cowhouse	6	9	11	2	0
Box cowshed	0	0	0	1	1
Free-stalls	0	0	4	2	4
Litterless	0	0	1	2	4
Shallow litter	6	9	13	3	1
Deep litter	0	0	1	0	0

Table 6. Number of farms in relation to the milking type and the annual sales of milk.

Milking system	Annual sales of milk in thousand litres				
	<50	50-100	100-250	250-500	Above 500
Wired	0	3	13	2	0
Bucket parlour	6	6	1	0	0
Herringbone parlour	0	0	1	3	5

Therefore, in all dairy farms maize for silage is grown. Crop production provides the basic feed for animal, so farmers increasingly try to intensify it.

References

Jankowski K., Kolczarek R., Jankowska J. and Sosnowski J. (2013) The strategies of grassland management in farms of northeastern part of Poland. *Journal of Life Sciences* 7(7), 727-731.

Jankowski K., Sosnowski J., Wiśniewska-Kadżajan B. and Kolczarek R. (2014) Milk production and profitability in relation to size of grassland farms. *Grassland Science in Europe* 19, 411-413.

Sosnowski J., Jankowski K., Truba M., Kaczorek A., Król J., Romańczuk T. and Kolczarek R. (2014) Economical analysis of milk production in the farms of Siedlce Region. *Journal of Life Sciences* 8(7), 626-631.

Current state of the feeding systems on dairy farms in the Principality of Asturias (Spain)

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Abstract

Nowadays, a wide range of dairy farms coexist: from family farms to large-scale dairy farms. In order to determine the feeding systems of the dairy farms in Asturias (Spain), a sample of close to 2% of the total number of dairy farms (2,446) was randomly selected and surveyed. Farms were stratified according to their milk quota into four groups: <175, 175-325, 325-500 and >500 Mg year^{-1}. Milk yields in each group were 6,120, 7,525, 7,997 and 9,537 kg cow^{-1} per lactation, respectively ($P<0.05$). The 54.5% of the cows in smaller farms use grazing, while this percentage decreases to 7.1% in the larger farms. The preserved forage used is different between groups. Maize silage is more frequently used on large farms (0, 41.2, 80 and 100%, respectively), while the use of grass silage is higher in smaller farms (100, 76.5, 70 and 64.3%, respectively). In conclusion, feeding systems are influenced by the size of the farms. The use of grazing is associated primarily with the smaller farms (less than 175 Mg milk year^{-1}), whereas maize silage has become the main part of the diet on larger farms (more than 325 Mg milk year^{-1}).

Keywords: dairy cow, feeding systems, silage, grazing

Introduction

In recent decades, the dairy sector has shown a global tendency toward an increase in the number of dairy cows per hectare. This has resulted in the current situation, in which there are a wide variety of dairy farms, ranging from family farms to large and technologically advanced farms, each with different levels of intensification. Milk production in the North of Spain is based on an increased use of concentrates in the diet and in the number of dairy cows per farm (Alvarez *et al.*, 2008). This tendency also causes the adoption of new technologies, such as silage (specifically maize silage), use of a mixer wagon to prepare diets, automatic milking, etc. In addition, pasture-based systems allow farmers to produce milk with lower average costs than high-input systems (Soder and Rotz, 2001). The aim of this study was to describe the feeding systems that coexist on dairy farms in the Principality of Asturias (Spain), classified according milk quota levels.

Materials and methods

According to official data, there are currently 2,446 dairy farms in the Principality of Asturias. For this study, farms were classified depending on their milk quota, and were distributed into four groups: (1) lesser than 175 Mg year^{-1}; (2) between 175 and 325 Mg; 3) from 325 to 500 Mg; and (4) more than 500 Mg year^{-1} (layers 1, 2, 3 and 4, respectively). A sample close to 2% of the total dairy farms was randomly established. Thus, there were 11 farms in layer 1, 17 farms in layer 2, 10 farms belonged to layer 3 and 14 farms in layer 4. A survey was compiled to obtain data about the characteristics of the selected farms. This survey was structured in the following blocks: (a) farm identification; (b) herd composition; (c) milk production; (d) usable agricultural area; (e) feeding management; (f) farmer labour and educational level; and (g) cows' reproductive status. This work is focused on the point 'e', which collects data about the feeding systems of dairy farms, such as grazing or no grazing, grazing season, time spent grazing per day, arable land surface and annual forage crops, type of preserved forages, kind of silages (ditch, trench, tower, round bale, etc.), amount of feed brought from outside the farm, and methods used to make the ration (with a mixer wagon or not). Surveys were conducted through personal interviews. Visits to farms

began on 3 December 2013 and 52 surveys were completed by 11 March 2014. Means were calculated for each of the four layers. Differences in milk production between groups were examined using the GLM proc (SAS, 1999).

Results and discussion

The average number of cows per herd in each layer was higher as the volume of quota increased. Farms in layer 1 had 18 cows, farms belonging to layer 2 had 34 cows, and layers 3 and 4 had 54 and 99 cows on average, respectively. Layer 1 presented the lowest level of milk yield per cow and per lactation, with 6,120 kg cow^{-1} (P<0.05). The following layers were progressively increasing their milk yield levels per lactation: layer 2 presented 7,525 kg cow^{-1}, layer 3 had 7,997 kg cow^{-1} and layer 4 reached the highest level of milk production, with 9,537 kg cow^{-1} (P<0.05). The cultivated area was 13.7 ha in farms of layer 1; 20.4 ha in layer 2; increasing to 27.8 ha in layer 3 and 52.8 ha in layer 4. However, the size of the farm was inversely related to grazing practice. Thus, the 54.5% of smaller farms (which belonged to layer 1) used grazing. By contrast, the proportion of farms that used grazing decreased as the farms became larger. In this way, the proportions of farms that grazed were 29.4% and 30% in layers 2 and 3, respectively. The lowest use of grazing was found in layer 4, where the percentage of farms that grazed was only 7.1%. Grazing takes place mainly in spring, summer and autumn, with an average of 9.9 hours per day spent grazing. In winter, cows were grazing for only 3.4 hours. When zero-grazing is considered, the percentage of farms that offer fresh grass in the stable reached 72.7% in layer 1, but it decreased to 58.8%, 30% and 14.3% in layers 2, 3 and 4 respectively.

The most common forage rotation (including two crops by year) was maize forage in summer and ryegrass (Italian or hybrid) in winter. Therefore, maize silage was the most frequently preserved forage used to feed dairy cows on the largest farms, with 100% of them using it. The proportion of farms that used maize silage in layer 3 was 80%, and in layer 2 it was 41.2%; finally, the smallest farms did not use maize silage for their milking cows. By contrast, smaller farms more frequently used grass silage to feed dairy cows. In this sense, all farms (100%) belonging to layer 1 used grass silage. This percentage decreased gradually in the following layers, from 76.5% for layer 2, 70% for layer 3, and to 64.3% for layer 4. The maize silage is mostly made on platform or trench silos, while the traditional form for grass silage is in round bales due to the ease of use and for transport between paddocks. The use of mixer-wagon for preparing the ration was more widespread on larger farms, of which 92.9% used it, whereas no small farm (layer 1) used a mixer wagon. The proportions of farms that used a mixer wagon in layers 2 and 3 were 35.3% and 60%, respectively.

Conclusions

The dairy farms in the Principality of Asturias (Spain) have different feeding systems according to their milk quota. Maize silage has become the mainstay of the diet on larger farms (those with more than 325 Mg milk year^{-1}), whereas grazing is associated primarily with smaller farms (less than 175 Mg milk year^{-1}).

Acknowledgements

References

Alvarez A., Del Corral J., Solís D. and Pérez J.A. (2008) Does intensification improve the economic efficiency of dairy farms? *Journal of Dairy Science* 91, 3693-3698.

SAS (1999) *SAS User's guide.* SAS Institute. Carry, NC, USA, 378 pp.

Soder K.J. and Rotz C.A. (2001) Economic and environmental impact of four levels of concentrate supplementation in grazing dairy herds. *Journal of Dairy Science* 84, 2560-2572.

The behaviour and production of dairy cattle when offered green pasture or exercise pen

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Abstract

The aim of the experiment was to investigate the activity and behaviour of dairy cows with access to different outdoor areas. The study took place on two commercial farms with loose-housing and automatic milking systems (AMS). One farm offered 2.8 hectares of green pasture and the other offered a 0.7-hectare exercise pen. Sixty-six percent of the cows with access to green pasture went outside whenever possible. More activity was observed on 'pasture-days'. Most observations were spent grazing (72.2%). Milk yield was, however, lower ($P<0.01$) and number of visits to the AMS fewer ($P<0.001$), on days with access to pasture. In the farm with access to an exercise area, only 31% of the cows went outside when possible. Most of the observations were standing/walking with head up (43.2%) and lying (33.2%). The number of cows outside was mainly controlled by the indoor feeding interval. Access to the exercise pen did not affect the daily milk yield, but resulted in an increase in number of milking visits ($P=0.005$). In conclusion, access to outdoor areas, preferably pasture, is important for dairy cows and may have a positive effect on animal welfare and their ability to practice natural behaviour.

Keywords: behaviour, milk yield, weather factors, animal welfare

Introduction

Norway has experienced major structural changes in its dairy production and the country now has the highest number of dairy barns with AMS in Scandinavia. One consequence of this seems to be reduced grazing and pasture access for the cows. Van den Pol-van Dasselaar *et al.* (2008) found less use of grazing on farms with AMS than on farms with other milking systems, and farmers claim that the milk production and number of visits to the AMS will be reduced if pasture is offered. Previous research has shown that cows are reluctant to leave an attractive pasture field to be milked (Ketelaar-de Lauwere *et al.*, 1999) but this also emphasizes the fact that access to green grass is positive for animal welfare. Norwegian animal welfare legislations now demand that all dairy cows, regardless of housing-system, are offered access to pasture for a minimum of eight weeks during summer (LMD, 2004). Some farmers consider using exercise enclosures as an alternative to pasture due to a lack of suitable pastures. The regulations permit this, when pasture is unavailable. Current knowledge on the behavioural effects of pasture vs exercise enclosures is, however, limited. The aim of this study was to investigate behaviour and activity of dairy cows offered different outdoor areas, on two commercial farms with AMS located indoors.

Materials and methods

The pilot study was performed in two commercial dairy farms with loose housing and AMS on the coast of Helgeland (65°N) in Norway during the summer of 2013. Farm 1 had a herd of 50 dairy cows and a DeLaval milking robot (DeLaval, Tumba, Sweden) with controlled cow traffic. A 2.8-ha field with green pasture was offered, just outside the barn. All cows were allowed access to the pasture, using strip grazing, after the first harvest, for a total of 33 days (8 July to 26 August) between 9:00 am and 16:00 pm on days without precipitation (<3 mm day^{-1}). Farm 2 had a herd of 50 dairy cows and a Lely milking robot (Lely Holding, Maassluis, the Netherlands) with free cow traffic. The cows were offered an exercise enclosure of 0.74 ha in a small forest in connection with the building. Cows had access to the outdoor area the whole day for 15 days (from 12-27 August), except on rainy days. Both farms had Norwegian Red (NRF) dairy

cattle, and offered the normal feed ration (grass silage and a commercial concentrate) indoors during the experimental periods. Water was only available indoors.

At both farms, a present observer performed direct observations of the cows when outdoors. Each observation period lasted 90 minutes. We performed 28 observation periods at farm 1 and 6 observation periods at farm 2. The total number of cows outdoors and the number of cows performing each of seven pre-defined behaviour categories were registered. Observations were done between 9 am and 4 pm, using instantaneous sampling in two minutes intervals for a minimum of 90 minutes per day. Mutually exclusive behaviour categories were defined. Focal animals were fitted with activity loggers. Weather factors were recorded and later categorized according to air temperature, wind speed and direction and precipitation. Production data from the AMS units were gathered from both farms from seven days with access, and seven days without access to the outdoor area. A Generalized Linear Model (GLM) was applied to test effects on number of cows outdoors and pre-defined behaviours. The following class variables were utilized; 'weather category' (1-5) and 'number of days since outdoor access' (1 = first day out this year, 2 = three to five days since outdoors due to bad weather; 3 = the cows were outdoors the day before). The latter variable was specified as a random effect in the model. Differences between means were analysed using a Tukey-Kramer test. The effect of access to outdoor area on cow activity, milking frequency and milk yield was tested using paired T-tests for data on same individuals over seven selected days with, and seven days without access to outdoor areas.

Results and discussion

Farm 1 with pasture: the cows went outdoors whenever possible. On average, 66% of the cows were located outdoors at any given time during each observational period. The weather conditions did, however, influence the duration of the outdoor visits. On days with warm (15-20 °C), sunny weather or rain/drizzle, significantly fewer cows (23.6±0.3) were found outdoors than in partly cloudy weather and 10-15 °C (30.2±0.35; $P<0.05$). With access to pasture the cows were more active, spending 80.4±2.6% of their time in an upright position vs 36.8±2.9% on days without access to pasture ($P<0.05$). The most common behaviour on pasture was grazing (72.2±0.4% of total observations), and lying behaviour (4.7±0.2%) was observed much less than in farm 2 (33.2±1.3%).

In this study, cows with access to green pasture reduced their mean daily milk yield with 0.8 kg milk day^{-1} on 'pasture days' (Figure 1), and number of visits to the AMS were reduced from 2.7 when indoors to 2.5 ($P<0.001$), on days with access to pasture.

Farm 2 with exercise enclosure: only 31% of the cows went outside when possible, and the number of cows outdoors and outdoor behaviour was not sensitive to weather conditions. This was probably due to
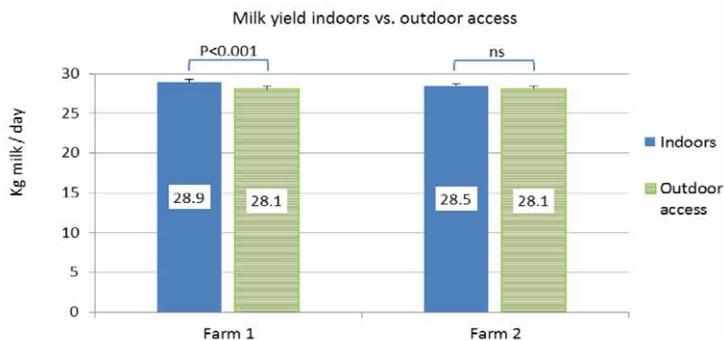
Figure 1. Mean individual milk yield in two farms, with and without access to outdoor areas.

a low number of observations at this location. The cows returned to the barn as soon as they heard the automatic feeder start to administer fresh roughage. Access to the exercise pen did not affect the daily milk yield (Figure 1), but resulted in an increase in number of visits to the AMS from 2.9 to 3.1 visits per day (P=0.005). Even though cows at farm 2 got all their feed indoors and they only had access to a small forest area, grazing/eating constituted 18.3±1.1% of the observations.

All forms of outdoor access and exercise are considered positive for health and behaviour in dairy cows (Krohn, 1994; Boyle *et al.*, 2008). Studies have shown that it is possible to maintain and even increase milk yield on pasture but it requires high quality pastures combined with optimal management, grass-species and number of animals per hectare (e.g. Sairanen *et al.*, 2006). By introducing rotational or strip grazing it might be possible to provide sufficient AMS visits (Lyons *et al.*, 2013).

Conclusions

A reduction in daily milk yield was found when cows were offered green pasture, compared to when only kept indoors. This effect may, however, be counteracted by optimal pasture management and cow traffic control through the AMS.

References

Boyle L.A., Boyle R.M and French P. (2008) Welfare and performance of yearling dairy heifers out-wintered on a wood-chip pad or housed indoors on two levels of nutrition. *Animal* 2, 769-778.

Ketelaar-de Lauwere C.C., Ipema A.H., Van Ouwerkerk E.N.J., Hendriks M.M.W.B., Metz J.H.M., Noordhuizen, J.P.T.M. and Schouten W.G.P. (1999) Voluntary automatic milking in combination with grazing of dairy cows. Milking frequency and effects of behaviour. *Applied Animal Behaviour Science* 64, 91-109.

Krohn C.C. (1994) Behaviour of dairy cows kept in extensive (loose housing/pasture) or intensive (tie stall) environments. III. Grooming, exploration and abnormal behaviour. *Applied Animal Behaviour Science* 42, 73-86.

LMD (2004) FOR 2004-04-22-665. Forskrift om hold av storfe. Landbruks og matdepartementet 2004. [in Norwegian]. Available at: http://lovdata.no/dokument/SF/forskrift/2004-04-22-665.

Lyons N.A., Kerrisk K.L and Garcia S.C. (2013) Comparison of 2 systems of pasture allocation on milking intervals and total daily milk yield of dairy cows in a pasture-based automatic milking system. *Journal of Dairy Science* 96, 4494-4504.

Sairanen A., Khalili H., Virkajarvi P. and Hakosalo, J. (2006) Comparison of part-time grazing and indoor silage on milk production. *Agricultural and Food Science* 15, 280-292.

Van den Pol-van Dasselaar A., Vellinga Th.V., Johansen A. and Kennedy, E. (2008) To graze or not to graze, that's the question. In: Hopkins A., Gustafsson T., Bertilsson J., Dalin N., Nilsdotter-Linde G. and Spörndly E. (eds.) *Biodiversity and animal feed – future challenges for grassland production*. Proceedings of the 22nd General Meeting of the European Grassland Federation, SLU, Uppsala, Sweden, 9-12 June, 2008, page 131.

Duration is important in the effect of pasture allowance restriction on subsequent milk production, in early lactation

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Abstract

In pasture-based dairy systems, feed supply can be limited in early spring due to inadequate pasture growth. The objective of this experiment was to investigate if different pasture allowances offered to early lactation grazing dairy cows, for different durations, influenced milk production. Cows were offered one of four pasture allowances (60, 80, 100 or 120% of intake capacity) for either 2 or 6 weeks. Once the 2- and 6-week time durations had elapsed, the cows in all treatments were offered 100% of intake capacity. At the end of the first 2 weeks of the experiment, milk yield was significantly different between all four allowances (18.5, 19.8, 21.4 and 23.1 kg cow^{-1} day^{-1} for 60, 80, 100 and 120% treatments, respectively). During weeks 7-10 there were no differences in milk yield between the 2-week treatments (23.5 kg cow^{-1} day^{-1}). Milk yield of the 60×6 treatment was lower than the 100×6 and 120×6 treatments, but was similar to the 80×6 treatment. The 80×6 treatment was similar to the 100×6 treatment, but different to the 120×6 treatment. The 100×6 and 120×6 treatments were similar to each other. This indicates that differences in pasture allowance imposed for a 6-week period affected subsequent production and the data suggest that in early lactation the effect of pasture allowance on milk yield depends on the amplitude and the duration of the treatment application.

Keywords: pasture allowance, early lactation, dairy cow

Introduction

There is little grass growth over winter in Ireland (Hurtado-Uria *et al.*, 2013), which may result in limited feed supply during early spring in intensive grazing systems. In the post-quota era, increased herd sizes and stocking rates on farms may further deplete the availability of grass in spring. Restricting pasture allowance (PA), by altering post-grazing height, for a ten-week period in early lactation has previously been shown to reduce immediate milk production but cumulative milk production was unaffected (Ganche *et al.*, 2013) as the amplitude and the duration of the restriction were not overly severe. The objective of this experiment was to investigate if different PA, offered for varying time durations to grazing dairy cows during early lactation influenced milk production.

Materials and methods

96 dairy cows (41 primiparous and 55 multiparous) were assigned to a randomised complete block design with a 4×2 factorial arrangement of treatments from 25 March to 27 November 2014. Cows were balanced on calving date (17 February, standard deviation (s.d.) 15.5 d), breed (Holstein-Friesian, n=52; Jersey × Holstein-Friesian, n=38; Norwegian Red, n=6), lactation number (2.4, s.d. 1.61) and production variables from the two weeks prior to the start of the experiment: milk yield (22.6, s.d. 4.20 kg d^{-1}), milk fat (55.8, s.d. 9.18 g kg^{-1}), milk protein (34.5, s.d. 3.00 g kg^{-1}) and milk lactose (46.9, s.d. 1.87 g kg^{-1}) concentrations, milk solids yield (2.03, s.d. 0.408 kg d^{-1}), bodyweight (BW; 469, s.d. 68.2 kg) and body condition score (BCS; 3.09, s.d. 0.193). Cows were then randomly assigned to one of four PA (60, 80, 100 or 120% of intake capacity; IC) for either 2 or 6 weeks. Once the 2- and 6-week time durations had elapsed, the cows in all treatments were offered 100% of their IC. Intake capacity was calculated using the equation of Faverdin *et al.* (2011) based on age, parity, days in milk, BW, BCS and potential milk

yield. Fresh pasture areas were offered after each milking while treatments were being imposed and on a 24-hour basis thereafter. Pre- and post-grazing sward heights were measured daily using a rising plate meter (diameter 355 mm and 3.2 kg m^{-2}; Jenquip, Fielding, New-Zealand). Herbage mass (HM; >3.5 cm) was measured twice weekly by cutting 6 strips (120 m^2) per grazing area. Pasture allowance (>3.5 cm) for the 60, 80 and 120% treatments were calculated based on the IC of the 100%×6 weeks treatment. As HM was similar between treatments daily area allocations were different between treatments. Milk yield was recorded daily and milk composition was measured weekly. Data were analysed using covariate analysis and mixed models in SAS v9.3. Terms for parity, breed, allowance, duration and the interaction of allowance and duration were included. Pre-experimental values were used as covariates in the model.

Results and discussion

The mean PA for the 60, 80, 100 and 120% treatments for weeks 1 and 2 were 8.1, 10.7, 13.4 and 16.0 kg DM cow^{-1} day^{-1}, respectively (P<0.001). This resulted in post-grazing heights (PGH) of 2.6, 3.1, 3.7 and 4.2 cm, respectively (P<0.001). The mean PA and PGH during weeks 3-6 were 8.7, 11.6, 14.4, 17.5 kg DM cow^{-1} day^{-1} and 2.8, 3.3, 3.9, 4.3 cm for the 60, 80, 100 and 120% 6-week treatments. Pasture allowance and PGH for the 2-week treatment, which was grazed as a single herd during weeks 3-6, were 14.3 kg DM ha^{-1} and 3.8 cm, respectively.

During the first two weeks of the experiment the effect on milk yield of offering different PA was evident as all treatments were different to each other (P<0.001). The 60% cows had the lowest milk yield (18.5 kg cow^{-1} day^{-1}), while the 120% cows had the highest milk yield (23.1 kg cow^{-1} day^{-1}). The 80% and 100% were intermediate but different to the other two treatments and to each other (19.8 and 21.4 kg cow^{-1} day^{-1}, respectively).

There was a significant effect of the interaction between PA and duration on milk yield during weeks 3-6 (P<0.001) and weeks 7-10 (P<0.01; Table 1). Average milk yield during weeks 3-6 was similar for the 2-week treatments (22.3 kg cow^{-1} day^{-1}) indicating no carryover effect of PA. The 60×6 and 80×6 treatments were similar but lower than the 100×6 and 120×6 treatments, as expected because PA treatments were still being imposed. The 100×6 and 120×6 treatments also differed significantly from each other. During weeks 7-10 there were no differences in milk yield between the 2-week treatments (23.5 kg cow^{-1} day^{-1}). Milk yield of the 60×6 treatment was lower than the 100×6 and 120×6 treatments but was similar to the 80×6 treatment. The 80×6 treatment was similar to the 100×6 treatment but different to the 120x6 treatment. The 100×6 and 120×6 treatments were similar to each other. These effects indicated that differences in PA imposed for a 6-week period affected subsequent production. This carryover effect was not observed when treatments were applied for 2 weeks.

The four 2-week treatments had a similar cumulative 10-week milk yield (1,482 kg cow^{-1}), but cows offered 60% of IC for 6 weeks had a reduced cumulative 10-week milk yield compared with those offered 100 or 120% of IC for 6 weeks. The 80×6 treatment, while similar to the 100×6 treatment, was lower than the 120×6 treatment. Cows offered 100 or 120% of IC for 6 weeks in early lactation also had similar cumulative 10-week milk yield.

Table 1. Milk yield of early lactation dairy cows offered 1 of 4 pasture allowances for either 2 or 6 weeks.[1,2]

	60×2	80×2	100×2	120×2	60×6	80×6	100×6	120×6	SED	PA	D	PA × D
Wk 3-6 (kg day^{-1})	22.2[a]	22.6[ac]	21.8[a]	22.8[ac]	18.7[b]	19.4[b]	22.1[a]	24.3[c]	0.99	0.001	0.019	0.001
Wk 7-10 (kg day^{-1})	24.1[ac]	24.5[ac]	22.2[ab]	23.1[ac]	20.2[b]	22.2[ab]	23.2[ac]	25.6[c]	1.25	0.118	0.305	0.003
Wk 1-10 (kg)	1,463[ac]	1,509[ac]	1,444[ab]	1,512[ac]	1,265[b]	1,342[ab]	1,472[ac]	1,617[c]	65.0	0.001	0.088	0.005

[1] Pasture allowances (PA) 60, 80, 100 or 120% of intake capacity; D = duration; SED = standard error of the difference; Wk = week.

[2] 60×2; 60% of intake capacity for 2 weeks (intake capacity × duration for all treatments).

Conclusions

In early lactation, milk yield recovers immediately after short-term (i.e. 2-week) PA restrictions. Restricting PA for a 6-week period can, however, affect cumulative milk yield for at least 4 weeks after the restriction is removed.

Acknowledgements

References

Faverdin P., Baratte C., Delagarde R., and Peyraud J.L. (2011) GrazeIn: a model of herbage intake and milk production for grazing dairy cows. 1. Prediction of intake capacity, voluntary intake and milk production during lactation. *Grass and Forage Science* 66, 29-44.

Ganche E., Delaby L., O'Donovan M., Boland T.M., and Kennedy E. (2013) Direct and carryover effect of post-grazing sward height on total lactation dairy cow performance. *Animal* 7, 1390-1400.

Hurtado-Uria C., Hennessy D., Shalloo L., Schulte R.P.O., Delaby L., and O'Connor D. (2013) Evaluation of three grass growth models to predict grass growth in Ireland. *Journal of Agricultural Science* 151, 91-104.

Achieving high milk production performance at grass with minimal concentrate supplementation with spring-calving dairy cows: actual performance compared to simulated performance

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Abstract

The aim of high-profitability grazing systems is to produce milk efficiency from grazed pasture. There is very limited information available on the milk production capacity of dairy cows offered a grass-only diet for the main part of her lactation. In this study, spring-calving dairy cows were managed to achieve high milk production levels throughout the grazing season without supplementation. The calving date of the herd was 12 April; the herd had access to grass as they calved and remained full-time at grass until 20 November. During this period the herd produced 5,513 kg milk, while receiving 130 kg concentrate supplementation. The herbage mass offered was maintained at 1,490 kg dry matter ha^{-1} (>3.5 cm) and the herd grazed to 4.5 cm across the grazing season. The weekly milk production performance achieved was then compared to the Herd Dynamic Milk model. The root mean square error (RMSE) and relative predicted error (RPE) for milk yield (as expressed weekly across lactation) was 1.47% and 6.09%, respectively, for body condition score the RMSE and RPE were 0.093% and 4.14% respectively. Offering spring-calving cows high levels of high quality grass resulted in excellent animal performance, however, this can be achieved with very good daily grazing management.

Keywords: potential, grass milk, dairy production, herd dynamic milk model

Introduction

Grazed grass is the cheapest feed source available to Irish dairy farmers, with a relative cost ratio of grazed grass to concentrate of 1:2.4 (Finneran *et al.*, 2010). Increasing the proportion of grazed grass in the dairy cow diet will reduce the dependence on purchased feed, which is subject to substantial price volatility. Grass dry matter intake has a major effect on the production performance of grazing dairy cows (Dillon *et al.*, 2005) and dairy farm profitability (Shalloo *et al.*, 2009). As a result increasing the proportion of grazed grass in the dairy cow diet results in lower costs of milk production and increased profitability. Grass, when managed well, is a high quality feed that can maintain high levels of milk production performance. There has been little research work, or indeed modelling research, to establish what is the potential performance achievable when cows are offered high levels of pasture. The objective of this work was to create an experiment which offered a spring-calving herd high levels of grass and a low level of concentrate, but still targeted high grass utilization and milk production across the grazing season. The measured performance was then compared to a dairy simulation model (Herd Dynamic Milk model or HDM) (Ruelle *et al.*, 2014).

Materials and methods

The experiment was conducted at Fermoy, Co. Cork, Ireland (52°16' N, 8°25' W), on a free-draining soil comprising acid brown earth with a sandy loam-to-loam texture. Thirty mixed-age Holstein-Friesian cows were selected for the experiment. Seven were second lactation, eleven were third lactation, and the remainder fourth to eighth lactation. Mean lactation number was 3.5 (standard deviation (s.d.) = 1.38) and mean calving date was 12 April (s.d. = 15.88). The experiment took place over a 39-week period from 27 February to 20 December. Grass intake measurements were undertaken during two periods in

weeks 14 (May 21) and 20 (July 10) of the study. As animals calved they were offered 4 kg of concentrate for the first week of lactation and then 1 kg until 27 May; thereafter, they were unsupplemented until 4 November, when they were offered 1.5 kg concentrate day^{-1} to the end of lactation. The cows were grazed on a *Lolium perenne* pasture (on average nine years old, with no clover present). The animals were grazed as one herd. Grazing (full time) started on 10 March as the first cow calved, the herd was housed by night on 20 November, but the herd continued to graze by day until 8 December. Only milk production from a grazing diet is reported in this paper. The grazing area consisted of ca. 12 ha sub-divided into 10 paddocks. Cows were grazed in a rotational system. Paddocks were strip-grazed using temporary fences. Cows had access to the previous day's allocation, as paddocks were grazed for 2-3 days and no back fences were erected in the main grazing season. Nitrogen (N) fertiliser (calcium ammonium nitrate) was applied following grazing to supply 230 kg N ha^{-1}.

Results and discussion

Cows were offered a pre-grazing herbage mass (>3.5 cm) of 1,490 kg dry matter (DM) ha^{-1} (s.d. 310.55), pre-grazing height 8.8 cm (s.d. 1.87) and daily herbage allowance 16.9 kg DM cow^{-1} day^{-1} (s.d 4.32). The herd grazed to a post-grazing height of 4.4 cm (s.d. 0.76) during the study. Over the study the mean grazing area per cow was 114.4 m^2 (s.d. 32.44). Mean milk production performance was 5,513 kg milk (s.d. 665.06), Milk fat % was 4.31 (s.d. 0.321), Milk protein % was 3.56 (s.d. -0.155), Milk lactose was 4.64%, s.d. 0.107), Total fat was 236 kg (s.d. 27.46), Milk protein was 196.2 kg (s.d. 21.5). In May, total DM intake measured was 17.7 kg DM cow^{-1} day^{-1}, grass dry matter intake was 16.7 (s.d. 2.45) kg DM cow^{-1} day^{-1}. In early July, grass dry matter intake was 21.0 kg DM cow^{-1} day^{-1} (s.d. 2.07). Concentrate input per cow was <130 kg DM cow^{-1} for the study.

The HDM is a dynamic and stochastic model capable of simulating the performance of dairy animals individually, with a daily time step. The simulation of the milk production per day is calculated as an interaction between the energy intake by the cow, the change of body condition score (BCS) and the individual animal theoretical milk potential. If the energy intake allows a lower production than the potential, the cow will mobilize body reserves (lose BCS), which will allow her to produce more milk than would be possible through feed alone. If the energy intake allows a higher milk production than the cow's potential, part of this energy is used to increase the body reserves of the cow (regain of BCS) and the other part will go for additional milk production. The model was used to recreate this study's experiment. The model has been initialised with the description of the herd at the beginning of lactation. The weekly herbage allowance and grass quality has been set as an input to reproduce the actual experiment execution. The daily and individual output in terms of milk production (Figure 1) and
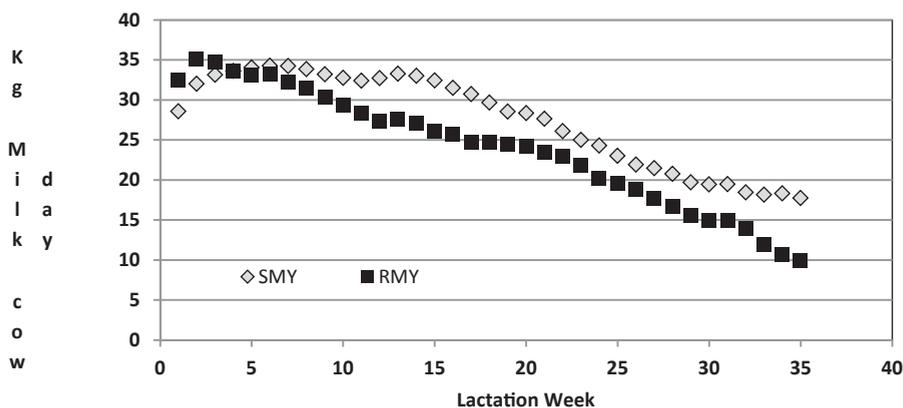
Figure 1. Comparison of mean milk yield of the herd as measured against the simulated performance by Herd Dynamic Model. SMY = simulated milk yield; RMY = recorded milk yield.
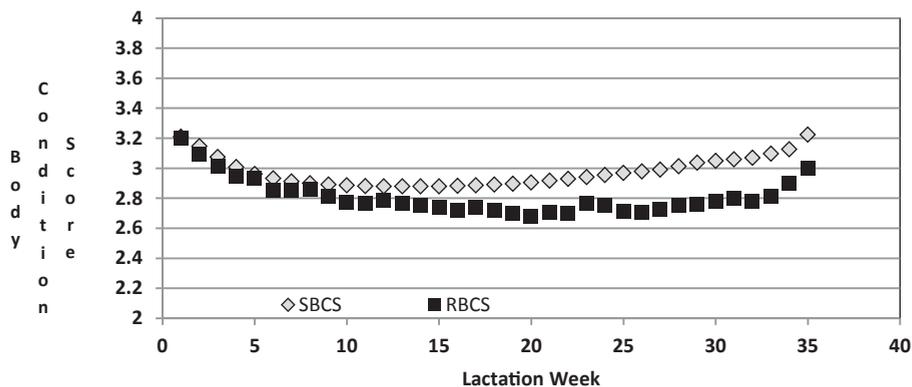
Figure 2. Mean body condition of the herd and its simulated body condition score using the Herd Dynamic model. SBC = simulated body condition score; RBCS = recorded body condition score.

BCS (Figure 2) have been extracted and averaged by week of lactation for the dairy cows to permit the comparison against the measured data. The root mean square error (RMSE) and relative predicted error (RPE) for milk yield (as expressed weekly across lactation) was 1.47 and 6.09, respectively, for BCS the RMSE and RPE were 0.093 and 4.14, respectively.

Conclusions

Offering spring-calving cows high levels of high quality grass resulted in high animal production performance achieved with minimal levels of supplementation offered. The simulation of the herd performance with the HDM model was precise and shows that grazing herd performance can be simulated accurately with the model. High milk production performance can be achieved at pasture with very good daily grazing management.

References

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005) Optimising financial return from grazing in temperate pastures. In: Murphy J.J. (ed.) *Utilisation of grazed grass in temperate animal systems*. Proceedings of a satellite workshop of the 20th International Grassland Congress, Cork, Ireland, July 2005. Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 131-147.

Finneran E., Crosson P., O'Kiely P., Shalloo L., Forristal D. and Wallace M. (2010) Simulation modelling of the cost of producing and utilising feeds for ruminants on Irish farms. *Journal of Farm Management* 14, 95-116.

Ruelle E., Delaby L., Wallace M. and Shalloo L. (2014) Development and evaluation of the Herd Dynamic Milk (HDM) Model for Dairy Systems. *Agricultural Systems*, submitted.

Shalloo L. (2009) Pushing the barriers on milk costs/outputs. In: *Teagasc National Dairy Conference*, Mullingar and Killarney, Ireland, 18 Nov 2009. Teagasc, Carlow, Ireland, pp. 19-39.

Synthesis of systems of European grassland typologies at plot, farm and region levels

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Abstract

On the basis of a literature search, a compilation of agronomic, agri-environmental and phytosociological typologies of grasslands are presented at plot, farm and region levels.

Keywords: agronomy, agri-environment, phytosociology, synthetic indexes

Introduction

Grassland typologies have been developed in Europe since the beginning of the 20th century by phytosociological research. At that time, grassland vegetation was still very diverse in most parts of the continent and plant communities were good indicators of environmental and management characteristics. After the beginning of the intensification period starting roughly in the 1960s, grassland communities were progressively homogenized, vegetation differences were reduced and phytosociological typologies became less relevant. Agronomic typologies based on the forage value of dominant or reference species, or synthetic indexes were designed in different countries. In addition to these efforts developed at plot and farm levels, attempts were made for defining typologies at international and European levels. Several administrations developed their own systems while scientists recently also contributed to the definition of grassland terms and their use in a coherent statistical classification system. However, these typologies were never harmonized on a European scale. This paper is a first attempt to develop a synthesis of grassland typologies.

Materials and methods

This paper is based on an analysis of the literature of the last 60 years. It envisages agronomic, agri-environmental (*sensu lato*) and phytosociological typologies and tries to make a synthesis at plot, farm and region levels.

Results and discussion

Table 1 shows a synthesis of classification systems. The Pastoral value (PV) mentioned in Table 1 is a synthetic index calculated in the following way:

$$PV = (\Sigma A_i \% \times I_i) / 10 \qquad \text{where } A_i = \text{proportion of species i and } I_i = \text{forage value of species i.}$$

A similar formula can be used for the plot ecological index, that can be calculated on the basis of species indicator values of Ellenberg (1952) and Ellenberg *et al.* (1992) for light (L), moisture (F), reaction (R), nitrogen (N), salt (S), temperature (T) and continentality (K) (Peeters, 1989). Briemle and Ellenberg (1994) and Briemle *et al.* (2002) proposed a set of grassland utilization indicator values. The indicator values cover mowing tolerance, grazing tolerance, trampling tolerance, forage value for livestock, forage value for deer. Some examples of agronomic typologies are illustrated in Table 2.

Conclusions

This first synthesis should now be completed. A European system could then be developed on this basis.

Table 1. Agronomic, agri-environmental (*sensu lato*) and phytosociological typologies at plot, farm and region levels.

	Agronomic	Agri-environmental	Phytosociological
Plot level	• List or proportion (%) (species forming the first 80% of the biomass) (Hédin *et al.,* 1972; Vivier and Binet, 1972) • Proportion (%) of the best forage species (ex.: perennial ryegrass (De Vries and De Boer, 1959)) • Proportion (%) of the best group of species (ex.: 'good grasses' (De Vries and De Boer, 1959)) • Proportions (%) of each of the following categories: grasses, legumes and other species • Proportion (%) of weeds (e.g. *Cirsium* spp., *Urtica* spp., *Rumex* spp.) • Grassland utilization indicator values (Briemle and Ellenberg, 1994; Briemle *et al.*, 2002) • Pastoral value (Daget and Poissonnet, 1972; De Vries and De Boer, 1959) and the similar Sward Quality Index (SQI) (Briemle, 1996; Klapp *et al.,* 1953; Stählin, 1971) • Functional trait classification (Ansquer *et al.,* 2009)	According to the national/ regional agri-environmental schemes: • Late cut or very late cut meadows • Low stocking rate pastures • Etc.	Identity of the plot vegetation in the: • Natura 2000 habitats • EUNIS classification (Davies and Moss, 2002) • Phytosociological alliances (Rodwell *et al.,* 2002) Ecological index that can be calculated on the basis of species indicator values of Ellenberg (1952) and Ellenberg *et al.* (1992)
Farm level	Same indicators by calculating a weighted average for all plots at farm level	Same indicators by calculating a weighted average for all plots at farm level	Proportion (%) in the farm of each habitat of the: • Natura 2000 habitat types list • EUNIS classification list (Davies and Moss, 2002) • Phytosociological alliances (Rodwell *et al.,* 2002) Same indicator by calculating a weighted average of ecological index for all plots at farm level

Region level	• UNFCCC, IPCC Good Practice Guidance for LULUCF (2003)
	• LUCAS nomenclature
	• FAO Land Cover Classification System (LCCS)
	• FAOSTAT under the land statistics (part of the Resource statistics)
	• EAGLE group (EIONET Action Group on Land monitoring in Europe)
	• Eurostat: Farm Structure Survey
	• Common Agricultural Policy classification
	• International terminology for grazing lands and grazing animals (Allen *et al.,*. 2011)
	• EGF Grassland term definition and classification (Peeters *et al.,* 2014)
		• Proportion (%AA or % permanent grasslands) of grasslands into the agri-environmental scheme
		• HNV classification (Oppermann *et al.,* 2012):
		  – Proportion (%) of grasslands in the HNV farming area
		  – Proportion (%) of HNV grasslands in the AA
			Proportion (%) of habitat from the following classifications in the region:
			• European habitat classifications, including Annex I habitats of the EU Habitats Directive
			• EUNIS habitat classification (Davies and Moss, 2002)
			• Phytosociological alliances (Rodwell *et al.,* 2002)
			
			Nomenclatures of the following databases:
			• CORINE Biotopes
			• CORINE Land Cover (CLC) classification
			
			DG Environment project: Ecologically Valuable Grassland

Acknowledgements

Table 2. Typologies based on frequency (F%) of perennial ryegrass (*Lolium perenne*), good grasses or weeds in the sward.

Plot value	F% of perennial ryegrass in the sward	F% of good grasses in the sward	F% of weeds in the sward
Good	>60	>30	<25
Medium	51-60	16-30	26-50
Low	≤50	<15	>50

References

Allen V.G., Batello C., Berretta E.J., Hodgson J., Kothmann M., Li X., McIvor J., Milne J., Morris C., Peeters A. and Sanderson M. (2011) An international terminology for grazing lands and grazing animals. *Grass and Forage Science* 66, 2-28.

Ansquer P., Duru M., Theau J. P. and Cruz P. (2009) Functional traits as indicators of fodder provision over a short time scale in species-rich grasslands. *Annals of Botany* 103(1), 117-126.

Briemle G. (1996) *Farbatlas Kräuter und Gräser in Feld und Wald*. Ulmer, Stuttgart, Germany.

Briemle G. and Ellenberg H. (1994) Zur Mahdverträglichkeit von Grünlandpflanzen. Möglichkeiten der praktischen Anwendung von Zeigerwerten. *Natur und Landschaft* 69, 139-147.

Briemle G., Nitsche S. and Nitsche L. (2002) *Grassland utilization indicator values for vascular plant species*. Bundesamt für Naturschutz, Bonn, Germany. Schriftenreihe für Vegetationskunde H. 38, pp. 203-225.

Daget P. and Poissonnet J. (1972) Un procédé d'estimation de la valeur pastorale des pâturages. *Fourrages* 49, 31-39.

Davies C.E. and Moss D. (2002) EUNIS habitat classification. European Topic Centre on Nature Protection and Biodiversity, Paris, France.

De Vries D.M. and De Boer T.A. (1959) Methods used in botanical grassland research in the Netherlands and their application. *Herbage Abstracts* 2, 1-7.

Ellenberg H. (1952) Wiesen und Weiden und ihre standörtliche Bewertung. *Landwirtschaftliche Pflanzensoziologie* 2: 143.

Ellenberg H., Weber H.E., Düll R., Wirth V., Werner W. and Paulissen D. (1992) Zeigerwerte von Pflanzen in Mitteleuropa. *Scripta Geobotanica* 18, 1-258.

Hedin L., Kerguelen M. and De Montard F. (1972) *Ecologie de la prairie permanente française*. Masson, Paris, France.

Klapp E., Boeker P., König F. and Stählin A. (1953) *Wertzahlen der Grünlandpflanzen – Das Grünland*. Schaper, Hannover, Germany.

Oppermann R., Beaufoy G. and Jones G. (eds.) (2012) *High Nature Value farming in Europe*. Verlag Regionalkultur, Ubstadt, 544 pp.

Peeters A. (1989) *Management techniques, vegetation and grass feeding value: study of their triangular relationships in grassland-based systems*. PhD thesis. Agricultural Sciences, UCL, Belgium.

Peeters A., Beaufoy G., Canals R.M., De Vliegher A., Huyghe C., Isselstein J., Jones G., Kessler W., Kirilov A., Mosquera-Losada M., Nilsdottir-Linde N., Parente G., Peyraud J.L., Pickert J., Plantureux S., Porqueddu C., Rataj D., Stypinski P., Tonn B., Van den Poel-van Dasselaer A., Vintu V. and Wilkins R.J. (2014) Grassland term definitions and classifications adapted to the diversity of European grassland-based systems. *Grassland Science in Europe* 19, 743-750.

Rodwell J.S., Schaminée J.H.J., Mucina L., Pignatti S., Dring J. and Moss D. (2002) *The diversity of European vegetation. An overview of phytosociological alliances and their relationships to EUNIS habitats*. EC-LNV nr. 2002/054, National Reference Centre for Agriculture, Nature and Fisheries, Wageningen, the Netherlands.

Stählin A. (1971) *Gütezahlen von Pflanzenarten in frischem Grundfutter. Das wirtschaftseigene Futter*, Sonderheft 5. DLG-Verlag, Frankfurt/Main, Germany.

Vivier M. and Binet P. (1972) Le fonds prairial dans le Bessin et le Pays d'Auge. *Bulletin de la Société d'écologie* 3(2), 170-172.

Using models to establish the most financially optimum expansion strategy for Irish dairy farms

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Abstract

Determining the impact of a change of management on differing farm characteristics is a significant challenge in the evolution of dairy systems, due to the interacting components of complex biological systems. In this study the impact of increased concentrate supplementation and/or an increase in grazing intensity is simulated to determine the effect on the farm system and its economic performance. Three different grazing systems (with three different stocking rates 1.9, 2.2 and 2.5 cows per hectare, three different post-grazing heights 5.2, 4.5 and 3.8 cm, three different nitrogen fertilisation rates 160, 200 and 250 kg per ha) and four different concentrate-supplementation strategies (0.0, 0.5, 1.0 and 1.5 Mg per lactation) resulting in 12 different scenarios were simulated. Three different models (Moorepark Grass Growth Model, Pasture Base Herd Dynamic Milk model and the Moorepark Dairy Systems Model) were integrated and simulated in order to simulate the different scenarios. Overall, this study has shown that increasing concentrate supplementation generally resulted in a reduction in farm profitability, while in general increasing grazing intensity resulted in an increase in farm profitability.

Keywords: grazing intensity, concentrate supplementation, models, economic

Introduction

With the end of the EU milk quota regime in 2015, dairy farmers will get an opportunity to expand their dairy enterprises unhindered for the first time in a generation. The restrictions at farm level will move most farmers from a scenario where they are limited by milk quotas to a scenario where some other features of the farm will be limiting. For most farmers this will be land. In Ireland, it is anticipated that most dairy farmers will increase the number of animals on farm, and invest in technology to increase pasture productivity, while a minority will increase the levels of concentrate supplementation to increase the overall milk outputs.

In order to investigate the optimum strategies for the farm, taking into account the various stocking rates and feeding level interactions, a mechanistic model is required which is capable of modelling the complex animal-sward interactions. The models used must be capable of simulating the complex interactions of the system, which include the effect of increasing fertiliser levels on grass growth, the effect of grazing severity on animal intake, milk yield and body condition score (BCS) and the effect of all of these characteristics on farm profitability. The objective of this study was to evaluate the impact of different system options for dairy farmers in a post-EU quota environment through combining three different models (Paillette *et al.*, unpublished data; Ruelle *et al.*, in press; Shalloo *et al.*, 2004).

The models were applied to evaluate three different levels of grazing intensity (different level of stocking rate (SR) (number of animals per unit area of land), post grazing height and nitrogen fertilisation) and four different levels of concentrate feed per lactation (0.0, 0.5, 1.0 and 1.5 Mg per cow) on overall farm biological and economic performance across a range of different milk and concentrate prices.

Materials and methods

This study focuses on simulating the complex interactions between grass growth, grass intake, animal performance and overall farm profitability to evaluate different strategies to increase milk output at farm level around grazing intensity and concentrate feeding in a post-quota environment. Three separate models developed in Teagasc Moorepark were integrated to simulate all aspects of the production system. In this study, three models are used to evaluate twelve different systems across different grazing systems and concentrate-feeding levels. The models included a grass growth model, the Moorepark Grass Growth Model (MGGM) (Paillette *et al.*, unpublished data) which is used to simulate the effect of nitrogen fertiliser and SR on grass growth, an animal intake and performance model (Ruelle *et al.*, in press) which is used to simulate the interaction between the animal and the sward across different grazing pressures and concentrate supplementation levels, with all of these data combined into the Moorepark Dairy System Model (MDSM) (Shalloo *et al.*, 2004) to evaluate the overall effect on the economic performance of the farm. The analysis was conducted with cows that have been selected for a balance of traits encompassing both milk production and fertility. The simulations were completed on a 40 ha farm with each simulation fed from one model to the other. Overall, for each simulation the farm size is fixed at 40 ha with 18 paddocks. Twelve main scenarios have been completed; three different grazing systems (GS) with different SR and grazing intensities:

- LGS: 1.9 cows per ha (76 cows), post-grazing height of 5.2 cm and nitrogen fertilisation of 160 kg per hectare;
- MGS: 2.2 cows per ha (88 cows), post-grazing height of 4.5 and 200 kg of nitrogen fertilisation;
- HGS: 2.5 cows per ha (100 cows), post-grazing height of 3.8 cm and 250 kg of nitrogen fertilisation per hectare.

Four different concentrate levels were used across the different stocking rates (objective of 0 Mg cow^{-1} (0C), 0.5 Mg cow^{-1} (LC), 1.0 Mg cow^{-1} (MC), 1.5 Mg cow^{-1} (HC) per lactation). The base milk and concentrate prices included in the analysis were 29.5c l^{-1} and €250 Mg^{-1} with sensitivity analysis completed with a milk price of 24.5 and 34.5c l^{-1} and €150 and €350 Mg^{-1} for milk and concentrate costs, respectively.

Results

At a base milk price (29.5 c l^{-1}) and an average concentrate price (€250 Mg^{-1}) all farms were profitable, with the most profitable farm generating €24,156 (MGS-0C) while the least profitable farm generated €3,914 (LGS-HC). At a low milk price most scenarios lost money, with the most profitable scenario returning a profit of €1,410 (MGS-0C) and the largest deficit being €-22,807 (HGS-HC).

Mainly the increase of concentrate level induced a decrease of the overall farm profit (average decrease of profit of €5,747 for an increase of 0.5 Mg cow^{-1} of concentrate between all scenarios and milk prices). However, in specific cases the increase of concentrate supplementation led to an increase of the farm profit. Indeed, in the case of a high milk price (34.5 c l^{-1}) in the HGS the LC farm was €2,719 more profitable than the 0C. At a low concentrate cost (€150 Mg^{-1}) increasing concentrate level from 0C to LC was beneficial at all three stocking rates (€2,032, €2,948 and €7,120 for the LGS, MGS and HGS).

Overall the increase in grazing intensity led to an increase of the profit on farm. The increase in grazing intensity is always beneficial with a high milk prices (34.5 c l^{-1}). In the case of a low milk price (24.5 c l^{-1}), the increase in grazing intensity does not result in an increase in farm profit except for the 0C or the LC between the LGS and the MGS.

Discussion

As grazing intensity and level of concentrate feed increase, there is an increase in the vulnerability of the business to variation in input and output prices. In this study at the different milk prices and concentrate supplementation levels, the most profitable system ranged from MGS-0C, HGS-LC and the HGS-MC. The MGS-0C has been the most efficient system in the case of a low or average milk price at an average concentrate price or in the case of a high concentrate price. Without any concentrate, the optimum system is at the MGS. However, we have shown that the decrease of the concentrate supplementation led to a decrease of the minimal and average BCS of the animal through the lactation which may have reproduction implications, but that have not been simulated in this study. Some studies have shown than an underfeeding in early lactation could lead to a high decrease in BCS in early lactation, which could have a subsequent impact on the fertility of the animal (Berry *et al.*, 2003).

Without taking into account the scenario with 0 concentrate the most profitable was the HGS-LC. The two exceptions are in the case of a low milk price where the MSR-LC has a lower deficit of €688 and in the case of a low concentrate price were the HSR-MC is €831 more profitable. It could be anticipated that if the analysis was completed with an animal which was selected for a higher milk yield that these animals would produce a higher milk production response than the type of cow simulated in this study (Fulkerson *et al.*, 2008). Response to concentrate has been shown to be highly dependent to the type of cow (Fulkerson *et al.*2008), level of feed offered and the level of feed deficit that was in the diet before the concentrate feed was offered.

Conclusions

This study has compared the economic efficiency of four different concentrate supplementation strategies and three different grazing intensity levels. This study has shown that systems of milk production built around matching the supply and demand of home produced feed, minimising the level of supplementary feed were the most profitable and also resulted in the least variability of profitability across different input and output prices.

Acknowledgements

References

Berry D.P., Buckley F., Dillon P., Evans R.D., Rath M. and Veerkamp R.F. (2003) Genetic relationships among body condition score, body weight, milk yield, and fertility in dairy cows. *Journal of Dairy Science* 86, 2193-2204.

Fulkerson W.J., Davison T.M., Garcia S.C., Hough G., Goddard M.E., Dobos R. and Blockey M. (2008) Holstein-Friesian dairy cows under a predominantly grazing system: interaction between genotype and environment. *Journal of Dairy Science* 91, 826-839.

Ruelle E., Shalloo L., Wallace M. and Delaby L (in press) Development and evaluation of the pasture base herd dynamic milk (PBHDM) model for dairy systems. *Agricultural Systems*.

Shalloo L., Dillon P., Rath M. and Wallace M. (2004) Description and validation of the Moorepark Dairy System Model. *Journal of Dairy Science* 87, 1945-1959.

The amount of maize in the feed ration influences milk composition in Northern Spain

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Abstract

The oceanic climate conditions of Asturias (Spain) are favourable for grass and pasture production. However, the use of concentrates in dairy-cow diets has increased in the last decades. The aim was to study the differences in milk composition in the four feeding systems identified in the North of Spain through the monitoring of 16 dairy farms. The criteria to describe feeding systems were: grazing (G) and non-grazing. Moreover, three subgroups were identified within 'non-grazing' in terms of the percentage of the usable agricultural area (UAA) designated to maize culture: less than 20% (20M), about 50% (50M) and more than 75% (75M) of UAA. Four dairy farms were selected by their feeding system. Feed and milk were sampled and analysed in summer, autumn and winter of 2014. The results show that the protein, lactose and solids-non-fat in milk were higher ($P<0.05$) in 75M than in the other feeding systems. The highest fat content ($P<0.05$) and the lowest content of linolenic acid ($P<0.01$) and conjugated linoleic acid (CLA) ($P<0.05$) were in winter, when there was less use of grass. The concentration of saturated acids increased in the 75M system ($P<0.05$), reducing the ratio unsaturated:saturated ($P<0.05$). The fatty acid profile was influenced by feed management, with the grazing system producing an increase in vaccenic acid ($P<0.001$) and CLA ($P<0.01$).

Keywords: dairy cow, fatty acids, milk quality, pasture, maize

Introduction

Northern Spain has an oceanic climate, generally warm with wet summers and mild winters. These climate conditions are favourable for grass and pasture production. Taking this situation into account, grazing is proposed as a strategy to reduce the cost of feeding inputs in dairy cow farms. However, the dairy sector has been intensified in the last decades (Álvarez *et al.*, 2008). The economic evaluation of dairy cow farms in the studied area (Asturias, Spain) shows that there is a large dependence of the usable agricultural area (UAA) designated to maize culture (Servicios Técnicos de Central Lechera Asturiana, 2012). The purchase of feedstuffs from off-farm sources is lower in dairy cow systems with the highest UAA designated to maize culture. However, there are areas where there is less UAA designated to maize crop, due to the high altitude and slope. Pasture-based systems allow farmers to produce at lower cost (Soder and Rotz, 2001). In addition, cows grazing fresh grass produce milk with improved fatty acid profiles for human health, especially CLA and linolenic acid (Morales-Almaráz *et al.*, 2011). Increasing the concentration of desirable FA in ruminant products has received greater attention recently (Elgersma *et al.*, 2006). The aim was to study the differences in the milk composition and FA profiles in four feeding systems identified in Asturias (Spain).

Materials and methods

According to official data there are currently 2,446 dairy farmers in Asturias. Results from a previous survey in this region showed that the best criteria to describe the feeding systems used were: grazing farms (G) and non-grazing farms. In addition, three subgroups were identified in the non-grazing system according to the percentage of UAA designated to maize culture: less than 20% (20M), between 20% and 75% (50M) and more than 75% (75M) of UAA. Four dairy farms were selected by feeding system identified (n=16), and feed and milk were sampled and analysed three times (summer, autumn and

winter of 2014). Milk samples were analysed for fat, protein, urea, lactose and solids-non-fat-content. Milk FA profile was determined by gas-liquid chromatography. The results were analysed by ANOVA (R Core Team, 2014) using feeding system (F) and season (S) as main factors.

Results and discussion

The results show that the protein, lactose and solids-non-fat in milk were higher ($P<0.05$) in 75M than in the other feeding systems (Table 1). This feeding system, which used a high level of maize in the ration, has more energy available for the animal, producing an increased in protein and lactose content in milk. It was also noted that the fat content in milk was not influenced by the feeding system, but was affected by the season. The fat content in milk was higher in winter than in summer ($P<0.05$).

Table 2 shows the proportion of unsaturated and saturated fatty acids and the main C18 FA. Considering the total FA, the season had no effect on the degree of fat saturation. However, the concentration of saturated acids was highest ($P<0.05$) in the 75M management, reducing the ratio unsaturated:saturated fatty acids. The season had no effect on FA profile except on CLA and linolenic acid (C18:3 *n-3*) proportion. The lowest content of CLA and linolenic acids appeared in winter *($P<0.05$)*. This could be

Table 1. Chemical analysis of milk from four dairy cow feeding systems identified in Asturias (Spain) during summer, autumn and winter 2014.

	Season			Feeding systems[1]				Factors[2]			
	Summer	Autumn	Winter	G	20M	50M	75M	rsd	S	F	S×F
Fat (g 100 g^{-1})	3.71[b]	3.84	3.91[a]	3.84	3.89	3.74	3.82	0.206	*	ns	ns
Protein (g 100 g^{-1})	3.15	3.15	3.19	3.14	3.12[b]	3.13	3.29[a]	0.137	ns	*	ns
Lactose (g 100 g^{-1})	4.73	4.75	4.78	4.72[b]	4.73	4.76	4.82[a]	0.086	ns	*	ns
Solids-non-fat (g 100 g^{-1})	8.64	8.64	8.72	8.61[b]	8.63	8.61[b]	8.86[a]	0.198	ns	*	ns
Urea (mg kg^{-1})	280	302	274	255	303	279	310	49.9	ns	ns	ns

[1] G = grazing system; 20M = less than 20% usable agricultural area (UAA) destined for maize culture; 50M = 20-75% UAA destined for maize culture; 75M = more than 75% UAA destined for maize culture. rsd = relative standard deviation.

[2] S = season, F = feeding system. Statistical significance * = $P<0.05$.

[a,b] Values in the same row with different letters differ significantly.

Table 2. Proportion of unsaturated and saturated fatty acids and the proportion of the major C18 fatty acids (in g 100 g^{-1}).

	Season			Feeding systems[2]				Factors[3]			
	Summer	Autumn	Winter	G	20M	50M	75M	rsd	S	F	S×F
SFA	69.68	68.73	69.62	69.27	68.42	66.81[b]	74.04[a]	5.550	ns	*	ns
UFA	30.33	31.35	30.4	30.86	31.58	33.19[a]	25.96[b]	5.551	ns	*	ns
UFA/SFA	0.44	0.47	0.44	0.45	0.47	0.51[a]	0.37[b]	0.121	ns	*	ns
C18:0	12.17	10.52	11.32	11.35	10.73[b]	13.26[a]	9.58[b]	2.192	ns	**	ns
C18:1 trans11	1.02	0.88	0.76	1.26[a]	0.90[a]	0.89[a]	0.39[b]	0.422	ns	***	ns
C18:1 cis9	23.31	23.82	24.34	23.83	24.94	25.90	19.55	5.395	ns	ns	ns
C18:2 n-6	1.87	1.39	1.45	1.26	1.47	2.04	1.48	0.695	ns	ns	ns
CLA	0.36[a]	0.25	0.22[b]	0.40[a]	0.28	0.26	0.14[b]	0.152	*	**	ns
C18:3 n-3	0.24[b]	0.39[a]	0.19[b]	0.33	0.26	0.30	0.18	0.140	**	ns	ns

[1] SFA: saturated fatty acids; UFA: unsaturated fatty acids.

[2] Feeding systems: G = grazing system; 20M = less than 20% usable agricultural area (UAA) destined to maize culture; 50M = 20-75% UAA destined to maize culture; 75M = more than 75% UAA destined to maize culture.

[3] Factors: S = season; F = feeding system. Statistical significance: * = $P<0.05$, ** = $P<0.01$, *** = $P<0.001$.

[a,b] Values in the same row with different letters differ significantly.

explained by less use of forage during winter. The increase of CLA was very important in summer (0.359 g 100 g^{-1} FA, $P<0.05$) and, moreover, in the grazing system (0.397 g 100 g^{-1} FA, $P<0.01$). CLA and vaccenic acids (C18:1 trans11) were higher ($P<0.01$) in the grazing system (0.397 and 1.255 g 100 g^{-1} FA, respectively) than the 75M system (0.136 and 0.385 g 100 g^{-1} FA, respectively).

Conclusions

Increased proportions of maize in the feed ration improve the milk chemical composition in terms of protein, lactose and solids-non-fat, while the concentration of fat content was affected by the season. In addition, by using pastures results showed it is possible to improve the FA profile of cow milk, especially in the proportions of vaccenic acid and CLA. Information from this study supports previous findings that there is a potential for increased value-added attributes of milk, and that these differences could be identified in terms of differences between feeding systems during different seasons in the studied area.

Acknowledgements

References

Álvarez A., Del Corral J., Solís D. and Pérez J.A. (2008) Does intensification improve the economic efficiency of dairy farms. *Journal of Dairy Science* 91, 3693-3698.

Elgersma A., Tamminga S. and Ellen G. (2006) Modifying milk composition through forage. *Animal Feed Science and Technology* 131, 207-225.

Morales-Almaráz E., De la Roza-Delgado B., González A., Soldado A., Rodríguez M.L., Peláez M. and Vicente F. (2011) Effect of feeding system on unsaturated fatty acid level in milk of dairy cows. *Renewable Agriculture and Food Systems* 26, 224-229.

R Core Team (2014) R: A language and environment for statistical computing. R foundation for Statistical Computing, Vienne, Austria.

Servicios Técnicos de Central Lechera Asturiana (2012) Reducir el coste total de los alimentos comprados fuera de la explotación como estrategia para mejorar los resultados económicos de las explotaciones lecheras. *Frisona Española* 191, 114.

Soder K.K. and Rotz C.A. (2001) Economic and environmental impact of four levels of concentrate supplementation in grazing dairy herds. *Journal of Dairy Science* 84, 2560-2572.

Production pasture versus exercise and recreation pasture for cows in automatic milking systems

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Abstract

In an automatic milking unit, a daytime grazing system with production pasture (group P) was compared with offering cows a small grass-covered paddock only for exercise and recreation, i.e. exercise pasture (group E). Two experiments (Exp1 and Exp2) were performed during 12 and 5 weeks with 53 cows and 42 cows, respectively. Group P was offered new pasture daily with night-time access to grass silage *ad libitum* (Exp1) or in restricted amounts (Exp2). Group E was offered exercise pasture and silage *ad libitum* during 24 (Exp1) or 16 hours (Exp2) daily. In Exp1, group P had significantly ($P<0.05$) higher daily milk yield (+1.6 kg Energy Corrected Milk) than group E and daily silage intake in groups P and E was 9.8 and 12.2 kg dry matter (DM) per cow, respectively. In Exp2, cows in group P had similar milk yield to cows in group E and daily silage intake was 6.2 and 11.5 kg DM in group P and E, respectively. These results show that it is possible to achieve either higher milk yield (Exp1) or considerably lower intake of supplementary silage (Exp2) on production pasture compared with exercise pasture.

Keywords: grazing, automatic milking, supplements, restricted grazing, daytime, dairy cows

Introduction

Grazing during only part of the 24-hour period can offer several advantages, especially for dairy systems with automatic milking (AM). With part-time production pasture, cows are offered a new pasture area during 8-12 h daily and are given supplements when restricted indoors. In this system, pasture utilisation is high but the area needed for pasture is smaller than with full-time grazing. Thus, the distance to the pasture area can be shorter, which has been shown to give higher milk yield in AM systems (Spörndly and Wredle, 2004). Furthermore, the negative effects of large variations in pasture supply and quality can be avoided. In several Scandinavian countries (e.g. Sweden and Norway), animal welfare legislation requires cows to be grazed on pasture in summer and it is common for farmers with AM to comply with this law by offering access to a small field only for exercise and recreation, combined with full indoor feeding for the cows. The question is whether using production instead of exercise pasture can give higher yields or lower feed costs.

This study compared production pasture with exercise pasture in an AM system with daytime grazing. The hypothesis was that daytime production pasture, with silage supplementation during non-grazing hours, would give (1) lower intake of silage indoors and (2) higher milk yield than daytime exercise pasture with 24 h *ad libitum* silage feeding.

Materials and methods

Two experiments were carried out to study this hypothesis. Experiment 1 (Exp1) was performed with 53 cows of the Swedish Red Breed (SR) during 12 weeks in 2011 and experiment 2 (Exp2) with 42 cows of the Swedish Holstein (SH) and SR breeds during 5 weeks in 2013, with approximately one-third primiparous cows in both studies. In both experiments, milk yield, milking frequency, feed intake indoor and time on pasture (only Exp 2) were recorded automatically. Milk samples were collected for analysis before experiment start and thereafter every second week. All cows on pasture in each experiment were

observed every 15 min over three days and the following behaviours were recorded: location (cow lane or pasture/exercise area), position (standing or lying) and activity (grazing or other).

Pasture height and pasture allowance were measured daily, and samples of pasture and supplementary feed were collected daily for analysis to determine nutrient composition. Cows had access to the outdoor pasture/exercise area during 9.5-12 h in daytime and could move freely from the house to the pasture or exercise area during this time. During the remaining time, they were restricted to the house with access to supplementary feed.

Cows in both groups were offered drinking water in the house and were given concentrates according to milk production before the start of the experiment. The cows were then blocked and randomly assigned to the production pasture (P) or exercise pasture (E) treatments, which were applied simultaneously in each herd. On passing through a selection gate at the house exit, cows in each group were directed to their own pasture area (P or E) and stayed there from 06:00-15:30 in Exp1 and 06:00-18:00 h in Exp2. Silage and concentrate feeding and recording were performed at individual cow level using transponders.

Treatment E: Cows had access to the same 1-ha field (distance 200 m) throughout the experiments (continuous, low sward height and low allowance, 3 kg dry matter (DM) day^{-1}). Group E cows received silage *ad libitum* in the house during 24 h day^{-1} in Exp1 and 16 h day^{-1} in Exp2.

Treatment P: Cows were given a new grazing area daily at a high pasture allowance (>20 and 15 kg DM per cow and day in Exp1 and Exp2, respectively). During indoor confinement hours, cows were offered silage *ad libitum* in Exp1 and 6 kg DM silage in Exp2. The total area used for treatment P in Exp1 and Exp2 was 3.6 and 5 ha, respectively, and the distance to pasture was 20-200 m and 200-400 m, respectively. The results were analysed in a general linear model using the SAS programme (Ver. 9.2; SAS Institute Inc.). The model for statistical analysis of the production parameters (milk yield and milk components) in Exp1 contained the variable treatment (P or E) and lactation stage (only milk yield), using milk yield before experiment start as a covariate. The model for Exp2 was similar, but contained the additional variables breed and age (primiparous/multiparous) and excluded lactation stage due to lack of significance. In analysis of behaviour results in Exp1 the model contained only treatment as the variable, while in Exp2 the variables breed and age were also included as they were statistically significant.

Results and discussion

Both years were characterised by normal pasture conditions during the first part of the experiment, followed by dry weather during the latter part. The metabolisable energy content in silage and pasture herbage, and sward height differed between feed sources and years (Table 1) There were some significant differences in production and behaviour between Exp1 and Exp2 (Table 2). During Exp1 the cows on treatment P had 1.6 kg higher energy corrected milk yield than those on treatment E (Table 2). There was no significant difference in milking frequency (2.83 and 2.72 in the P and E groups, respectively). As

Table 1. Mean (± standard error) content of metabolisable energy in silage, production and exercise pasture, and sward height in experiment 1 and 2.

	Experiment 1			Experiment 2		
	Silage[1]	Production	Exercise	Silage[2]	Production	Exercise
Metabolisable energy, MJ kg^{-1} DM	10.8 (0.27)	11.0 (0.55)	11.1 (0.49)	11.2 (0.27)	9.7 (0.31)	9.4 (0.72)
Sward height, cm		9.3 (1.79)	2.6 (0.90)		11.3 (1.33)	2.6 (0.80)

[1] Dry matter (DM) in silage 40%.

[2] DM in silage 32%.

Table 2. Production and behaviour data (least square means) for cows on production or exercise pasture in experiment 1 and 2.

| | Experiment 1 | | | Experiment 2 | | |
	Production	Exercise	Sig.[1]	Production	Exercise	Sig.[1]
Production						
Milk, kg	35.6	33.3	**	32.2	32.6	NS
ECM[2], kg	35.8	34.2	*	32.5	32.1	NS
Milk fat, %	4.03	4.25	*	4.04	3.91	NS
Milk protein, %	3.36	3.37	NS	3.37	3.32	NS
Behaviour[3], hours (h)						
Outdoor time, h	3.1	1.9	***	4.5	3.5	***
Grazing time, h	2.0	1.1	***	2.3	1.1	***

[1] Significance: NS = not significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$.

[2] ECM = energy corrected milk.

[3] Data from 18 days of automatic recordings.

regards behaviour on pasture (Table 2), in Exp1, cows in group P spent approximately 3 h daily on pasture and only 2 h grazing, even though they were offered new pasture daily. Besides eating pasture herbage, cows in group P had an average indoor intake of 9.8 kg DM silage per day, whereas silage intake in group E cows was 12.2 kg DM per day. Thus, while the milk yield for group P cows was higher, the cost of this increased production was also high, as these cows were offered new high quality pasture herbage daily, yet they consumed large amounts of conserved feed.

In Exp2, average silage intake was 11.5 and 6.2 kg DM in groups E and P, respectively. There was no difference between the groups in milk yield or milk composition (Table 2). For milking frequency, there was a significant ($P<0.05$) interaction between treatment and parity in group E, with 2.75 and 2.51 milkings day^{-1} for primiparous and multiparous cows, respectively, while group P had similar frequencies for both ages ($\sim$2.65 milkings day^{-1}). There was also a significant interaction in milking frequency between breed and parity, with significantly lower milking frequency for multiparous compared with primiparous cows of the SR Breed (2.45 and 2.75 milkings day^{-1}, respectively; $P<0.01$) and compared with multiparous cows of the SH breed (2.72 milkings day^{-1}; $P<0.05$). The results of Exp2 showed that even when pasture conditions are less favourable (Table 1), cows on treatment P can achieve similar production results as cows on treatment E. In both Exp1 and Exp2, there was a significant difference in the time that the cows on the different treatments spent outdoors and spent grazing (Table 2). The cows on P pasture only exploited the opportunity to be outdoors for around 30-40% of the outdoor access time in both studies, and spent only around 20% of the outdoor access time grazing. Overall, the results show that it is possible to achieve either higher milk yield (Exp1) or a lower intake of supplementary silage (Exp2) on daytime production pasture compared with exercise pasture.

Acknowledgements

References

Spörndly E. and Wredle E. (2004) Automatic milking and grazing – effects of distance to pasture and level of supplements on milk yield and cow behavior. *Journal of Dairy Science* 87(6), 1702-1712.

Effect of indoor silage feeding on pasture time in a batch-milked automatic milking rotary system

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Abstract

The effect of indoor silage feeding on pasture time was studied in an automatic milking rotary system with batch milking two times daily. The objective was to study how pasture time is influenced by offering only pasture (PP) or both grass silage and pasture (SP) in the barn during grazing hours, in a night-time grazing system, where cows could move freely between barn and pasture during pasturing hours. From 9 June until 18 August, treatments SP and PP were repeated three and two times, respectively in two-week periods using the second week for measurements. During each measurement week, ten animals were fitted with HOBO® loggers that estimated grazing time from head position. Results were analysed in a mixed repeated measurement model using only cows (83) present during all periods. Results showed that animals on treatment PP spent approximately 8.5 hours on pasture with no difference between primi- and multiparous cows. In contrast, cows on treatment SP spent less time on pasture ($P<0.001$) and furthermore, time on pasture differed significantly between ages ($P<0.001$) in this group, with 4.7 h and 5.9 h for primiparous and multiparous cows, respectively. Analysis of data on the grazing hours, obtained from the HOBO loggers, showed a significant ($P<0.001$) difference between treatments with 3.8 and 2.2 hours of grazing on treatment PP and SP, respectively.

Keywords: night-time grazing, grazing time, pasture, indoor silage, premiparous, multiparous

Introduction

Farmers with intensive milk production systems generally aim at a high milk production as their main goal. Investing in automatic milking on the farm is a substantial cost and often leads to intensification of production. The automatic milking rotary (AMR™) is a system mainly designed for larger herds and it has been studied in several experiments in Australia under voluntary milking with pasture as the main roughage in the diet (Kolbach, 2012). However, in countries with a short grazing season, such as in Scandinavia, cows are often accustomed to eating large quantities of roughage in the barn and it is common to feed substantial amounts of supplementary silage indoors during the grazing season. With increasing automation combined with larger herd sizes, the difficulties in logistics and cow traffic with pasture have increased and farmers may prefer to keep their lactating cows in the barn throughout the year. However, it has been shown that grazing and pasture have beneficial effects on cow health and welfare and therefore it is important to find pasture management systems adapted for large herds with intensive production. The objective of this study was to analyse the effects of silage supplementation on cow traffic and choice of location of cows in an intensively managed AMR barn.

Material and methods

The experiment was performed with 83 cows in a group of approximately 120 cows in an AMR barn with batch milking two times daily. The cows were predominately (61 cows) of the Swedish Red breed (SR) and remaining animals (22) were of the breed Swedish-Holstein From 9 June until 18 August, cows in the barn were subjected to two treatments, each applied repeatedly during two-week periods, with the first week acting as an adaptation period and the second week used as a registration period. The cows were allowed to go on pasture approximately 12 hours at night, between evening and morning milkings. They were herded out to the pasture area after evening milking and thereafter allowed to move freely between

barn and pasture throughout the night. Starting on 9 June, cows were offered pasture (P) with *ad libitum* access to grass silage (S) indoors during grazing hours during the first two-week period, treatment (SP). In the following two-week period, cows had only pasture as roughage during the hours they had access to the pasture area, treatment (PP). The treatment SP and PP were repeated until the end of the experiment, giving a total of three periods with SP and two periods with PP. During the day hours, when the cows were confined in the barn, they always had free access to grass silage. Concentrates were fed according to milk production at the latest test milking occasion, according to the same routines for both treatments, and drinking water was available only in the barn. Cow traffic between barn and pasture was registered automatically at an individual level.

During registration weeks, 12 cows were fitted with HOBO loggers that were attached to the halter. The 3D loggers register the tilt of the head. This equipment has been validated and can, according to Nielsen (2013), be used as a tool to distinguish between grazing and non-grazing behaviour. The methodology of the validation study mentioned above was also used in the present study.

Cows were in a rotational grazing system, rotating between 7 different larger (~3 ha) pasture fields. Rotation varied between 4 and 6 days grazing per field depending on sward conditions. Samples of pasture were collected daily and pasture samples were pooled over a one-week period while silage samples were pooled over two-week periods for analysis. Sward height of pasture was measured daily with a Jenquip plate meter.

The statistical analysis system (SAS version 9.3) was used for the analysis of the effect of treatment (SP vs PP) on the cow traffic variables: time spent outdoors, number of outdoor visits and length of each outdoor visit. The final model for the cow traffic variables was a mixed model with the independent variables treatment, week, lactation number and the interaction between treatment and week with cow×treatment as repeated subject. The same model was used for the statistical analysis of the grazing time calculated from the HOBO loggers, without the factor lactation number as the data set for the grazing time was based on only data from 10 multiparous cows. No significant effects of sward height or nutritive value of pasture were observed and these variables were therefore excluded from the statistical analysis.

Results and discussion

There was a significant interaction between treatment and parity. The average pasture traffic variables for treatments SP and PP for primiparous and multiparous cows are presented in Table 1. Cows with access to silage indoors (SP) had a high proportion of cows coming back early to the barn. During the three periods on this treatment, as much as 44, 53 and 33% of the cows returned to the barn before 22:00 p.m., respectively, i.e. approximately within four hours after being let out onto the pasture in the evening. In contrast, the cows in group PP returned later to the barn. During the two periods that cows were on treatment PP, 62 and 73% of the returns to the barn occurred between 01:00 and 06:00 in the morning while corresponding figures for the three periods with treatment SP were 41, 25 and 23%, respectively. The data in Table 1 are based on outdoor time for the 83 cows that were in the barn during the entire 10 weeks that the experiment lasted. All passages in and out of the barn during pasture hours over the five measurement weeks are the base for results of the statistical analysis in Table 1.

The analysis of the data from the HOBO loggers is based on data from ten cows only. Initially 12 cows were fitted with loggers, but data from two of these cows proved to give unrealistically high grazing hours that were around 98% of outdoor hours and therefore had to be excluded from the dataset. Furthermore, it seemed that some cows were disturbed by the loggers and on 8 occasions out of the total 50 observation weeks (10 cows × 5 weeks) the loggers were lost during the observation week leading to 16% missing values in the dataset. However, data from the remaining loggers showed that cows on treatment PP spent

Table 1. Outdoor hours (h) and number of outdoor visits for primiparous and multiparous cows with 12 hour night-time access to the pasture area and with only pasture (treatment PP), or with *ad libitum* silage in the barn (treatment SP) as roughage during the night. Least square means with standard error in parenthesis (n=83).[1]

	Treatment PP		Treatment SP	
	Primiparous	Multiparous	Primiparous	Multiparous
Outdoor time, h	8.4[a] (0.26)	8.6[a] (0.21)	4.7[b] (0.24)	5.9[c] (0.20)
Outdoor visits, no.	1.8[a] (0.04)	1.5[b] (0.04)	1.2[c] (0.04)	1.1[d] (0.03)

[1] Values with different superscripts in the same row differ significantly (*P*<0.05).

significantly (*P*<0.001) more time grazing (3.8 hours) compared with cows on treatment SP (2.2 hours). On the treatment SP, where cows were offered both pasture and supplementary silage during pasture hours, grazing time decreased as the grazing season progressed with 2.7 hours spent grazing in June and 1.7 hours in mid-August. As a contrast, the cows on treatment PP spent approximately the same amount of time grazing during both periods, 3.7 and 3.9 hours in the first and second period, respectively.

Due to dry weather conditions, the average content of metabolisable energy (ME) in the pasture was low with an average of 10.2 and 9.7 MJ ME per kg dry matter (DM), on treatment PP and SP, respectively. The average energy content of the supplementary silage was somewhat higher than the pasture, 10.5 MJ ME kg^{-1} DM.

The conclusion of the study is that offering supplementary silage in the barn during pasture hours decreases outdoor and grazing time for the animals, especially as the season progresses, thus reducing the potential health and welfare benefits of pasturing.

Acknowledgements

References

Kolbach R. (2012) *Operational efficiency of incorporating a novel robotic rotary into a pasture-based dairy farming system.* MSc Thesis, Faculty of Veterinary Science, University of Sydney, Australia.

Nielsen P.P. (2013) Automatic registration of grazing behaviour in dairy cows using 3 D activity loggers. *Applied Animal Behaviour Science* 148, 179-184.

Production and cow-traffic management during the pasture season in large herds with automatic milking

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Abstract

A field study on management during the pasture season was conducted on 20 Swedish farms with at least two automatic milking (AM) units and over 130 cows registered in the official control system. The objective was to compare milk production during indoor and pasture seasons, and to study cow traffic management during the pasture season. Using data from the official monthly control milkings, average yield of milked cows during winter (November-March) and summer (June-August) seasons were analysed using a mixed model with farm as repeated subject and season as variable. Days in milk and cows per robot were tested in the model but were non-significant. Milk yield was 30.1 and 28.4 kg energy corrected milk in winter and summer season, respectively ($P<0.001$). A more detailed analysis, using daily production farm data from the AM unit from the months before and after pasture let-out on each farm, showed a significant ($P<0.05$) decrease in the number of cows milked per robot after pasture let-out (57.5) compared with before (60.1). When number of cows per robot was included in the model together with season, a significantly *($P<0.01$)* higher milking frequency per cow was observed before pasture let-out (2.57) compared with after (2.45). The effects of different management factors on production variables were also analysed but were not significant in this study.

Keywords: automatic milking, pasture, cow traffic, pasture selection gate, grazing, season

Introduction

Studies have shown that grazing often decreases when automatic milking (AM) is introduced on dairy farms (Mathijs, 2004). It seems that combining automatic milking with grazing is a challenge for many farmers. Over the latest decades, dairy farms in many countries have increased in size, further increasing the difficulties in logistics and cow traffic with combining grazing and AM. A common view among farmers is that milk production decreases over the pasture season. However, there are many economic and animal welfare benefits with pasture and grazing, and management solutions that facilitate grazing are thus of great interest to many European farmers, especially organic farmers where grazing is required. The objective of this study was therefore to investigate how 20 larger AM farms with production pasture organize cow traffic during the pasture season and to compare their milk production level during the pasture and indoor seasons.

Material and methods

The study is built on interviews and collected data from 20 Swedish AM farms with production pasture. All the farms had more than 130 dairy cows in the official cow control system, at least 2 milking robots and 18 of the farms were organic. At each farm visit, the pasture and the barn layout were inspected and management during the pasture season was recorded following a structured protocol with approximately 110 questions. Milk production data was downloaded from the AM computer together with data regarding cow numbers and utilization of the AM robot. Furthermore, with the permission of the farmers, production data from the latest production year was obtained from the official Swedish cow control system together with production averages of four categories of producers, all with more than 60 cows in the control system: (1) conventional milk producers without AM, (2) conventional milk producers with AM, (3) organic milk producers without AM and (4) organic milk producers with AM.

Statistical analysis was performed using the statistical analysis system SAS (version 9.3) with three data sets. Average milk production data from the cow control system during the indoor season (November-March) was compared with milk production during pasture months (June-August) on the 20 farms in a mixed model with farm as repeated subject and season (indoor vs pasture) as an independent variable. Days in milk and cows per robot were tested in the model but were non-significant. Furthermore, production data (milk yield and milking frequency per cow and per robot as well as robot utilization in percent) was downloaded directly from the milking robot for two periods, before and after pasture let-out, i.e. from 1st of March to pasture let-out and from pasture let-out to 22nd of June, respectively. Production before and after pasture let-out was compared in a mixed model with period, and with number of cows in the robot as independent variables using farm as repeated subject. Finally, a mixed model was used to study effects of various management routines on earlier mentioned production variables from the milking robot. The management routines that were evaluated statistically were effects of cow traffic system (free vs controlled), effects of amount of concentrate in the feed mixture, effects of location of drinking water (barn and/or pasture), and effects of controlled vs free exit to pasture.

Results and discussion

The statistical analysis of the differences between indoor and pasture season using the official cow control data showed production data was higher during the indoor season compared with the pasture season (Table 1). Although cows were later in lactation during the pasture season, this factor was not significant in the statistical analysis and could therefore not be the major reason for the observed results.

In the analysis of the production data obtained from the milking robot (Table 2), there was only a tendency for difference in milk production. However, milking frequency per cow and per robot was higher just before pasture let-out, compared with the period after. The number of cows per robot was

Table 1. Milk production during the indoor season (November-March) compared with the pasture season (June-August) for farms in the study based on data from the official cow control system. Least square means, standard error and significance (n=20).

	Indoor season	Pasture season	Standard error	Significance[1]
Milk, kg	29.5	28.4	0.4	*
ECM[2], kg	30.1	28.4	0.4	***
Milkfat, kg	1.23	1.13	0.02	***
Milkprotein, kg	1.01	0.96	0.01	**

[1] * = $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

[2] ECM = energy corrected milk.

Table 2. Effect of season on production parameters based on data from the milking robots on the farms in the study, during indoor and early pasture season, i.e. approximately 1.5 months before and after pasture let-out. Least square means, standard error and significance (n=20).

	Indoor	Early pasture	Standard error	Significance[1]
Robot utilisation, %[2]	78.7	74.7	0.7	***
Milkings robot^{-1}	149	143	2	**
Milkings cow^{-1}	2.57	2.45	0.04	**
Milk robot^{-1}	1,779	1,737	42	Tend
Milk cow^{-1}	30.0	29.7	0.4	Tend

[1] Tend = $P<0.1$; * $P<0.05$; ** = $P<0.01$; *** = $P<0.001$.

[2] % of time the robot is utilized.

significantly lower in the pasture season (57.5) compared with the indoor season (60.1) ($P<0.05$) and the number of cows was therefore included in the models.

The management differed substantially between farms. Pasture let-out differed substantially, occurring between early April and late May. Nineteen of the 20 farms in the study fed supplementary silage indoors throughout the summer period. Most of the farms (17) reported that they fed at least 6 kg dry matter (DM) silage in the summer compared with at least 12 kg DM in the winter period. Eight farms had no concentrate feeders while remaining farms had between 1 and 3. The amount of concentrate that was fed in the feed-mix varied, eight farms reported that the mix contained only 0-1 kg concentrate per cow while 10 farms made a mix with 2-5 kg concentrate and two farms had 6-8 kg concentrate in the mix. A majority of the farms (17) practiced some type of rotational grazing and most common (8) was a rotation period of 10-20 days. Almost all farms (16) offered drinking water only in the barn. A total of 13 farms had some type of controlled pasture let-out, using a selection gate (9 farms) or some other system to prevent cows with milking permission to leave the barn. Half of the farms fetched cows late for milking each day, five once a day and five twice daily. There was a large variation between the farms with regard to how the pastures were situated in relation to the barn, how the cows walked out to the pasture area, and the walking distance to pasture. In this study none of the management factors studied had any statistically significant effect on production parameters such as milking frequency, milk yield or robot utilisation.

The data from the official cow control system showed that for the farms in the present study, the average yield per cow in milk was 29.5 kg energy corrected milk (ECM), somewhat higher than the national average for cows on organic farms with (n=144), and without (n=93) AM who produced 28.6 and 27.7 kg ECM, respectively. As a comparison, corresponding figures for all conventional farms were higher, but the same for the group with (n=557) or without (n=751) AM, 31.1 and 31.2 kg ECM, respectively.

In conclusion, the results showed that most production parameters such as number of milkings and robot utilization were significantly lower in the early grazing period compared with the indoor period just before pasture let-out on the studied farms. The reason that there were fewer milkings during the grazing season, even when the lower number of cows per robot had been accounted for, was probably a combination of increased synchronization in the herd and that the cows came later to milking. A system with controlled pasture let-out, i.e. a system that prevents cows with milking permission to go out, is an effective way to improve cow traffic during the pasture season. This could be combined with earlier milking permission during summertime to improve milking frequencies.

Acknowledgements

References

Mathijs E. (2004) Socio-economic aspects of automatic milking. In: Meijering A., Hogeveen H. and De Koning C.J.A.M. (eds.) Automatic milking, a better understanding, Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 46-55.

Application of grass and cow sensor data to support grazing management in high output systems

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Abstract

An experiment was conducted with the objective of evaluating whether the combined data from grazing and rumen pH sensors could be used to support grazing management. Data were collected during the 2014 grazing season from a 60-cow herd. The average milk yield was 26.1 kg milk cow^{-1} day^{-1}. The cows were housed during the night (16:00-06:00 h) and received 8.4 kg dry matter (DM) of conserved forage cow^{-1} day^{-1}. During the daytime (06:00-16:00 h) the cows were strip-grazed. Daily, the cows were given an edible herbage allowance of approximately 8 kg DM above 5 cm stubble height cow^{-1}. Automatic milking system visits and milk yields were collected per cow. Concentrates were fed during milking with a transponder-controlled concentrate dispenser. Each cow was equipped with a grazing sensor to measure grazing time. Eight cows were equipped with boluses to measure rumen pH. Milk yield was recorded for each milking and milk composition was recorded weekly. Pre- and post-grazing sward height and herbage composition were recorded daily. Relationships between grass and sensor data and cow performance were derived on the basis of retrospective analysis of milk performance, grazing behaviour and rumen pH data. Rumen pH sensors appear to be of little value. There was no clear relationship between grazing activity and pasture characteristics.

Keywords: grazing, sensor, feeding, dairy cows

Introduction

In the Netherlands, dairy farming is characterized by a high milk output per cow. High milk yield requires high nutrient intake from well-balanced rations with little daily variation in composition. With grazing, feed allowance and diet composition are under less control than in confinement systems. This limited control over feed intake and diet composition is an important driver for dairy farmers to abandon grazing. However, recent technical developments have yielded a number of different sensors to measure cow behaviour (cow activity meters, grazing monitors) and rumen indwelling devices to record rumen pH. These sensors are potentially helpful for improving grazing management by providing farmers with information on changing grazing conditions and by giving better control over dry matter (DM) intake, nutrient intake and rumen function. It is widely recognized that the intake of highly digestible pasture herbage with low effective fibre and high concentrations of rapidly fermentable water soluble carbohydrates (WSC) may cause a depression of the rumen pH, resulting in sub-acute rumen acidosis (SARA). Based on a meta-analysis, Zebili and Metzler-Zebili (2012) proposed to define SARA as rumen pH <5.8 during 6 hours per day.

Low rumen pH and SARA are often associated with a reduced DM and fibre digestibility. Rumen pH sensors may help farmers to avoid these risks and adjust the feeding strategy by providing fibrous forage or concentrate supplements.

Sward structure (sward height and sward density) affects grazing behaviour of cattle. Within certain limits an animal is able to adjust its grazing time response to the structure of the sward (height and density) in order to maintain dry matter (DM) intake. Grazing activity sensors may provide information indicating whether available grazing time or grazing activity could be limiting for herbage DM intake at grazing.

This pilot study focusses on the potential of grazing activity and rumen pH data recorded with commercial sensors in conjunction with grassland data (composition, pre-grazing sward height) as tools to assist farmers with their grazing management.

Materials and methods

An experiment was conducted at the 'dairy campus' experimental farm in Leeuwarden, the Netherlands. The herd consisted of 60 Holstein-Friesian dairy cows, which were milked with a DeLaval automatic milking system (AMS). Between 16:00 and 6:00 h the cows were housed in a cubicles shed with a concrete slatted floor, a self-lock feeding fence and a computer-controlled concentrates feeder. At 16:30 h, the cows were fed a mixture of 30% grass and 70% maize silage on a DM basis at a rate of 8.4 kg DM cow^{-1} day^{-1}. The feed mixture was accessible until 6:00 h. Between 6:00 h and 16:00 h the cows were outside and strip grazing was used. The size of the grazed strips was adjusted daily to create a pasture allowance of 8 kg DM cow^{-1} day^{-1}. Measures of milk production (yield and frequency) were recorded at the AMS. All cows were equipped with a sensor which was attached at the neck and was able to record activity and intake behaviour. The sensor recorded total grazing time in 15-minute periods. Eight multiparous cows were equipped with indwelling systems (boluses) for monitoring reticulo-ruminal pH. Rumen pH was measured at intervals of 1 minute and averaged every 15 minutes, providing 96 recordings per day. During two measurement periods (Period 1 from 16 June – 26 July and Period 2 from 11 August – 14 September); the daily pre- and post-grazing DM yields of the pasture sward were estimated using a rising plate meter. In addition, the grazed herbage was sampled daily and analysed for the concentrations of DM, crude protein (CP), WSC, crude fibre, neutral detergent fibre (NDF), ash and organic matter digestibility (OMD%). The rising plate meter measurements were calibrated weekly, using the double sampling technique (Lantinga *et al.*, 2004).

Results and discussion

During the measurement periods there was considerable daily variation in the concentration of CP, WSC, and NDF (Figure 1). Higher grass heights were associated with lower concentrations of CP and NDF and higher concentrations of WSC. During Period 2, data transmission of five out of eight rumen pH boluses failed, and pH measurement of one bolus showed a large drift. Therefore, only rumen pH data for Period 1 are presented (Figure 2). Mean rumen pH differed among cows, but the diurnal pattern of rumen pH was very similar. In all cows, the nadir occurred shortly after feeding of the supplementary forage. Thereafter, rumen pH increased gradually and remained constant during the daytime at pasture. None of the measurements of rumen pH during the daytime were below the threshold value of pH 5.8. This suggests that the common advice (www.deweideman.nl, April 4, 2014) to provide cows which graze with high WSC pastures with supplementary forage in order to avoid low rumen pH, needs reconsideration. During Period 1, higher grass heights were associated with increased grazing time (not shown). However, the opposite was expected. Shorter swards are more difficult to graze, and cows can compensate for this by increasing their grazing time. The lower milk yields (Figure 3) when the cows were on shorter swards may
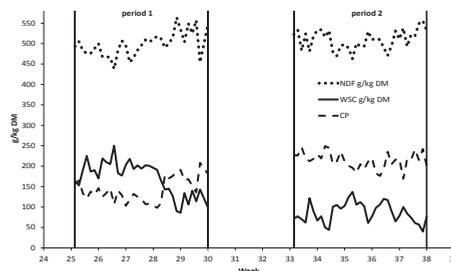
Figure 1. Concentrations (g kg^{-1} dry matter (DM)) of neutral detergent fibre (NDF), crude protein (CP), and water soluble carbohydrates (WSC) in the grazed grass.
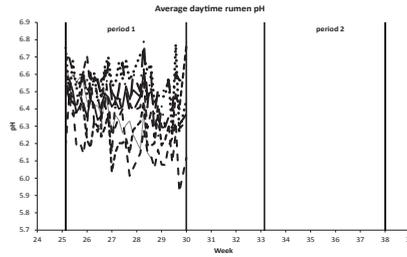
Figure 2. Mean daily rumen pH measured between 06:00 and 16:30 h.
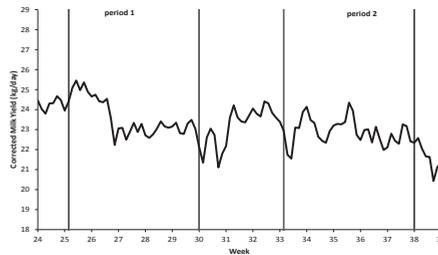
Figure 3. Milk yield (kg cow^{-1} day^{-1}) (all cows).
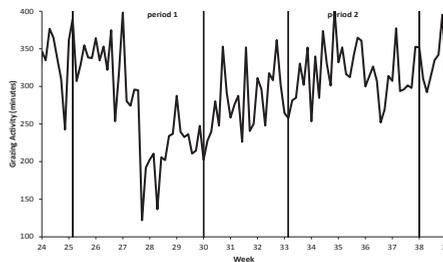
Figure 4. Mean grazing time measured between 06:00 and 16:30 h (all cows).

suggest that the cows reduced their DM intake. During Period 2 the relation between sward height and grazing time was less evident (Figure 4). In a grazing situation, factors such as the quality and growth of pasture herbage, weather conditions (rainfall, temperature, heat stress), day length and grazing behaviour are confounded. Further research on the role of these factors and their interactions would be desirable.

Conclusions

Rumen pH sensors are of little value as tools for grazing management because high WSC grass does not seem to be a risk factor for low rumen pH. Grazing activity sensors alone provide insufficient information as a support tool for grazing management.

Acknowledgements

References

Lantinga E.A., Neuteboom J.H. and Meijs J.A.C. (2004) Sward methods. In: Penning P.D. (ed.) *Herbage Intake Handbook, 2nd edition.* British Grassland Society, Reading, UK, pp. 23-52.

Zebeli Q. and Metzler-Zebeli B.U. (2012) Interplay between rumen digestive disorders and diet-induced inflammation in dairy cattle. *Research in Veterinary Science* 93, 1099-1108.

Session 2.
Grassland and fodder crops in high output systems

Production potential of grassland and fodder crops in high-output systems in the Low Countries in north western Europe and how to deal with limiting factors

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Abstract

The farming community currently growing fodder crops and grassland in areas with intensive dairy production in the EU is confronted with opportunities and threats related to (1) characteristics of cropping systems, (2) scientific and technological developments, (3) tightening of regulations, (4) scarcity of land and restricted freedom of use of the land, (5) changing climate and (6) changes in consumer attitudes and behaviour. Using highly productive varieties in appropriate crop rotations, and applying good agricultural practices, offers opportunities for reducing environmental impacts hence proactively preventing further strengthening of the regulations. The scarcity of land in densely populated areas and ongoing restrictions on the freedom to use the land are confronting intensive dairy farmers with problems for which technical solutions may not bring relief. The decreasing consumption of animal products in the developed world may change land use in the future.

Keywords: cropping systems, grassland, silage maize, regulations, land-use change

Introduction and scope of the paper

This text focuses on intensive dairy production systems in the Low Countries, in the coastal region in north-western Europe, where both herbage and forage crops (with a focus on silage maize) are used in animal rations. The area dedicated to grass or to silage maize is closely related to regulations regarding fertilisation: while regulations in the Netherlands are favouring grassland, this is not the case in Belgium. We report on optimising crop production within a context of regulations that continue to limit inputs by addressing the questions: 'How to enhance efficiency, nutrient-use efficiency and eco-efficiency in forage crop production?' Several technical and managerial options that influence the course of the production curve of grasses and silage maize are considered. Production curves can be taken to a higher level or their slope can change, e.g. by plant breeding and by good agronomic practices (Figure 1). Improved efficiencies result in reduced use of inputs, in producing more with equal amounts of inputs, or in producing with reduced levels of emissions. Legumes are mentioned here only briefly, as they have been addressed in recent EGF meetings. Potential effects of climate change and consumers' attitudes are intertwined where appropriate. No economic considerations are made.

Cropping systems: monocropping versus crop rotation

Intensive dairy farms in the lowlands of north-western Europe are predominantly dependent on two crops: grass and a cereal as an energy-supplying crop. Silage maize is the most important energy provider wherever the climate is favourable for its cultivation. The ratio of maize to grass silage in the rations supplied on farms with high milk production in the northern part of Belgium (Flanders) is about 60/40 from October to the end of April, whereas the ratio of silage maize to grass (grazed + conserved) is about 50/50 from May until the end of September. The high interest in silage maize is related to the high energy

content of the crop, which has substantially increased during the past decades. Indeed, compared to varieties grown around the year 2000, the newest varieties have a starch content in the dry matter (DM) that is about 20% higher, varying between 35 and 40% of the dry matter (data extracted from the Belgian Variety Catalogue Trials).

Silage maize is grown in a very tight crop rotation or in monocropping on many farms, which provides a very convenient cropping system in terms of economy and labour organisation (Van Eekeren *et al.*, 2008). Until recently many intensive dairy farms only had two crops: grass and silage maize, the latter frequently grown in monocropping. Nutrient regulations are tending to move the actual production away from the potential production. Given the shape of production functions, crops consequently become more sensitive to fluctuating environmental conditions and it is no longer an option to mimic or to restore bad agricultural practices by using extra inputs (Hanegraaf *et al.,* 2009; Nevens and Reheul, 2003; Smith *et al.*, 2007). There are more reasons to reconsider the cropping system. Simple repetitive agricultural practices such as monocropping favour weeds closely related to the crop (Murphy and Lemerle, 2006). The stable environment allows easy adaptation of the weeds to the control strategies (Harker, 2013). Maize monocropping entailed flora and weed shifts from broad-leaved weeds to panicoid grasses and favoured the development of herbicide-resistant biotypes of several weed species, e.g. the dicot species *Chenopodium album* and *Solanum nigrum* which became resistant to atrazine in the mid-1980s. Maize weed flora shifted from an easily controllable, species-rich well-balanced flora to a less easily controllable, unstable species-poor flora dominated by panicoid grasses in the years after 2010. Panicoid species such as *Echinochloa crus-galli, E. muricata, Digitaria ischaemum, D. sanguinalis, D. aequiglumis, Setaria viridis, S. verticillata, S. faberi, S. pumila, Panicum dichotomiflorum, P. schinzii and P. capillare* are currently spreading quickly within Belgian maize fields or are forming growing naturalized populations outside the fields (Groom, 2011; Hoste and Verloove, 2011; Van Landuyt *et al.*, 2006). According to Claerhout *et al.* (2015) weed populations from maize monocropping systems were consistently less sensitive (up to 14%) to foliar-applied maize herbicides than populations from cropping systems with maize in crop rotation.

Furthermore, crop rotation offers opportunities to fight some expanding pests (such as different species of soil nematodes and western corn rootworm, *Diabrotica virgifera virgifera*). It allows a more sustainable soil management (Lal, 2008, 2009), in particular a better management of soil organic matter and of nutrient dynamics (Kayser *et al.*, 2008; 2010; Spiertz, 2010; Thorup-Kristensen, 2006; Thorup-Kristensen *et al.*, 2012). The crop diversification topic within the greening of the Common Agricultural Policy (CAP) (2014-2020) may be considered as an incentive to focus on the value of crop rotations, although several scholars consider the new CAP as likely to be far too weak to result in any long-term provision of ecosystem services (Pe'er *et al.*, 2014).

Nevens and Reheul (2002b) compared silage maize grown in a 3-year rotation cycle (in the sequence of fodder beet, maize, faba bean and also in a sequence of fodder beet, maize, maize) with maize grown in monocropping during a period of over 10 years on a soil classified as silt loam (USDA soil texture classification) in Belgium. Crops were grown either on arable land continuously cropped with annual crops or in a ley-arable system (3 years grassland followed by 3 years arable land) and fertilised at different N levels. When grown on arable land continuously cropped with annual crops, maize in rotation outyielded maize in monocropping significantly in 80% of cases. The yield bonus (both DM yield and N-yield) was not significant at 180 kg N ha^{-1}, but was approximately 25% (and significant) at 75 kg N ha^{-1}. The effect on DM-yield of the crop rotation was marginal in the ley arable system (Figure 1).

The nitrogen dynamics in crop rotations and in ley-arable systems are modelled in Vertès and Mary (2007) and experimentally quantified in (1) Vertès *et al.* (2007), (2) Nevens (2003) and Bommelé (2007), reporting data from sandy loam soils in Belgium, and (3) more recently in Verloop (2013) reporting data
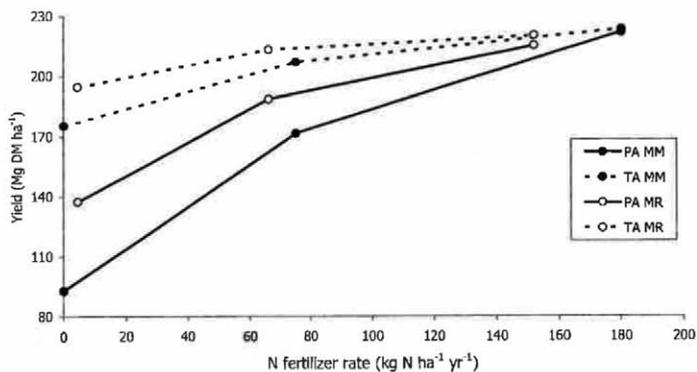
Figure 1. Yield of silage maize in relationship to nitrogen fertilisation. MM: maize in monocropping, MR: maize in crop rotation; PA: arable land continuously cropped with annual crops; TA: ley-arable system (3 years arable followed by 3 years ley or *vice versa*).

from sandy soils on the experimental farm The Marke in the Netherlands. The latter found no evidence for enhanced nitrate leaching due to the rotation of grass with silage maize compared to permanent cultivation, provided N fertilisation to the crops in the arable phase is adjusted. On the sandy loam soils in Belgium, the opening crop after the break-up of grassland did not need any N to produce a full yield. If maize was the opening crop, a cover crop was necessary to take up the residual mineralised N.

The inclusion of fodder beet in the crop rotation was very favourable for the environment, since this crop depleted the soil very effectively resulting in residual mineral soil nitrogen of less than 50 kg N ha^{-1} in a soil profile of 0-90 cm irrespective of the applied N fertilization. Carlier and Verbruggen (1992) studied nitrogen balances on 61 Flemish dairy farms and concluded that the farms that produced fodder beet had by far the lowest nitrogen surplus at the farm level. Growing fodder beet continues to be a challenge, although some of the drawbacks are more manageable than in the past decades. The more frequent occurrence of mild winters in the Low Countries may facilitate conservation of the fresh beets. Co-ensiling of ground beets with silage maize may take away the concerns regarding storage as fresh beets over winter, but it requires a good match of the harvest of both crops. Performances of dairy cows fed with this forage stay at very high levels provided the proportion of fodder beet in the silage is approximately 25% (on a DM basis) and soil contamination is low (De Brabander *et al.,* 1989). The techniques used to clean sugar beets can be used to remove most of the soil. However, the prospects for growing fodder beet in a crop rotation may be hampered by the rapid spread of *Rhizoctonia solani*, which is infecting fodder and sugar beet as well as maize and ryegrasses (Heremans *et al.*, 2007). We observed very important losses during winter conservation of fodder beets, produced in a long-term field trial at the University of Gent with a 4-year crop rotation: fodder beet – silage maize – Brussels sprouts – potato followed by Italian ryegrass as a cover crop (D'hose *et al.*, 2012) and we concluded that without using a *Rhizoctonia*-resistant variety, growing fodder beet in this rotation has no further value. These observations are supported by many experiences from practice, indicating that losses during conservation are frequently unacceptably high without *Rhizoctonia*-resistant cultivars. Currently, there are only a few *Rhizoctonia solani*-resistant varieties of fodder beet available in Europe.

Borelli *et al.* (2014) reported results of several cropping systems over a 26-year period on a sandy-loam soil in the lowlands of the Po Valley of northern Italy. Silage maize was tested in rotation cycles of 3 and 6 years with Italian ryegrass, grain maize, winter barley and ley. Crops were managed (1) either following farmers' practices or (2) with 30% less mineral inputs and 25% less herbicide inputs. The most important conclusion of the experiment was that year-to-year variability was overwhelming compared to the effect of the treatments and that the effects of crop rotation and input were more pronounced in low-yielding

years. They concluded that the rotation effect can compensate for a reduced input and that the adoption of rotation can be regarded as an insurance against low-yielding years; in other words, crop rotation improved yield stability: the longer the rotation, the better the yield stability, which is an important issue given climate change.

Nitrogen export and recovery

Nevens and Reheul (2002a,b) showed that N-export improved substantially in rotated maize (fodder beet, maize, maize) compared to maize in monocropping at equal N dressings. Rotated maize grown on permanent arable land with an N dressing of 180 kg ha^{-1} exported 7% more nitrogen than the maize in monocropping; at 75 kg ha^{-1} the bonus was 27%. In a ley-arable system, the surpluses were 5 and 7%, respectively.

Moreover, plant breeding may help to recover nutrients in different ways. Plant breeding continues to create silage maize varieties with a higher DM yield without the need for enhanced nutrient inputs. If the nutrient concentration does not decrease substantially, this must lead to a better nutrient productivity (DM yield per supplied quantity of nutrients) and smaller residues after harvest. Can we quantify this effect? Long-term analyses of the genetic progress in silage maize varieties show a more or less steady annual progress in DM yield of approximately 200 kg ha^{-1} during the period 1983-2012 (Laidig *et al.*, 2014; Piepho *et al.*, 2014; unpublished data of the analysis of the Belgian Variety Catalogue Trials). There are no signals that this progress is slowing down in forthcoming European varieties. According to silage maize breeders, there are no indications that these yield progresses come along with a dilution of nitrogen in the DM, but we have not found results of trials comparing old and new varieties at different N-levels. Analyses of maize silage in the Netherlands (BLGG, Wageningen) showed nearly constant total crude protein mean values in the period 2009-2011 and lower mean values in the period 2012-2014, but it is impossible to split genetic effects and non-genetic effects in these data. Nevens and Reheul (2002b) showed that nitrogen concentration in the DM increased with N fertilisation, and Wachendorf *et al.* (2006a) calculated this increase as 0.04 g (kg DM)$^{-1}$ per kg supplied N (within a range of 0-150 kg ha^{-1}). Barrière *et al.* (1997) found a negative correlation (r =-0.45) between N-content and biomass yield in 126 early hybrids in France. Experiences with grasses make us assume that the highest yielding varieties have a lower N concentration in the DM (although this decrease tends to become lower at high yield levels), but continue to have a higher N-yield (Figure 2). Trying to quantify this effect in silage maize, we come to the following speculative calculation. Assuming that varieties of a decade ago had a yield potential of 18 Mg DM ha^{-1} and current varieties have 20 Mg DM ha^{-1}, and also assuming an unchanged N concentration (1.2%), current varieties would export 24 kg N ha^{-1} more than varieties did a decade ago. If the actual N concentration is 5% points lower than before then the benefit would shrink to 12 kg ha^{-1}, and the benefit would disappear if the N concentration were to be 10% points less. So benefits
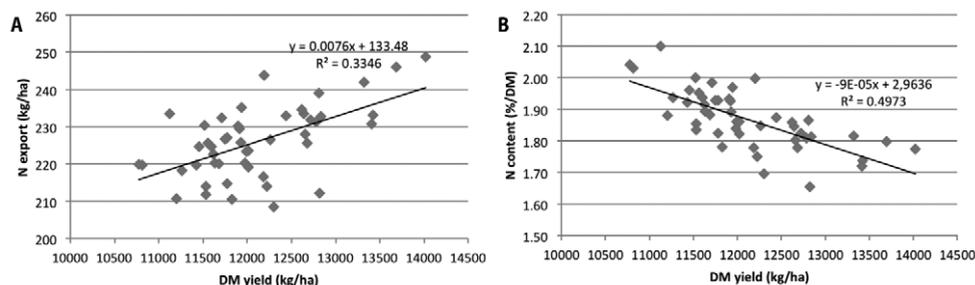
Figure 2. Relationship between N-content (A), N-export (B) and dry matter (DM) yield in 48 varieties and candivars of perennial ryegrass grown on a sandy loam soil in Belgium under a cutting regime; N-dressing: 260 kg ha^{-1} yr^{-1}. Data taken from the first year after the year of establishment.

are not miraculous but most probably non-negligible in soil nitrogen balances. The translation of this potential benefit into practice may be variable since Laidig *et al.* (2014) reported that only part of (if any) the genetic progress was capitalized in practice, proving that without good farming practices, genetic gains are not fully discounted. Or to turn it around: it takes good farming husbandry to benefit from breeding progress.

The role of catch crops is essential to reduce nutrient losses in all cropping systems. Cover crops need to be sown early in order to be effective. Schröder *et al.* (1996) and Schröder (1998) regressed the N-uptake by winter rye sown after the harvest of silage maize or Italian ryegrass undersown in the maize on the temperature sum (threshold 5 °C) starting from the sowing date (winter rye) or harvest of the maize. It took about 7 day×degrees to take up 1 kg N ha^{-1}, reflecting that in Dutch conditions a day in mid-September offers the opportunity to recover about 2 kg N ha^{-1}. Well-used cover crops can reduce the residual soil mineral nitrogen by approximately 50% (Schröder *et al.*, 1998; Wachendorf *et al.*, 2006). This means that late maturing silage maize varieties do not fit into good agro-environmental practices. Since the early maturing varieties may be as much as 5-10% less productive (e.g. Belgian Variety Catalogue Trials) a yield penalty can hardly be avoided by growing early varieties. However, early varieties usually allow (1) a harvest in better weather conditions causing less damage to soil structure and (2) an earlier installation of cover crops. Although it may be hard in the short term not to grow the most productive maize varieties, the proactive implementation of good agricultural practices (such as the tandem: early maturing maize followed by an effective cover crop) may avoid further tightening of the regulations, and which can be considered as an advantage in the long term.

At least two breeding companies in the EU are developing (non-GM) herbicide-tolerant varieties of *Lolium perenne* and *Festuca arundinacea*. The idea is to sow them simultaneously with the silage maize: applied herbicides suppress the early growth (thus minimizing the competition) and the grasses start to grow vigorously immediately after the maize harvest, provided they are not severely damaged by the harvesting machines. Undersowing takes away the need for soil tillage after the maize harvest and it eliminates the risk of not being able to timely install the cover crop. A trial at Gent University compared undersown tall fescue with Italian ryegrass installed immediately after the maize harvest (23 September) in 2014. The above-ground biomass of Italian ryegrass outyielded the above-ground biomass of undersown tall fescue at the end of February 2015. The very warm autumn of 2014 may have taken away the potential advantage of undersowing. There is a need for more research regarding the use of appropriate herbicides in order to find an equilibrium between suppressed early growth, competition with the silage maize and a quick recovery after the maize harvest.

Breaking-up of grassland

We are convinced that good grassland should be extremely well taken care of in order to keep it in good shape for as long as possible. Only if the botanical composition no longer allows high yields should break-up of the sward be considered. The newest CAP regulations have made it very difficult to break up permanent grassland. Keeping grassland in good condition is very much a management issue. The larger the herds, the more difficult it becomes to keep the grassland in good condition, either because of the heavy trampling by large groups of grazing animals or – as in case of zero grazing – the waning attention for any field activities. We have noticed during the past years that a high regional density of harvesting machines operated by professional contractors allows for quick harvests of cut grass during small windows of good weather conditions and we consider this as one of the best insurances for the persistence of productive grassland. If grassland should eventually be broken-up, it is common knowledge that spring-ploughing causes less N losses than autumn-ploughing (e.g. Schmeer, 2012) and that the older the sward, the greater its nitrogen fertilizer replacement value (NFRV). More data are provided in Nevens (2003) and Verloop (2013). We have commented in the previous section that an arable period

is a good option to take advantage of the NFRV provided one takes care to ensure a near-permanent groundcover by using appropriate crops and cover crops. An underestimated problem is the potential for insect damage to the opening crop, resulting in the substantial loss of seedlings. The problem can be solved by the use of insecticides but there is a need for other options. Crops that compensate for the loss of individual plants, e.g. because the surviving plants produce extra tillers (as in the case of forage grasses and cereals) can limit the damage. Early maturing spring cereals with stiff straw allow a timely installation of a cruciferous cover crop guaranteeing a good uptake of residual nitrogen. Another option is to install annual or perennial ryegrass to be harvested as a forage in the autumn and the following spring. Kayser *et al.* (2008) ploughed up 9-year-old grassland in the spring at three locations in Germany and installed spring barley followed by yellow mustard during year 1 and silage maize in year 2, to be compared with silage maize grown during the first 2 years. The barley+cover crop reduced the soil mineral nitrogen by about 50%. Schmeer (2012) used a spring cereal as break crop in northern Germany before re-installing grassland and showed that this option reduced N leaching by 40% compared to autumn ploughing. Ansari *et al.* (2009) and Campos-Herrera and Guttiérez (2009) reported on new work regarding the use of pathogenic strains of entomopathogenic nematodes and fungi for wireworm control. The former concluded that the combined use of these biocontrol agents may prove synergistic in the control of wireworms and may offer a chemical-free approach to control this pest.

Renewing grassland offers, in theory, the opportunity to take advantage of progress in plant breeding. However, progress in grass and white clover breeding has been much smaller than in arable crops. Chaves *et al.* (2009), analysing the Belgian official variety trials in the period of 1966 to 2007, reported an annual genetic gain in DM yield of about 0.3% for both *Lolium perenne* and *Lolium multiflorum*, data that are close to the results of Laidig *et al.* (2014) based on the German official variety trials. The annual genetic progress in DM yield of white clover and red clover is similar (Annicchiarico *et al.,* 2014): about 0.5% per year. This means that in the short term no spectacular yield advances are to be expected owing to genetic progress, all the more because the capitalizing of the genetic gain of grass varieties in practice seems very inconsistent (Laidig *et al.*, 2014). In the absence of spectacular genetic gains, good agronomic practices can offer remarkable opportunities.

Reheul *et al.* (2007) and Bommelé (2007) reported substantial differences in DM yield between grassland sown after ploughed-down grassland and grassland sown on arable land. Grassland established on arable land significantly outyielded renewed grassland (means of N fertilizations of 100, 300 and 400 kg ha^{-1} yr^{-1}) during the first two years after the year of (spring) establishment. The DM yield bonus over a period of three years (the year of establishment was not included) was 10%; even at 400 kg N ha^{-1} yr^{-1} the bonus was still 5%. It was even 20% in 2003, a year with a very dry summer. In addition, the establishment of white clover was much better on arable land than in renewed grassland, most probably because of the high amounts of mineralized N after renewing: over a period of three years (year of establishment not included), white clover DM in the total DM yield was twice as high in grassland installed on arable land compared to renewed grassland (means over N rates of 0, 100, 300 and 400 kg ha^{-1}). All benefits started to fade away after the third year of establishment. Therefore, remarkable but partly unexploited benefits can be gained by installing grassland in arable land instead of resowing it. These data are valuable in the context of adaption to the effects of climate change, with a higher probability of dry summers in temperate Europe.

Growing more drought-tolerant species is another option to cope with dry periods and climate change in general. *Dactylis glomerata* and *Festuca arundinacea* (tall fescue) are promising species in this respect (Pontes *et al.,* 2007). Cougnon *et al.* (2014) studied perennial ryegrass and tall fescue in Belgium either in a single-species sward (300 kg N ha^{-1} yr^{-1}) or mixed with white clover (165 kg N ha^{-1} yr^{-1}) under a cutting regime. Over a period of three years following the year of establishment, pure swards of tall

fescue outyielded pure swards of perennial ryegrass by 23%; the difference between perennial ryegrass and tall fescue increased every year, and during dry spells differences were as high as 50% (Cougnon, 2013), most probably owing to the deeper rooting of tall fescue. Since N-content of the two species was not significantly different, tall fescue showed a net higher N-productivity than perennial ryegrass. A trial studied during 2011-2014 with both tall fescue, meadow fescue, perennial ryegrass, hybrid ryegrass and *Festulolium* confirmed the high DM yield, N-export (Figure 3), N-productivity and N-recovery of tall fescue compared to the other species (Table 1). Disadvantages of the species, compared to perennial ryegrass, are the lower digestibility of the organic matter (up to 7%-units less; Cougnon *et al.*, 2014), the slow establishment and the lower animal preference. Progress in breeding for these traits probably will come at the expense of DM yield. The lower animal preference tends to disappear when the forage is wilted and ensiled (Luten and Remmelink, 1984). The lower digestibility of the organic matter is less of a problem when farms are in need of rations with a high structural value or fibre content.

Access to land

The access to land is threatened in some areas by land use changes and the operational freedom is hampered by ever increasing regulations. Land is taken out of agriculture particularly in densely populated and peri-urban areas, both for urbanization, roads and industry, as well as for non-agricultural biological production (Poelmans, 2010). The scarcity of agricultural land is leading to increased competition between farmers for the available land, thus increasing land prices.

According to Poelmans (2010) built-up areas will occupy about 15% of the territory of Belgium, the Netherlands, the northern part of France, the western part of Germany and the south of UK by 2030;
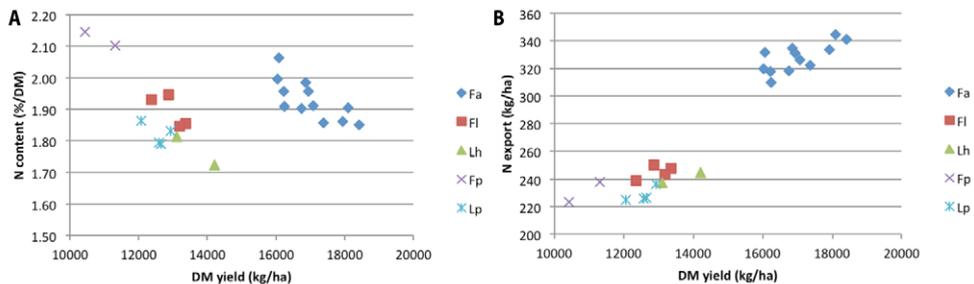
Figure 3. Relationship between N-content (A), N-export (B) and dry matter (DM) yield in five grass species grown on a sandy loam soil in Belgium. Field trial with cutting regime established in September 2011. Data taken from 2013; N-dressing: 300 kg ha^{-1} yr^{-1}. Fa: *Festuca arundinacea*, Fl: × *Festulolium*; Lh: *Lolium × hybridum*; Fp: *Festuca pratensis*, Lp: *Lolium perenne*.

Table 1. Dry matter (DM) yield (kg ha^{-1}), N-export (kg ha^{-1}), N-recovery (kg N exported (kg N supplied)$^{-1}$), nutrient-use efficiency (NUE) (kg DM (kg N$_{exported}$)$^{-1}$), N-productivity (kg DM (kg N$_{supplied}$)$^{-1}$) and N-content (%) for *Festuca arundinacea* (Fa), *Festulolium* (Fl) and *Lolium perenne*. Same trial as in Figure 3. Cumulative data of 10 cuts in the period 2012-2014. Standard deviations between brackets.

	300 kg N ha^{-1} yr^{-1}			190 kg N ha^{-1} yr^{-1}		
	Fa (n=12)	Fl (n=4)	Lp (n=4)	Fa (n=12)	Fl (n=4)	Lp (n=4)
DM yield	32,264 (1,333)	29,986 (1000)	28,812 (504)	25,740 (1,675)	25,465 (610)	23,282 (734)
N-export	612 (17.4)	540 (10.7)	506 (3.0)	462 (24.4)	417 (18.4)	378 (6.8)
N-recovery	1.02	0.9	0.84	1.22	1.10	0.99
NUE	53	56	57	56	61	62
N-productivity	54	50	48	68	67	61
N-content	1.90	1.80	1.76	1.79	1.64	1.62

mostly areas with an important dairy farming. Bomans *et al.* (2011) concluded that about 5% of the total area of Flanders is taken up by 'horsification', representing nearly 70,000 ha, in order to feed at least 140,000 horses. Belgium had 485,000 dairy cows in 2012 (Statbel). At least half of these 70,000 ha was former agricultural land until quite recently. One third of the Flemish pasture land is used for horses. This area is very unevenly distributed over the territory: few horses in the western part of the region, where both dairy, arable crops and vegetable production are very important, and high numbers in the province of Antwerp, also a very important dairy area. According to Van der Windt *et al.* (2007) there were about 400,000 horses in the Netherlands (occupying approximately 200,000 ha with a very strong growth in the 1990s). There were about 1.44 million dairy cows in the Netherlands in 2006 (Eurostat). Therefore, in both Belgium and the Netherlands the number of horses is at least a quarter of the number of dairy cows. A similar 'horsification' trend is found in the peri-Berlin area in Germany (Zasada *et al.*, 2013) with both extensive and intensive (up to 52 horses per ha) holdings. Horse-keeping increases land prices and creates ambivalent environmental impacts. The extensively managed holdings may be beneficial for the environment, landscape and biodiversity while intensively managed holdings are characterized by overgrazing with high loads of nutrients and detrimental consequences for the visual landscape (Zasada *et al.*, 2013).

More challenges, threats and trade-offs in intensive dairy systems

The huge imports of protein into Europe are calling, at about every 10 years, for more home-grown proteins. In the past, grass has been considered as a protein crop but the restrictions on N input may put an end to this. It is common knowledge that both DM yield and N concentration drop with decreasing N supply (as can be deduced in Table 1). The current N input on grassland under a cutting regime is set on 300-320 kg ha^{-1} plant available N in Flanders and in the Netherlands (385 kg ha^{-1} on clay soils in the Netherlands). Bommelé (2007) calculated an average N yield of 374 kg N ha^{-1} during 2002-2005 for different types of grassland – both permanent and young grassland – managed under a cutting regime with a mineral N supply of 300 kg ha^{-1}. The corresponding average DM yield was 13,754 kg ha^{-1}, resulting in a N-content of 2.72% (crude protein content of 17%.) The N-content in Table 1 is much lower (probably owing to higher yields): on average about 1.80% at 300 kg N ha^{-1}. Tighter restrictions may further decrease the N yield and concentration, resulting in grass with rather low contents of crude protein (on average 11.3% protein at 300 kg N ha^{-1} and 10.5% crude protein at 190 kg N ha^{-1}: Table 1) and hence a growing need to supply more non-grass protein. If grass has to be considered as a protein crop, the use of sufficient nitrogen is crucial. There is ample organic N available on dairy farms but its use is limited to 170 kg ha^{-1} in Belgium and the Netherlands. In cases where derogation (coupled with a number of restrictions on land use, cover crops and mineral P-fertilisation) is allowed, up to 230-250 kg ha^{-1} slurry N is allowed. The derogation is crucial under the high-output system: without derogation, both grazing and on-farm nutrient recycling come under pressure. A good recycling allows more farm-produced protein (particularly with grass), thus restricting the import of non-farm protein.

Westhoek *et al.* (2011) provide an excellent overview of the protein puzzle. In line with the CAP reform 2014-2020 many member states are supporting protein crops from 2015 on. Protein crops fit into two parts of the new regulation: they can figure as a third crop and they are eligible in the frame of Ecological Focus Area. As a consequence, the fading production of peas, faba beans and lucerne may resume. The grain legumes all have at least one constant when grown in temperate areas: the yield stability cannot compete with the stability provided by grassland and silage maize. Recently new initiatives are being taken to breed and to grow soybeans in areas where this crop has never been considered before. Preliminary results clearly show that opportunities are limited in the short term in temperate climate regions of Europe. Current early-maturing types have a growing season that ends late in September, jeopardizing a safe harvest. Their yields in Belgium and the Netherlands are at about 2.5-3.0 Mg ha^{-1} (at 15% moisture). Since annual progress by breeding varies between 10 and 45 kg ha^{-1}, a combination

of breeding efforts and good agronomic practices will be necessary to substantially increase yields in the mid- and long-term (J. Aper, soy breeder at ILVO). Combining silage maize with a protein crop is also a returning issue. Although the potential advantages of multispecies cropping systems are well known (e.g. Malézieux *et al.*, 2009) farmers' adoption has been extremely low so far in Europe. The KWS breeding company in Germany is putting a lot of effort in combining silage maize with *Phaseolus* beans with realistic perspectives. The eligibility of crop associations within the context of crop diversity of the CAP may help to implement this association in practice. Several European breeding companies and institutes are increasing breeding work with forage legumes: white and red clovers are the favourites in the lowlands and more attention is going to the development of varieties performing well in mixtures with grasses.

There is an ongoing trend in the western world to consume less animal products, including dairy products; the opposite is occurring in developing countries (Westhoek *et al.*, 2011). Several drivers push consumers to consume less livestock products, e.g. the realisation that overconsumption of animal products is unhealthy, that livestock need large areas for feed production, and that livestock production has a large water footprint as indicated by Mekonnen and Hoekstra (2010, 2012). People get overwhelmed with water consumption values of up to 15,000 l kg^{-1} meat, but usually it is not mentioned that this includes the rainwater falling on crop and pasture land. As rain is falling on any land (be it cropped or not), this figure has no honest meaning in the absence of a comparison with other outputs of the land. If the downward trend of consumption of animal products in the EU continues, one can wonder what the consequences will be for dairy farming in the EU and for the associated crop production. Westhoek *et al.* (2011) studied several scenarios regarding decreases in consumption of animal products in the EU. Modelling showed that when consumption of livestock products decreases by one third, the grassland area in the EU would decrease by 4%. The model predicts a more extensive production system but farmers would only abandon grassland to a minor extent in order not to lose CAP subsidies. The area cultivated with arable crops would not decrease; on the contrary it would increase by 2 million ha compared to the reference (situation 2007) scenario, and biodiversity would suffer due to the loss of pasture land. Based on modelling, and making a lot of assumptions (e.g. permanent grassland stays as permanent grassland), Westhoek *et al.* (2014) concluded that if we halve our animal protein intake, 9.2 million ha of temporary grassland and 14.5 million ha of arable land would no longer be necessary to feed European livestock; this land would be used for cereal production or for perennial energy crops. N emissions would decrease by approximately 40%; greenhouse gases by approximately 40% if perennial energy crops are grown, and by approximately 20% in the case of cereal production.

Reidsma *et al.* (2006) quantified the impacts of land-use change on biodiversity in the EU. One of their striking statements is 'The ecosystem quality of intensively managed grassland corresponds to the situation between extensive (ecosystems quality of 25%) and intensive (ecosystems quality of 10%) cropland management' indicating that even intensively managed grassland is not too bad for biodiversity. Particularly because its value for ecosystem services, biodiversity conservation, landscape diversification and cultural or historical heritage, more and more grassland is confronted with strong restrictions for use and management. Danckaert *et al.* (2008) analysed the legal status of permanent grassland in Flanders and came to remarkable conclusions. About a quarter of the agricultural area of Flanders is covered by permanent grassland (approximately 150,000 ha). About 80% of this surface is situated in areas with at least one legal way of protection with corresponding restrictions for management and use. About 20% is historical permanent grassland and/or ecologically fragile grassland with a forthcoming absolute prohibition to plough the sward or to renew it. This may be good news for nature conservation but it substantially restricts the degrees of freedom for farming activities. If one has a high proportion of land affected by these limitations, surviving becomes very difficult. Owing to recent decisions regarding N emissions, farmers may lose their licence to produce when their farm is in the vicinity of a Natura 2000 area. According to Folke *et al.* (2014) cowsheds and fertilization activities are responsible for 50% and

45%, respectively, of the ammonia emissions in Dutch agriculture. It is clear that in these circumstances the fertilization of crops will be monitored very strictly and that future fertilization will have to be as emission-poor as possible and as tight as possible related to the crops' needs.

Conclusions

Intensive dairy systems are very closely linked with nutrient management and land use. The efficient use of nutrients will be crucial to maintain high crop yields. Good crop husbandry, well planned cropping systems and the best available agronomic practices, underpinned by plant breeding, are necessary to optimize yields in times of restrictions of nutrient use. The protein content in grass is declining and hence more non-grass protein will be needed in case restrictions become further strengthened. An important dilemma is whether or not to use home-grown protein or to use imported protein. The availability of land will be a crucial factor in this debate. Scarcity of land, the shrinking degrees of freedom to use it, and developments in the margins of, or outside the agricultural world, are calling for a continuous vigilance in order to safeguard intensive dairy systems.

References

Annicchiarico P., Barett B., Brummer E.C, Julier B. and Marshall A. (2014) Achievements and challenges in improving temperate perennial forage legumes. *Critical Reviews in Plant Sciences* 34, 327-380.

Ansari M.A, Evans M. and Butt T.M. (2009) Identification of pathogenic strains of entomopathogenic nematodes and fungi for wireworm control. *Crop Protection* 28, 269-272.

Barrière Y., Argillier O., Michalet-Doreau B., Hébert Y., Guingo E., Ciauffret C. and Emile J.C. (1997) Relevant traits, genetic variation and breeding strategies in early silage maize. *Agronomie* 17, 395-411.

Bomans K., Dewaelheyns V and Gulinck H. (2011) Pasture for horses: an underestimated land use class in an urbanized and multifunctional area. *International Journal of Sustainable Development and Planning* 6, 195-211.

Bommelé L. (2007) *Growing potatoes and grass-clover after turned down grassland*. PhD thesis, University of Gent, Belgium.

Borrelli L., Castelli F., Ceotto E., Cabassi G. and Tomasoni C. (2014) Maize grain and silage yield and yield stability in a long-term cropping system experiment in Northern Italy. *European Journal of Agronomy* 55, 12-19.

Campos-Herrera R. and Guttiérrez C. (2009) Screening Spanish isolates of steinernematid nematodes for use as biological control agents through laboratory and greenhouse microcosm studies. *Journal of Invertebrate Pathology* 100, 100-105.

Carlier L. and Verbruggen I. 1992. *Report of the activities of the national centre for research into grassland and fodder crops*. 36 pp. In Dutch.

Chaves B., De Vliegher A., Van Waes J., Carlier L. and Marynissen B. (2009) Change in agronomic performance of *Lolium perenne* and *Lolium multiflorum* varieties in the past 40 years based on data from Belgian VCU trials. *Plant Breeding* 128, 680-690.

Claerhout S., Reheul D. and De Cauwer B. (2015) Sensitivity of *Echinochloa crus-galli* populations to maize herbicides: a comparison between cropping systems. *Weed Research*, in press.

Cougnon M. (2013) *Potential in mixes swards and breeding of tall fescue* (Festuca arundinacea *Schreb*). PhD thesis, Gent university, Belgium. 257 pp.

Cougnon M., Baert C., Van Waes J. and Reheul D. (2014a) Performance and quality of tall fescue (*Festuca arundinacea* Schreb.) and perennial ryegrass (*Lolium perenne* L.) and mixtures of both species grown with or without white clover (*Trifolium repens* L.) under cutting management. *Grass and Forage Science* 69, 666-677.

Cougnon M., Baert J. and Reheul D. (2014b) Dry matter yield and digestibility of five cool season forage grass species under contrasting N fertilizations. *Grassland Science in Europe* 19, 175-177.

D'hose T., Cougnon M., De Vliegher A., Willekens K., Van Bockstaele E. and Reheul D. (2012). Farm compost application: effects on crop performance. *Compost Science and Utilization* 20, 49-56.

Danckaert S., Carels K. and Van Gijseghem D. (2008) *Legal-scientific state of permanent grassland in the framework of cross compliance*. Flemish Community, Department of Agriculture and Fishery, section Monitoring and Study, 57 pp. In Dutch.

De Brabander D., Vanacker J.M., Andries J.I., De Boever J.L. and Buysse F.X. (1989). Silage of maize mixed with fodder beet for dairy cows. *Landbouwtijdschrift* 42(6), 1391-1405. In Dutch.

Eurostat (nd) *Dairy cow population 2001, 2006, 2011*. Available at: http://tinyurl.com/lbrlesk.

Groom Q. (2011) *Manual of the alien plants of Belgium*. Available at: http://alienplantsbelgium.be.

Folke R., Arnouts R., Backes C., van Dam J., Van der Hoek D-J. and van Schijndel M. (2014) *Assessment of a programmatic approach of nitrogen: expected impact for nature and licenses to produce.* Planbureau voor de Leefomgeving, Den Haag, the Netherlands. 218 pp. In Dutch.

Hanegraaf M.C., Hoffland E., Kuikman P.J. and Brussaard L. (2009). Trends in soil organic matter contents in Dutch grassalnds and maize fields on sandy soils. *European Journal of Soil Science* 60, 213-222.

Harker K.N. (2013) Slowing weed evolution with integrated weed management. *Canadian Journal of Plant Science* 93, 759-764.

Heremans B., Garrido S.A. and Haesaert G. (2007). The aggressiveness of *Rhizoctonia solani* isolates. *Communications in Agricultural and Applied Biological Sciences* 72(4), 989-991.

Hoste I. and Verloove F. (2001) The expansion of C4 grasses in quickly shifting weed vegetations in maize fields between Brugge and Gent. *Dumortiera* 78, 2-11. In Dutch.

Kayser M., Müller J. and Isselstein J. (2010) Nitrogen management in organic farming: comparison of crop rotation residual effects on yields, N leaching and soil conditions. *Nutrient Cycling in Agroecosystems* 87, 21-31.

Kayser M., Seidel K., Müller J. and Isselstein J. (2008) The effect of succeeding crop and level of N fertilisationon N leaching after break-up of grassland. *European Journal of Agronomy* 29, 200-207.

Laidig F., Piepho H-P., Drobek T. and Meyer U. (2014). Genetic and non-genetic long-term trends of 12 different crops in German official variety performnance trials and on-farm yield trends. *Theoretical and Applied Genetics* 127, 2599-2617.

Lal R. (2008) Soils and sustainable agriculture. *Agronomy for Sustainable Development* 28, 57-64.

Lal R. (2009) Laws of sustainable soil management. *Agronomy for Sustainable Development* 29, 7-9.

Luten, W. and Remmelink, G.J. (1984) *Intake of perennial ryegrass, tall fescue and Italian ryegrass by dairy cattle*. Proefstation foor Rundveehouderij, Lelystad, the Netherlands. In Dutch.

Malézieux E., Crozat Y., Dupraz C., Laurans M., Makowski D., Ozier-Lafontaine H., Rapidel B., De Tourdonnet S. and Valantin-Morison M. (2009) Mixing plant species in cropping systems: concepts, tools and models. A review. *Agronomy for Sustainable Development* 29, 43-62.

Mekonnen M.M. and Hoekstra A.Y. (2010) *The green, blue and grey water footprint of farm animals and animal products*. Value of Water Research Report Series No. 48, UNESCO-IHE, Delft, the Netherlands.

Mekonnen M.M. and Hoekstra A.Y. (2012) A global assessment of the water footprint of farm animal products. *Ecosystems* 15, 401-415.

Murphy C.E. and Lemerle D. (2006) Continuous cropping systems and weed selection. *Euphytica* 148, 61-73.

Nevens F. (2003). *Nitrogen use efficiency in grassland, silage maize and ley/arable rotations*. PhD thesis, Gent University, Gent, Belgium. 231 pp.

Nevens F. and Reheul D. (2002a) Crop rotation versus monoculture: yield, N yield and ear fraction of silage maize at different levels of mineral N fertilization. *Netherlands Journal of Agricultural Science* 49, 405-425.

Nevens F. and Reheul D. (2002b) The nitrogen – and non-nitrogen contribution of ploughed grass leys on the following arable forage crops: determination and optimum use. *European Journal of Agronomy* 16, 57-74.

Nevens F. and Reheul D. (2003) The consequences of wheel-induced soil compaction and subsoiling for silage maize on a sandy loam soil in Belgium. *Soil and Tillage Research* 70, 175-184.

Pe'er G., Dicks L.V., Visconti P., Arlettaz R., Báldi A., Benton T.G., Collins S., Dieterich M., Gregory R.D., Hartig F., Henle K., Hobson P.R., Kleijn D., Neumann R.K., Robijns T., Schmidt J., Shwartz A., Sutherland W.J., Turbé A., Wulf F. and Scott A.V. (2014) EU agricultural reform fails on biodiversity. *Science* 344, 1090-1092.

Piepho H-P., Laidig F., Drobek T and Meyer U. (2014) Dissecting genetic and non-genetic sources of long-term yield trend in German official variety trials. *Theoretical and Applied Genetics* 127, 1009-1018.

Poelmans L. (2010). *Modelling urban expansion and its hyrodological impacts*. PhD thesis, University of Leuven, Leuven, Belgium. 167 pp.

Pontes L S, Carrière P, Andueza D, Louault F, and Soussana J F (2007) Seasonal productivity and nutritive value of temperate grasses found in semi-natural pastures in Europe: responses to cutting frequency and N supply. *Grass and Forage Science* 62, 485-496.

Reheul D., De Vliegher A., Bommelé L. and Carlier L. (2007). The comparison between temporary and permanent grassland. *Grassland Science in Europe*, 12, 1-13.

Reidsma P., Tekelenburg T., Van den Berg M. and Alkemade R. (2006). Impacts of land-use change on biodiversity: an assessment of agricultural biodiversity in the European Union. *Agriculture, Ecosystems and Environment* 114, 86-102.

Schmeer M. (2012). *Der Einfluss von Bodenverdichtung sowie Grünlanderneuerung auf Stickstoffemissionen und Ertragsleistungen von Futterbausystemen*. PhD thesis, Kristian-Albrecht-Universität, Kiel, Germany. 119 pp.

Schröder J.J. (1998) *Towards improved nitrogen management in silage maize production on sandy soils*. PhD thesis, Wageningen University, Wageningen, the Netherlands. 223 pp.

Schröder J.J. (2014) The position of mineral nitrogen fertilizer in efficient use of nitrogen and land: a review. *Natural resources* 5, 936-948.

Schröder J.J., Van Dijk W. and De Groot W.J.M. (1996) Effects of cover crops on the nitrogen fluxes in a silage maize production system. *Netherlands Journal of Agricultural Sciences* 44, 293-315.

Smith R.G., Menalled F.D. and Robertson, G.P. (2007). Temporal yield variability under conventional and alternative management systems. *Agronomy Journal* 99, 1629-1634.

Spiertz J.H.J. (2010). Nitrogen, sustainable agriculture and food security. A review. *Agronomy for Sustainable Development* 30, 43-55.

Statbel (2014) Kerncijfers landbouw. De landbouw in België in cijfers 2013. Available at: http://tinyurl.com/lle9t5b. In Dutch.

Thorup-Kristensen (2006). Effect of deep and shallow root systems on the dynamics of soil inorganic N during 3-year crop rotations. *Plant and Soil* 288, 233-248.

Thorup-Kristensen K., Dresboll D.B. and Kristensen H.L. (2012) Crop yield, root growth and nutrient dynamics in a convention al and three organic cropping systems with different levels of external inputs and N recycling through fertility building crops. *European Journal of Agronomy* 37, 66-82.

Van der Windt N.P., Olde Loohuis R.J.W. and Agricola H.J. (2007) *The image of horse keeping*. Alterra report 1444, Alterra, Wageningen University, 83 pp. In Dutch.

van Eekeren N., Bommelé L., Bloem L., Schouten T., Rutgers M., de Goede R., Reheul D. and Brussaard L. (2008). Soil biological quality after 36 years of ley-arable cropping, permanent grassland and permanent arable cropping. *Applied Soil Ecology* 40, 432-446.

Van Landuyt W., Hoste I., Vanhecke L., Van Den Brempt P., Vercruysse W. and De beer D. (2006) *Atlas van de Flora van Vlaanderen en het Brussels Gewest*. Instituut voor Natuur- en Bosonderzoek, Nationale Plantentuin van België & Flo. Wer., Belgium, 1007 pp. In Dutch.

Verloop K (2013). *Limits of effective nutrient management in dairy farming: analyses of experimental farm De Marke*. PhD thesis, Wageningen University, Wageningen, the Netherlands. 192 pp.

Vertès F. and Mary B. (2007) Modelling the long term SOM dynamics in fodder rotations with a variable part of grassland. In: Chabbi A. (ed.) *Organic Matter Dynamics in Agro-Ecosystems*, pp. 549-550.

Vertès F., Hatch D., Velthof G., Taube F., Laurent F., Loiseau P and Recous S. (2007) Short-term cumulative effects of grassland cultivation on nitrogen and carbon cycling in ley-arable rotations. *Grassland Science in Europe* 7, 227-246.

Wachendorf M., Volkers K.C., Loges R., Rave G. and Taube F. (2006a) Performance and environmental effects of forage production on sandy soils. IV. Effect of grass understory, slurry application and mineral N fertilizer on yield and nitrogen surplus under maize for silage. *Grass and Forage Science* 61, 232-242.

Wachendorf M., Büchter M., Volkers K.C., Bobe J., Rave G., Loges R. and Taube F. (2006b) Performance and environmental effects of forage production on sandy soils. V. Effect of grass understory, slurry application and mineral N fertilizer on nitrate leaching under maize for silage. *Grass and Forage Science* 61, 243-252.

Westhoek H., Rood T., van den Berg M., Janse J., Nijdam D., Reudink M and Stehfest E. (2011) *The protein puzzle: the consumption and production of meat, dairy and fish in the European Union*. PBL Netherlands Environmental Assessment Agency, The Hague, the Netherlands 218 pp.

Westhoek H., Lesschen J.P., Rood T., Wagner S., De Marco A., Murphy-Bokern D., Leip A., van Grinsven H., Sutton M.A. and Oenema O. (2014). Food choices, health and environment: effects of cutting Europe's meat and dairy intake. *Global Environmental Change* 26, 196-205.

Zasada I., Berges R., Hilgendorf J. and Piorr A. (2013) Horsekeeping and the peri-urban development in the Berlin Metropolitan Region. *Journal of Land Use Science* 8, 199-2014.

Possibilities and constraints for grazing in high output dairy systems

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Abstract

In temperate and oceanic regions, grazed grass is the lowest cost feed available for milk production. In other regions, grazed grass is less important but can contribute to the diet of livestock. Within high output systems the interaction between the animal and sward is challenging for a host of reasons, including intake and milk production potential, substitution, grass allowance, quality, etc., which often means that grass utilisation and quality are compromised. Adaptation of grazing management and implementation of a range of grazing strategies can provide possibilities to increase the proportion of grazed grass in the diet of dairy cows in high output systems. As Europe transitions to a non-milk quota situation, increasing scale, or herd size, will probably lead to a trend towards a reduction in grazing, and may lead to a loss of the benefits of grazing. Therefore, strategies are required to increase the level of grazed grass in the diet of dairy cows on high output farms through the integration of grassland measurement and budgeting within everyday grassland management practices. There is a growing body of literature describing the benefits of grazing from an economic, environmental, animal welfare and overall social dimension. However, there are fewer reviews highlighting the constraints and difficulties to maintaining a high level of grass utilisation and good grazing performance in high output systems. The objective of this review is to present a balanced overview of the possibilities and the constraints for grazing in dairy systems in the future.

Keywords: grazing, dairy system, grassland managements, low-cost feed

Introduction

Global population growth to circa 9 billion by 2050 (UN Population Division, 2012) will result in an increased requirement for food globally, and specifically an increased requirement for meat and milk products, largely driven by the increased wealth of populations in developing countries. Increased food production must take place in a sustainable manner to minimise the environmental consequences. Grass, the feed for grazing livestock is, unlike concentrate feed for livestock, not suitable for human consumption. Furthermore, in many regions grassland occupies land area that is not suitable for growing crops which can be used to provide feedstuffs for humans. Agricultural reforms, increased demand for feed, drought and environmental considerations may indicate that self-sufficient farming using local or on-farm resources such as grazed grass will become more important in the future (e.g. Hofstetter *et al.*, 2014). Increased legislative pressures (e.g. Common Agricultural Policy reform, Kyoto Protocol, Gothenburg Protocol, EU Nitrate Directive) mean that in Europe increased milk production must be achieved in an economically and environmentally sustainable manner. Dillon *et al.* (2005) and Shalloo (2009) have shown that key drivers of profitability at farm level in temperate regions are associated with increased grass utilisation. In other regions, grazed grass is less important but can contribute to the diet of livestock during periods when there is optimum grass growth. While there are clear benefits to including grazing in dairy production systems, generally in Europe the contribution of grazed grass to dairy cow diets is declining, particularly as production systems intensify (Van den Pol-van Dasselaar *et al.*, 2008). There are a variety of reasons for this decline including increasing stock numbers per farm, declining availability of labour, shortage of summer feed supply, changing calving patterns, high genetic-

merit cows, land fragmentation, etc. Overall, in high output systems there are many possibilities for and constraints to grazing. Possibilities include the adaptation of grazing management and implementation of a range of grazing strategies to provide opportunities to increase the proportion of grazed grass in the diet of dairy cows. Maximising the utilisation of grazed grass in all systems will have benefits including economic sustainability and animal welfare. There are also many constraints to grazing in high output systems which can broadly be divided into two: infrastructural and cultural. Infrastructural constraints include farm fragmentation, facilities, demand for milk and mechanisation. Cultural constraints include perceived importance of high milk yield per cow, grassland management skills, access to alternative forages, EU and local government policy, milk price and market. In this paper we aim to explore the possibilities and constraints for grazing in high output systems and demonstrate that grazing can have a positive role in those systems.

Definition of high-output systems and grass-based systems

High output can be high output per cow or high output per hectare (ha). Legislation, including previous EU milk quotas, and restrictions on nitrogen (N) and phosphorus (P) use have resulted in many farmers opting for high output per cow. Maximising profit from the farm is the farmer's ultimate goal, therefore considering output from the total farm unit may be the most appropriate measure of productivity. In high output systems the focus must be on output per ha (or per farm) rather than output on an individual cow basis. Focussing on high output per ha (or farm) ensures maximum use of the resources available on farm. In a meta-analysis, McCarthy *et al.* (2011) found that as stocking rate increased on dairy farms, milk output per cow decreased by approximately 8% but milk output per hectare increased by about 20%. For the purposes of this paper, high output is considered to be on a per hectare basis.

In this paper, grass-based systems refer to systems where the diet of the dairy cow is mainly based on grazed grass, with grass silage the primary winter feed and also available for supplementing grazed grass during the grazing season.

Constraints to maximising grazed grass in the annual dairy cow feed budget

While this section of the paper deals with constraints, both real and perceived, to grazing in high output systems, it also includes some options to overcome or partially overcome some of those constraints.

Constraints: grass growth and quality

In European countries where grazed grass contributes to dairy cow diets there is a large variation in herbage production (Huyghe *et al.*, 2014) both within and between years (Hurtado-Uria *et al.*, 2013). Grass growth is influenced by many factors, some are within the farmers control (e.g. fertiliser application, grazing intensity, rotation length, etc.), and others are beyond the farmers control (e.g. temperature, rainfall, solar radiation, soil type, etc.). As a result of these factors grass availability is somewhat variable and difficult to forecast. A key issue for many is the lack of control over feed quality and availability associated with grazing (Dillon *et al.*, 2005). Consistency in feed supply and quality is desirable in high output systems. However, grass can still contribute to the feed budget when it is well managed and through the integration of buffer feeding and supplementation during periods of deficit it can be an extremely stable part of the overall cow diet. When available, grazed grass is a higher quality feed than grass silage for milk production. Management can be adapted to optimise grass supply and quality, and ensure it contributes significantly to the feed budget in high output systems.

Constraints: plant animal interaction

The key focus of grazing systems centres on the grass-animal interaction. It is at this level that the costs associated with grazed grass can increase or decrease dramatically depending on grass utilisation and animal performance. Within high output systems the interaction between the animal and the sward is

challenging for a whole host of different reasons, including herbage dry matter intake (DMI) and milk production potential, substitution rate, grass allowance, etc., which often means that grass growth and utilisation are not optimised (Peyraud and Delagarde, 2011). In grass-based systems, the level of grazing intensity has a direct influence on grass utilised and grass quality, and ultimately performance per ha (McCarthy *et al.*, 2013; McMeekan and Walsh, 1963). The most limiting factor for milk production in grass-based systems is herbage DMI. The feed requirements of high genetic-merit cows cannot be met solely by grazed grass and so the quantity of other feed stuffs increases. Often, producers feel they have more control of the cows' diet when feeding total mixed ration (TMR) and purchased feed stuffs and they are not confident of the feed value of their grass. Kolver and Muller (1998) reported that grass-fed cows have lower feed efficiency than indoor-fed cows due to limited energy intake on grass. Kolver and Muller (1998) also found that high genetic-merit dairy cows produced less milk from grazed grass than when feed indoors on a TMR (29.6 and 44.1 kg milk cow^{-1} day^{-1}, respectively). Van Vuuren and Van den Pol-van Dasselaar (2006) calculated that when fed on a grass-only diet, the DMI can satisfy the maintenance requirements of the dairy cow and milk production of 22 to 28 kg cow^{-1} day^{-1}. Fluctuating grass supply and quality can affect animal performance, and this is something that generally does not appeal to farmers (Peyraud and Delagarde, 2011).

Constraints: cow type

Fertility is one of the main issues impacting on animal production and farm profit across Europe. In intensive grass-based ruminant production systems requiring seasonal calving good reproductive performance is essential (Shalloo *et al.*, 2014). There is strong evidence that animals selected based on high concentrate diets with little focus on fertility have poorer reproductive efficiency and cannot express full genetic potential for milk yield in a grass-based environment (Buckley *et al.*, 2005; Macdonald *et al.*, 2005; McCarthy *et al.*, 2007). Although high genetic-merit dairy cows cannot fully express their milk potential on grass-only diets, Buckley *et al.* (2000) found that cows could produce up to 7,000 kg milk cow^{-1} yr^{-1} on a well-managed grass-based system.

The animal required for efficient grass-based production systems must be robust and 'easy care', as well as being capable of high levels of performance from grazed pasture. Suitable breeds/strains are adapted to achieving a large intake of forage relative to their potential milk yield, are fertile and healthy; have good conformation to walk long distances and high survivability (Buckley *et al.*, 2005; Dillon *et al.*, 2007). Ideally for a grass-based system, dairy cows will calve early in spring every year and then immediately go to grass, thereby resulting in the best fit between grass supply and feed demand. Large differences in performance (especially in relation to fertility and survival) and overall farm profitability occur between divergent strains/breeds of dairy cows on a grass-based system when compared to a high concentrate system (Dillon *et al.*, 2007; McCarty *et al.*, 2007). Crossing the Holstein-Friesian with an alternative dairy breed sire (e.g. Normande in France, Jersey or Norwegian Red in Ireland) can provide producers with an alternative to increase overall animal performance by increasing herd health, fertility and milk value through hybrid vigour (Lopez-Villalobos, 1998; Prendiville *et al.,* 2011; Delaby *et al.*, 2014).

Constraints: grazing management skills

Specific skills are required for managing grass-based systems. These include cow breeding management, grassland management and feed budgeting skills. Cow breeding management is hugely important as grass-based systems are best suited to compact seasonal (spring) calving to match feed demand to grass supply. The breeding period must be short to achieve a compact calving pattern and heat detection and management of cow body-condition score at key times during the year (e.g. dry-off, calving, post-calving, breeding) are crucial to ensure a high submission rate and a high in-calf rate in a short breeding season (10-13 weeks). That said, seasonal-calving systems do not suit all situations in Europe, for example many north-western European grazing systems use year-round calving.

Grazing management is often perceived as complicated and uncertain. While that is partially true, it is certainly possible to manage grazing. For example, in some regions of Europe lack of rainfall in summer and high temperatures result in little or no summer grass growth, and this means that grazing is not possible. However, grazing in spring and autumn is still possible with good management. In some European countries grazing management skills have been lost to a large extent, primarily due to the increased emphasis on high-input systems. However, in regions of Europe where there is increased interest in grazing, existing technologies such as those mentioned above can be adapted. For example, Ireland adapted the spring rotation planner from New Zealand, and the Netherlands introduced the FarmWalk to more than 500 dairy farmers in 2014 and is aiming to introduce it to more than 1000 dairy farmers in 2015.

Constraints: technology

The role of technology in milk-production systems is increasing. The single greatest technological advance in milk-production systems is the automatic milking system (AMS) which automates the most labour-intensive aspect of the milk-production systems (O'Donovan *et al.*, 2008) and offers advantages in terms of lifestyle. Traditionally, the main markets for AMS have been in countries with high-yielding cows, high milk prices, high labour costs and indoor feeding systems (Lind *et al.*, 2000). In recent times, with technological advances and reduced equipment costs, there is an increasing trend in the use of AMS across Europe. However, generally as AMS increases, grazing decreases, and indoor feeding systems are common place (Van den Pol-van Dasselaar *et al.*, 2012). With the reduction or loss of grazing the benefits of grass in the dairy cow diet, as discussed later in this paper, are also lost. In New Zealand, Jago and Burke (2010) found that AMS can be successfully integrated with grazing and that the fundamental requirements of profitable grass-based systems do not have to be compromised through the introduction of AMS. Jago and Burke (2010) suggest that some compromise between production per cow and per ha might be required, i.e. production per cow might be reduced by introducing more cows to ensure maximum production per milking unit but production per ha will be increased. The FP7-funded AutoGrassMilk Project is examining the opportunities for incorporating AMS with grass-based systems in Europe. For some European countries, e.g. Sweden, Denmark and the Netherlands, that means introducing grazed grass to cows on the AMS and for others, such as Ireland, it means introducing the AMS to grass-based systems.

Constraints: scale and fragmentation

As Europe transitions to a non-milk quota situation, increasing scale, or herd size, will probably lead to a trend towards a reduction in the overall levels of grazing, thus requiring very clear strategies to increase the levels of grazed grass in the diet of dairy cows through the integration of grassland measurement and budgeting within the everyday grassland-management practices at farm level. Fragmentation of farms is a huge issue across Europe in terms of grass-based milk production. In essence, the size of the block of land around the milking parlour, or within walking distance of the milking parlour, dictates the quantity of grazed grass available for the dairy cow herd. In general, maize, grass silage and other crops should be grown on blocks of land away from the milking parlour, and similarly young stock should be reared on outside land blocks.

Across northern Europe there is an increasing trend in the amalgamation of dairy farms. Usually cows are grouped together at one site to improve efficiencies around milking and labour use. Farmers also hope to achieve economies of scale and increased production efficiency. In some instances, when farms are adjacent to each other, the grazing area is increased for grazing herds. However, in many instances the amount of grazing ground is reduced for the amalgamated herd, resulting in reduced grazing and grazing-season length, as some of the land is not accessible for grazing. In those cases indoor feeding increases and sometimes zero grazing is practised – fresh grass harvested and fed indoors. The N-surplus also increases

as grazing pressure on the available grazing land increases. This type of system results in more machinery, more time feeding and overall less efficiency.

Possibilities to increase grazed grass in the annual dairy cow feed budget

There are many possibilities for, and advantages to, grazing in high-output systems. It may be necessary to supplement grazed grass with other feed stuffs, but with strategic management, grazed grass can significantly contribute to the diet of dairy cows in high-output systems. Well managed grass has a high nutritive value and can meet feed requirements particularly in spring, summer and early autumn. Adaptation of grazing management can also allow grazed grass to make a significant contribution to dairy cow diets. Possibilities for grazing in high-output systems include economic, milk quality, environmental, animal welfare and labour-efficiency benefits.

Possibilities: economic and labour efficiency

Since the reduction in market support at EU level, European milk production is more exposed to the volatility of the world market. Milk price volatility will remain for the foreseeable future and is probably one of the biggest challenges for European dairy farmers. Economic efficiency is defined as maximising the returns from a fixed set of resources, e.g. land, labour and capital (McInerney, 2000). In dairy production systems, land is an important fixed resource. The farmer has a choice in terms of the production system he adapts based on land availability. For grazing, especially the land availability around the milking parlour, is particularly important. Many studies show that grazed grass is the lowest-cost feed for milk production (e.g. Dillon *et al.*, 2005; Finneran *et al.*, 2012). As grazed grass is a natural TMR (it contains fibre, protein, energy, minerals, etc.), incorporating grazed grass into dairy cow diets has the potential to significantly contribute to the economic sustainability of milk production systems and can reduce production costs; particularly around purchased feed and conserved forage, but not exclusively. Dillon *et al.* (2005) showed that total costs of production tend to increase as the proportion of grazed grass in the milk-production system declines (Figure 1). Shalloo (2009) showed that 44% of the variation in milk-production costs in Ireland can be explained by the quantity of grass utilised by the dairy herd. Van den Pol-van Dasselaar *et al.* (2014b) showed that the economic benefit of grazing in the Netherlands depends on the fresh grass intake of grazing dairy cows (Figure 2). Grazing is financially attractive if the grass intake is higher than 600 kg DM cow^{-1} yr^{-1}. If the intake of fresh grass falls below this threshold, then grazing is less profitable than keeping the cows in the barn.
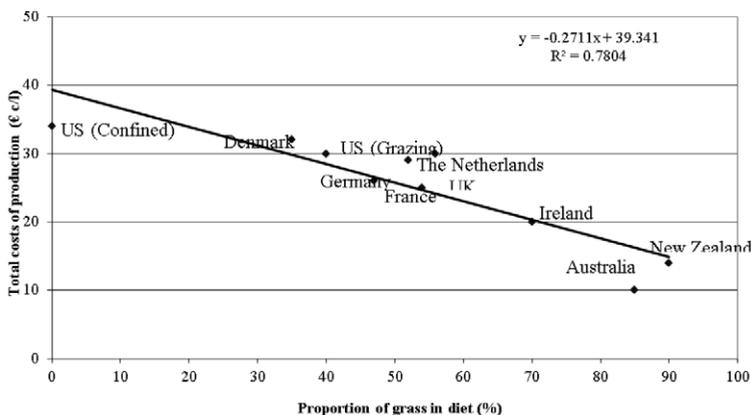
Figure 1. Relationship between total costs of production and proportion of grass in the diet of dairy cows (Dillon *et al.*, 2005).
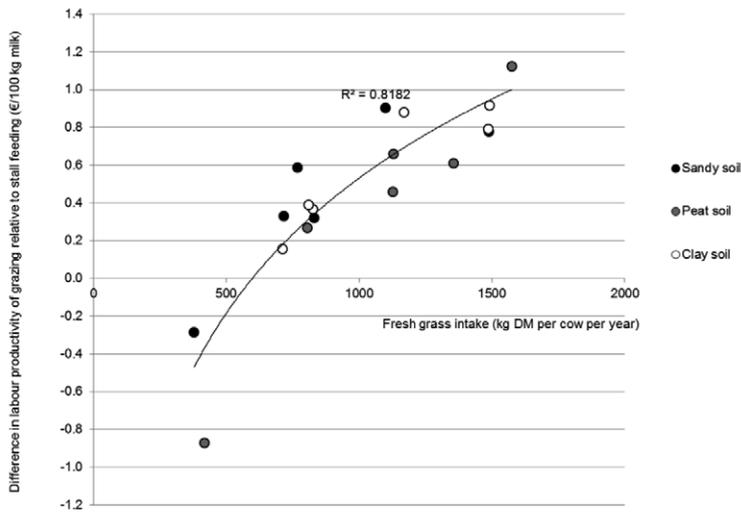
Figure 2. Income from grazing minus income with summer feeding (silage in the barn) relative to the quantity of fresh grass (kg dry matter (DM) intake per cow per year) for three soil types in the Netherlands as simulated by the whole farm model DairyWise. Positive numbers indicate an economic advantage for grazing (Van den Pol-van Dasselaar *et al.*, 2014b).

Labour is a high cost in any dairy production system, and the availability of skilled labour is a concern for producers. There is a perception that grass-based systems are labour intensive. In fact, labour is different and differently spread across the year depending on the calving pattern and the reproductive season length. In countries where milk producers aim to take advantage of grass supply and where compact calving practised, the labour demand around calving and breeding tends to be concentrated into a short period of the year, generally spring and early summer. Hofstetter *et al.* (2014) reported that grass-fed dairy cows had significantly shorter calving intervals, empty time and time from calving to first service compared to cows fed indoors. Year-round calving, and therefore year-round breeding, is dominant in indoor feeding systems and also in part-time grazing situations in many north-western European countries. Geary *et al.* (2014) reported that spring-calving grass-based systems had higher net profit per farm than less-seasonal calving systems, due to lower labour demand. The effect of grazing on labour in year-round calving systems is highly variable. In theory, grazing leads to fewer labour hours, since the cows fetch their feed themselves and they transport the manure to the field. However, grazing dairy farmers sometimes report peaks in daily labour needed for fetching the cows to the milking parlour.

Other economic and labour efficiency advantages of grazing include reduced reseeding costs (reseeding of grass pastures is not necessary on an annual basis), reduced costs for mechanically harvesting of grass and spreading of slurry, and less feed storage and slurry storage costs.

Possibilities: environmental

One of the key challenges facing agriculture today centres on the requirement to reduce environmental losses and impacts. Many studies have been undertaken at country level examining the implications of different production systems on greenhouse gas (GHG) emissions (Casey and Holden, 2005; Schils *et al.*, 2005; O'Brien *et al.*, 2012), eutrophication (Basset-Mens *et al.*, 2009; Benoit and Simon, 2004; Benoit *et al.*, 1995; Briggs and Courtney, 1989) and biodiversity (Atkinson *et al.*, 2005; McMahon *et al.*, 2010; Nitsch *et al.*, 2012; Taube *et al.*, 2014). While all studies use different methodologies and are therefore difficult to compare directly, one key conclusion is evident across all: increasing resource-use efficiency is associated with increased environmental sustainability. Generally, grass-based systems are more resource

efficient as they use home-grown feed stuffs and minimise the requirements for purchased feedstuffs and therefore the resources (area, energy, machinery) associated with those feedstuffs. Total consumption of non-renewable energy is reduced in grass-based systems compared to indoor systems (Le Gall *et al.*, 2009).

It is well accepted that there is a high N surplus in grazed grassland due to N fertiliser use, N fixation by legumes when present, and urine and faecal deposition by grazing livestock. However, permanent grassland acts as a store for N (Brogan, 1966; O'Connell *et al.*, 2003), lowering the risk of N loss to water. In long-term productive grassland soils there is usually net N mineralisation (Jarvis and Oenema, 2000). Recently, McCarthy *et al.* (in press) showed that increasing stocking rate, while keeping concentrate input and fertiliser N input constant, increased the N-use efficiency and reduced surplus N in grass-based milk production systems due to increased grass utilisation. Grassland has a high capacity to capture N, as grass is present year-round and grass is actively growing for a large part of the year (7 to 10 months). However, with very high stocking rates or in overgrazed situations, N losses can be high because faeces and urine are not evenly distributed over the field during grazing. This leads to more N leaching, more denitrification and more nitrous oxide emissions. Ammonia volatilisation, on the other hand, is less during grazing. Permanent grassland is ploughed infrequently, thereby minimising N loss from cultivation. Minimum tillage options for reseeding minimise soil disturbance and therefore minimise N and C loss (Del Prado *et al.,* 2014). Reseeding or renewing grassland ensures that there are productive species in the sward which are fast growing and can maximise N utilisation.

Wims *et al.* (2010) demonstrated that feeding lactating dairy cows on high quality low herbage mass swards can reduce CH_4 emissions per cow per day (282 g CH_4 cow^{-1} day^{-1}) and per kg milk solids (MS) produced (203 g CH_4 kg MS^{-1}) compared to cows grazing high herbage mass swards with lower quality (+21 g CH_4 cow^{-1} day^{-1} and +26 g CH_4 kg MS^{-1}) obtained through a higher regrowth period.

Grassland soils and associated vegetation are an important sink for C, particularly in the form of soil organic C (Peeters and Hopkins, 2010). Increasing the area of long-term grassland by reducing short term leys, arable crops and maize can increase C sequestration, as can maintaining existing permanent grassland, particularly on peat soils (Freibauer *et al.*, 2004).

Possibilities: milk quality and food safety

Animal nutrition affects the quality and nutritional value of dairy products (Downey and Doyle, 2007). The diet of ruminant animals can affect the taste and the chemical composition of the product produced (Hopkins and Holz, 2006). Coakley *et al.* (2007), Wyss *et al.* (2010) and Butler *et al.* (2011) all report increased levels of the unsaturated fatty acids, conjugated linoleic acids, vaccenic acid, and omega-3 fatty acids in milk from cows fed predominantly on grazed grass compared to other diets, including grass silage and concentrate-based diets. Unsaturated fatty acids are believed to be better for human health. Milk from cows on largely grass diets is higher in vitamins A and E than from other cow diets (Martin *et al.*, 2004). Milk processors are increasingly aware of the health benefits of grass-fed milk and use it as part of their marketing campaigns (e.g. http://www.kerrygold.com/advertising).

Food safety is of increasing concern as the food supply chain lengthens. As the length of the food chain increases, the sharing of knowledge, trust and understanding between farmers, processors, retailers and consumers declines and ultimately ceases. A large proportion of raw materials for animal feeds come from outside the EU. Maximising the quantity of grazed grass and home-produced grass silage or hay in the diet of dairy cows reduces the requirement for purchased feed.

European consumers have concerns about food quality and safety and tend to view grass-based milk production systems being as sustainable, safe and delivering high quality products and multiple ecosystem services (Van den Pol-van Dasselaar *et al.*, 2014a). They associate milk production with cows grazing in green fields. They consider these to be natural and local production systems. Citizens mention that they are prepared to pay for milk from grass-based production systems, but dairy companies often indicate that it is difficult to get the associated money from the market. In some European countries, such as the Netherlands, a so-called grazing premium is available to producers who allow their animals access to grazed grass.

Possibilities: animal welfare

There is a general perception that the welfare of grazing animals is better than that of housed animals or animals on intensive feed lots. Animal welfare includes the possibility to express natural behaviour and animal health. Grazing animals generally are not restricted in terms of space and have free access to exercise and for roaming. Allowing animals to graze outdoors in groups permits social contact and allows the selection of the hierarchy of the herd. In general, in grazing situations animals can express their natural behaviour better than in situations of indoor feeding. Grazing has advantages and disadvantages with respect to animal health, but in general the advantages are seen as more important. They mainly focus on claw health and udder health. Leaver *et al.* (1988) reported that the prevalence of lameness is low during the grazing period. Olmos *et al.* (2007) found that pasture-based dairy cows had reduced lameness and better locomotive ability and also had a greater opportunity for uninterrupted lying time compared to housed dairy cows. Benefits of grass-based systems in terms of lameness must be considered with caution as in certain circumstances, such as when cow tracks are not maintained in grass-based production systems, incidence of lameness can still be high (Lean *et al.*, 2008). Washburn *et al.* (2002) reported that there are several examples in the literature showing that access to pasture can improve aspects of cow health such as mastitis.

Possibilities: grazing management

Technologies such as the Grass Wedge (Teagasc, 2009), Herb'aVenir (Defrance *et al.*, 2005) or Pâtur'Plan (Delaby *et al.*, this volume) facilitate grassland management and allow the anticipation of the availability of grass for grazing. In the Netherlands, these technologies have been incorporated in the FarmWalks where 5-10% of the dairy farmers jointly learn about grazing management. Grassland management skills can be learned, but require regular practice and it can take time to be entirely comfortable with the measurements and trust the measurements. Grassland management tools such as the spring rotation planner, the grass wedge and autumn budgeting combined with a weekly farm cover measurement (www. teagasc.ie) provide the farmer with reliable information with which to make decisions around managing surpluses and deficits in grass supply, feeding, supplementation, and fertiliser. Farmer discussion groups can help farmers learn the required grassland management and budgeting skills through mentoring and peer support.

Every farm can incorporate grazed grass into the diet of dairy cows through different management strategies. For example, when there is limited land area available, or when soil or weather conditions are poor, restricted access to grazing can be practised (Pérez-Ramírez *et al.*, 2008; Kennedy *et al.*, 2009; Kennedy *et al.*, 2014). This management approach involves turning cows out to grass for a fixed period of time each day. Kennedy *et al.* (2009) showed that in spring, dairy cows achieved 90% of their daily grass DMI when provided with access to grass for three hours after morning and evening milking, and milk production was not reduced compared to cows that were fulltime grazing. Similarly in autumn, Kennedy *et al.* (2014) found no negative effects of restricted access to grass for cows in late lactation. In France, Pérez-Ramírez *et al.* (2008) reported that restricting access time to pasture reduced milk yield and composition in spring and early summer. Grass-clover swards offer benefits in terms of extending

regrowth period, particularly in periods of low or no grass growth due to low rainfall and high temperature (Lüscher *et al.*, 2014). In areas with low summer growth, it is worth considering altering the calving pattern to match feed demand with grass growth. One possible strategy is to have two compact-calving periods, one in spring and one in autumn; this will allow the herd to maximise the amount of grass converted to milk (Delaby and Fiorelli, 2014).

New technologies are continuously being developed and new grassland Decision Support Tools (DSTs) such as the Grasshopper described by MacSweeney *et al.* (2014), cow sensors (Ipema *et al.*, 2014) and virtual fencing (MacSweeney *et al.*, 2014) will assist farmers in accurately allocating herbage to grazing dairy cows. These tools are also likely to increase farmers' confidence when it comes to grazing management and herbage allocation (Delaby *et al.*, this volume). The increase in accuracy and availability of precision technologies increases the potential integration of precision grazing into grass-based systems through the replacement of some of the skills required for optimised grazing management.

Conclusions

Although there are many constraints to grazing in Europe, there are many possibilities to overcome those constraints. Adapting existing grassland management tools from countries with grass-based milk production systems will help improve the management of grazing systems. New and evolving technologies will also have a role to play in incorporating grazing into high-output milk production systems. Adapting the herd in terms of breeding and calving period can also increase the role that grazed grass plays in the diet of dairy cows in high-output systems. Maximising the utilisation of grazed grass in all systems will increase the sustainability of high-output dairy systems.

References

Atkinson P.W., Fuller R.J., Vickery J.A., Conway G.J., Tallowin J.R.B., Smith R.E.N., Haysom K.A. Ings T.C., Asteraki E.J. and Brown V.K. (2005) Influence of agricultural management, sward structure and food resources on grassland fields used by birds in lowland England. *Journal of Applied Ecology* 42, 932-942.

Basset-Mens C., Ledgard S. and Boyes M. (2009) Eco-efficiency of intensification scenarios for milk production in New Zealand. *Journal of Ecological Economics* 68, 1615-1625.

Briggs D.J. and Courtney F. (1989) *Agriculture and Environment. The Physical Geography of Temperate Agricultural Systems.* Longman, London, UK. 442 pp.

Benoit M., Saintôt D. and Gaury F. (1995) Measures en parcelled d'agriculteurs des pertes en nitrates. Variabilité sous divers systèmes de culture at modélisation de la qualité de l'eau d'un bassin d'alimentation, *Comptes Rendus de l'Academie d'Agriculture de France* 81, 175-188.

Benoit M. and Simon J.-C. (2004) Grassland and water resources: recent findings and challenges in Europe. *Grassland Science in Europe* 12, 117-128.

Brogan J.C. (1966) Organic carbon in Irish pasture soils. *Irish Journal of Agriculture and Food Research* 5, 169-176.

Buckley F., Dillon P., Rath M and Veerkamp R.F. (2000) The relationship between genetic merit for yield and live weight condition score, and energy balance of spring calving Holstein-Friesian dairy cows on grass based systems of milk production. *Journal of Dairy Science* 83, 1878-1886.

Buckley F., Holmes C. and Keane, M.G. (2005) Genetics characteristics required in dairy and beef cattle for temperate grazing systems. In: *Utilisation of grazed grass in temperate animal systems.* Proceedings of *Satellite Workshop of the XXth International Grassland Congress*, July 2005, Cork, Ireland, pp. 61-79.

Butler G., Stergiadis S., Seal C., Eyre M. and Leifert C. (2011) Fat composition of organic and conventional retail milk in northeast England. *Journal of Dairy Science* 94, 24-36.

Casey J.W. and Holden N.M. (2005) The relationship between greenhouse gas emissions and the intensity of milk production in Ireland. *Journal of Environmental Quality* 34, 429-436.

Coakley M., Barrett E., Murphy J.J., Ross R.P., Devery R. and Stanton C. (2007) Cheese manufacture with milk with elevated conjugated linoleic acid levels caused by dietary manipulation. *Journal of Dairy Science* 90, 2919-2927.

Defrance P., Delaby L. and Seuret J.M. (2005) Herb'aVenir, a simple decision support tool for grazing management. *Rencontres Recherches Ruminants* 12, 80.

Delaby L., Duboc G., Cloet E. and Martinot Y. (2015) Pastur'Plan, a dynamic tool to support grazing management decision making in a rotational grazing system. *Grassland Science in Europe,* this volume, pp. 200-202.

Delaby L. and Fiorelli J.L. (2014). Systèmes laitiers à bas intrants: entre traditions et innovations. *Productions Animales* 27(2), 123-134.

Delaby L., Hennessy D., Gallard Y. and Buckley F. (2014) Animal choice for grass-based systems. *Grassland Science in Europe* 19, 795-797.

Del Prado A., Van den Pol-van Dasselaar A., Chadwick D., Misselbrook T. Sandars D., Audsley E. and Mosquera-Losada M.R. (2014) Synergies between mitigation and adaptation to climate change in grassland-based farming systems. *Grassland Science in Europe* 19, 61-74.

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005). Optimising financial return from grazing in temperate pastures. In: Murphy J.J. (ed.), *Utilisation of grazed grass in temperate animal systems*, Cork, Ireland, pp. 131-147.

Dillon P., MacDonald K., Holmes C.W., Lopez-Villalobos N., Buckley F., Horan B. and Berry D. (2007) Cow genetics for temperate grazing systems. In: *Australasian Dairy Science Symposium 2007*, Melbourne, 18-Oct-2007, pp. 152-184.

Downey L. and Doyle P.T. (2007) Cow nutrition and dairy product manufacture – implications of seasonal pasture-based milk production systems. *Australian Journal of Dairy Technology* 62, 3-11.

Freibauer A., Rounsevell M.D.A., Smith P. and Verhagen J. (2004) Carbon sequestration in the agricultural soils of Europe. *Geoderma* 122, 1-23.

Finneran E., Crosson P., O'Kiely P., Shalloo L., Forristal D. and Wallace M. (2012) Stochastic simulation of the cost of home-produced feeds for ruminant livestock systems. *Journal of Agricultural Science* 150, 123-139.

Geary U., Lopez-Villalobos N., Garrick D.J. and Shalloo L. (2014) Spring calving versus split calving: effects on farm, processor and industry profitability for the Irish dairy industry. *Journal of Agricultural Science* 152, 448-463.

Hofstetter P., Frey H.-J., Gazzarin C., Wyss U. and Kunz P. (2014) Dairy farming: indoor v. pasture-based feeding. *Journal of Agricultural Science* 152, 994-1011.

Hopkins A. and Holz B. (2006) Grassland for agriculture and nature conservation: production, quality and multi-functionality. *Agronomy Research* 4, 3-20.

Hurtado-Uria C., Hennessy D., Shalloo L., O'Connor D. and Delaby L. (2013) Relationships between meteorological data and grass growth over time in the south of Ireland. *Irish Geography* 46, 175-201

Huyghe C., De Vliegher A., van Gils B. and Peeters A. (2014) *Grasslands and herbivore production in Europe and effects of common policies*. Éditions Quae, Versailles, France.

Ipema A.H., Holshof G. and De Mol R.M. (2014) Using real time cow information for daily grazing management. In: Book of abstracts 65th *Annual Meeting of the European Federation of Animal Science* EAAP.

Jarvis S.C. and Oenema O. (2000) Measuring and monitoring nitrogen and phosphorus flows and losses in grassland systems. In: 't Mannetje, L. and Jones R.M. (eds.) *Field and laboratory methods for grassland and animal production research*. CAB International, Cambridge, UK, pp. 305-325.

Jago J. and Burke J. (2010) An evaluation of two pastoral dairy production systems using automatic milking technology. In: *Proceedings of the New Zealand Grassland Association*, 72, pp. 109-116.

Kennedy E., McEvoy M., Murphy J.P., and O'Donovan M. (2009) Effect of restricted access time to pasture on dairy cow milk production, grazing behaviour, and dry matter intake. *Journal of Dairy Science* 92, 168-176.

Kennedy E., Garry B., Ganche E., O'Donovan M., Murphy J.P. and Hennessy D. (2014) Effects of restricting access time to pasture on late lactation dairy cow production. *Grassland Science in Europe* 19, 737-739.

Kolver E.S. and Muller L.D. (1998) Performance and nutrient intake of high producing Holstein cows consuming pasture or a total mixed ration. *Journal of Dairy Science* 81, 1403-1411.

Le Gall A., Béguin E., Dollé J.B., Manneville V. and Pflimlin A. (2009) Nouveaux compromis techniques pour concilier efficacité économique et environnementale en élevage herbivores. *Fourrages* 198, 131-151.

Lind O., Ipema A.H., de Koning C., Mottram T.T. and Hermann H.-J. (2000). Automatic milking: reality, challenges and opportunities. In: Proceedings *Robotic Milking,* Lelystad, the Netherlands. Wageningen Pers, Wageningen, the Netherlands, pp. 19-31.

Lopez-Villalobos N. (1998) *Effects of crossbreeding and selection on the productivity and profitability of the New Zealand dairy industry*. PhD. Thesis, Massey University, Palmerston North, New Zealand.

Lüscher A., Mueller-Harvey I., Soussana J.F., Rees R.M. and Peyraud, J.L. (2014) Potential of legume-based grassland-livestock systems in Europe: a review. *Grass and Forage Science* 69, 206-228

Macdonald, K., Thorrold B., Glassey C., Lancaster J., Verkerk G.A., Pryce J.E. and Holmes C.W. (2005) Farm performance of Holstein-Friesian cows of three genetic strains on grazed pasture. In: *Utilisation of grazed grass in temperate animal systems*. Proceedings of satellite workshop of the XXth International Grassland Congress, July 2005, Cork, Ireland, pp. 175.

Martin B., Fedele V., Ferlay A., Grolier P., Rock E., Gruffat D. and Chilliard Y. (2004) Effects of grass based diets on the content of micronutrients and fatty acids in bovine and caprine dairy products. *Grassland Science in Europe* 12, 876-886.

McCarthy B., Delaby L., Pierce K. M., Journot F. and Horan B. (2011) Meta-analysis of the impact of stocking rate on the productivity of pasture-based milk production systems. *Animal* 5, 784-794.

McCarthy J., Delaby L., Hennessy D., McCarthy B., Ryan W., Pierce K.M., Brennan A. and Horan B. (in press) The effect of stocking rate on soil solution nitrate concentrations beneath a free draining dairy production system in Ireland. *Journal of Dairy Science.*

McCarthy S., Horan B., Dillon P., O'Connor P., Rath M. and Shalloo L. (2007) Economic comparison of divergent strains of Holstein-Friesian cows in various pasture-based production systems. *Journal of Dairy Science* 90, 1493-1505.

McInerney J.P. (2000) Economic aspects of grassland production and utilisation. In: Hopkins A. (ed.) *Grass: its production and utilisation*. Blackwell Science, Oxford, UK, pp. 394-428.

McMahon B.J., Helden A., Anderson A., Sheridan H., Kinsella A. and Purvis G. (2010) Interactions between livestock systems and biodiversity in South-East Ireland. *Agriculture, Ecosystems and Environment* 139, 232-238.

McMeekan C.P. and Walsh M.J. (1963) The inter-relationships of grazing method and stocking rate in the efficiency of pasture utilization by dairy cattle. *Journal of Agricultural* Science 61, 147-166.

McSweeney D., Foley C., Halton P., Umstatter C., and O'Brien B. (2014) Novel concept to allow automation of grazing management within a dairy farm system. In: *International Conference of Agricultural Engineering*, 6-10 July 2014, Zurich, Switzerland.

Nitsch H., Osterburg B., Roggendorf W. and Laggner B. (2012) Cross compliance and the protection of grassland – illustrative analyses of land use transitions between permanent grassland and arable land in German regions. *Land Use Policy* 29, 440-448.

O'Brien D., Shalloo L., Patton J., Buckley F., Grainger C. and Wallace M. (2012) Evaluation of the effect of accounting method, IPCC v. LCA, on grass-based and confinement dairy systems' greenhouse gas emissions. *Animal* 6, 1512-1527.

O'Connell K., Humphreys J. and Watson C.J. (2003) Quantification of nitrogen sources for grassland. In: *Proceedings of the Fertiliser Association of Ireland* 40, 15-29.

O'Donovan K., O'Brien B., Ruane D.J, Kinsella J. and Gleeson D. (2008) Labour input on Irish dairy farms and the effect of scale and seasonality. *Journal of Farm Management* 13, 327-342.

Olmos G., Boyle L., Hanlon A., Patton J., Murphy J.J. and Mee J.F. (2007) Hoof disorders, locomotion ability and lying times of cubicle-housed compared to pasture-based dairy cows. *Livestock Science* 125, 199-207.

Pérez-Ramírez E., Delagarde R. and Delaby L. (2008) Herbage intake and behavioural adaptation of grazing dairy cows by restricting time at pasture under two feeding regimes. *Animal* 2, 1384-1392.

Peeters A. and Hopkins A. (2010) Climate change mitigation in European grasslands. *Grassland Science in Europe* 15, 72-74.

Peyraud J.L. and Delagarde R. (2011) Managing variations in dairy cow nutrient supply under grazing. *Animal* 7, 57-67.

Prendiville R., Shalloo L., Pierce K.M. and Buckley F. (2011) Comparative performance and economic appraisal of Holstein-Friesian, Jersey and Jersey×Holstein-Friesian cows under seasonal pasture-based management. *Irish Journal of Agriculture and Food Research* 50, 123-140.

Schils R.L.M., Verhagen A., Aarts H.F.M. and Sebek L.B.J. (2005) A farm level approach to define successful mitigation strategies for GHG emissions from ruminant livestock systems. *Nutrient Cycling in Agroecosystems* 71, 163-175.

Shalloo L, Cromie A. and McHugh N. (2014) Effect of fertility on the economics of pasture-based dairy systems. *Animal* 8, 222-231.

Shalloo L. (2009) Milk production costs – Can we compete? *Teagasc National Dairy Conference*, Cork, Ireland, pp. 19-38.

Taube F., Gierus M., Hermann A., Loges R. and Schönbach P. (2014) Grassland and globalization – challenges for north-west Europe grass and forage research. *Grass and Forage Science* 69, 2-16.

Teagasc (2009) *Grazing notebook*. Available at: www.teagasc.ie.

UN Population Division (2012) World Population Prospects, the 2012 Revision. United Nations, Department of Economic and Social Affairs Publication, New York, USA.

Van den Pol-van Dasselaar A., Vellinga T.V., Johansen A. and Kennedy E. (2008) To graze or not to graze, that's the question. *Grassland Science in Europe* 13, 706-716.

Van den Pol-van Dasselaar A., De Haan M.H.A. and Philipsen A.P. (2012) Combining grazing and automatic milking. *Grassland Science in Europe* 17, 279-281.

Van den Pol-van Dasselaar A., Goliński P., Hennessy D., Huyghe C., Parente G. and Peyraud J.-L. (2014a) Évaluation des fonctions des prairies par les acteurs européens. *Fourrages* 218, 141-146.

Van den Pol-van Dasselaar A., Philipsen A.P. and De Haan, M.H.A. (2014b) Economics of grazing. *Grassland Science in Europe* 19, 662-664.

Van Vuuren A.M. and Van den Pol-van Dasselaar A. (2006). Grazing systems and feed supplementation. In: Elgersma A., Dijkstra J. and Tamminga S. (eds.) *Fresh herbage for dairy cattle, the key to a sustainable food chain*. Wageningen UR Frontis Series Volume 18, Springer, Dordrecht, the Netherlands, pp. 85-101.

Washburn S.P., White S.L., Green Jr. J.T. and Benson G.A. (2002) Reproduction, mastitis, and body condition of seasonally calved Holstein and Jersey cows in confinement or pasture systems. *Journal of Dairy Science* 85, 105-111.

Wims C.M., Deighton M.H., Lewis E., O'Loughlin B., Delaby L., Boland T.M. and O'Donovan M. (2010) Effect of pregrazing herbage mass on methane production, dry matter intake, and milk production of grazing dairy cows during the mid-season period. *Journal of Dairy Science* 93, 4976-4985.

Wyss U., Munger A. and Collomb M. (2010) Variation of fatty acid content in grass and milk during the grazing season. *Grassland Science in Europe* 15, 422-424.

Intercropping maize and Caucasian clover to reduce environmental impact of maize silage production

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Abstract

Maize (*Zea mays* L.) silage has become an increasingly important forage crop in high output dairy farming systems in Europe and North America because of its high energy density, relatively uniform nutritive value, and efficiency of production. But due to lack of surface residue and organic matter inputs and high nitrogen (N) fertilizer inputs, maize silage production is one of the most demanding cropping systems imposed on our soil and water resources. We investigated intercropping maize with the persistent rhizomatous legume, Caucasian clover (*Trifolium ambiguum* M. Bieb.), as a means to provide continuous living groundcover to minimize nitrate leaching, nutrient runoff and soil erosion. Maize was sown into existing stands of Caucasian clover that had been suppressed to reduce competition, and into areas with no clover. Total nitrate-N leached was reduced by 74% relative to the control monocrop maize under intercropped maize silage. On loess soils with 8 to 15% slope, during simulated, short, heavy rainstorms, Caucasian clover intercrop reduced water runoff by 50%, soil loss by 77%, and P and N losses by 80% relative to monocrop maize. Intercropping maize with Caucasian clover can eliminate N-fertilizer inputs and greatly reduce negative environmental impacts associated with maize silage production.

Keywords: *Trifolium ambiguum*, maize silage, nitrate leaching, soil erosion, phosphorus

Introduction

Maize silage is an important source of forage for dairy cattle in Europe and the USA because it is highly palatable, contains high energy density, produces high yields in a single harvest and has relatively uniform nutritional value. The cost per ton of dry matter is also typically much lower than for other mechanically harvested forage crops. Land area in maize silage is approximately 5.0 M ha in the EU and 3.0 M ha in USA. In Europe the area in maize silage is increasing as adapted hybrids become available and as demand increases to meet livestock and biofuel interests. In temperate climates maize for silage is a 5-month crop and for the remainder of the year fields lie dormant, radiation is not captured for photosynthesis, soil organic carbon is lost through respiration, the soil surface is unprotected increasing soil erosion and nutrient runoff, and nutrient-rich water is prone to leach out of the root zone. Biological intensification of maize silage production systems could mitigate some of these negative off-site impacts on surface water, ground water, and atmospheric greenhouse gases (Krueger *et al.*,2012). Our earlier work demonstrated that maize can be grown in suppressed Caucasian clover (Affeldt *et al.*, 2004; Zemenchik *et al.*, 2000) and that nearly the entire nitrogen requirement of the maize crop is met (Albrecht and Sabalzagaray, 2006; Berkevich, 2008). Caucasian clover initiates growth in early spring and recovers from suppression under the maize canopy and continues to grow into late autumn, extending time of soil surface cover by at least 2 months and maintaining a living root system year around. We explore some environmental impacts of such an intercropping system in this current paper.

Materials and methods

Experiment 1. Water and nitrate leaching research was conducted on silt loam soils near Arlington, WI (43°18′ N, 89° 21′ W) in fields sown to Caucasian clover 2 years earlier. Treatments in the 2.5-year experiment were N-fertilized no-till maize following killed Caucasian clover (control) and maize

no-till sown into suppressed Caucasian clover receiving 0 or 90 kg N ha^{-1}. A water balance method (Ochsner *et al.*, 2010) and ceramic suction cup samplers were used to estimate water drainage, nitrate-N concentrations in soil solution below 1 m and calculate nitrate-N leaching.

Experiment 2. Water, soil, and nutrient runoff research was conducted on silt loam soils with 8 to 15% slope near Lancaster, WI (42°50' N, 90°48' W) in fields sown to Caucasian clover 2 years earlier. Treatments in this experiment were no-till maize following killed Caucasian clover (control) and maize no-till sown into suppressed Caucasian clover. Simulated rainstorms of 70 mm per hour were applied four times during the maize silage production season and once in spring following maize silage harvest. Water runoff and soil and nutrient concentrations in the runoff water were determined.

Results and discussion

For Experiment 1, data were separated into 6-month periods approximating the growing season (GS, April-September) and the dormant season (DS, October-March) (Table 1). The total nitrate-N leached under the intercropped maize-clover system with no added N was reduced 74% compared to the control. Total nitrate-N leached under the intercropped maize receiving 90 kg N ha^{-1} was reduced 31% relative to the control. Water drainage was similar across treatments (data not shown) so the observed large reductions in nitrate-N leaching were due primarily to lower nitrate-N concentrations below the intercropped maize-clover. The very large amount of leached nitrate-N in GS 3 is associated with 200 mm rainfall over an 8-day period. Negative values in GS 2 result from upward net water flow as roots took up water at depths greater than 1 m during a dry season. Nitrate-N concentration in leachate under intercropped maize with no N-fertilizer was never above 12 mg l^{-1}, whereas under the control system nitrate-N concentration was frequently above 40 mg l^{-1}. Similar concentrations of nitrate-N under conventional and intercropped maize were observed by Zemenchik *et al.* (2000), who noted that mineralization of N from decaying, supressed Caucasian clover seemed to be occurring at a rate adequate to meet the N demands of the growing maize crop.

In Experiment 2, the amount of time lapsing before water runoff occurred was always greater in maize intercropped with Caucasian clover compared to control maize (Table 2). This was associated with greater soil aggregate stability (data not sown) supporting greater water infiltration in the intercropping system. The combination of less runoff volume and lower amounts of suspended sediment in runoff resulted in less total soil loss from fields with maize intercropped with Caucasian clover compared to control maize. Total nitrogen and phosphorus lost from fields in runoff was associated primarily with runoff volume rather than concentration of nutrients in the runoff, and were always lower in the intercropped maize than in the control. Greater ground cover, greater soil aggregate stability, and greater infiltration were associated with less runoff of water, soil and nutrients in the maize-Caucasian clover intercrop than in control maize.

Table 1. Nitrate-N leached for three growing seasons (GS 1, 2, and 3) and two dormant seasons (DS 1 and 2) on silt loam soils at Arlington, Wisconsin.[1]

Treatment	Season					Total
	GS 1	DS 1	GS 2	DS 2	GS 3	kg N ha^{-1}
	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}	kg N ha^{-1}	
Maize	4	31	-13	50	80	151
Maize in clover + 90 kg N ha^{-1}	2	14	-6	36	57	104
Maize in clover + 0 N	2	8	-3	7	25	39

[1] The combination of data collection and modelling used to generate these values precludes statistical analysis.

Table 2. Runoff volume and content from plots with conventional maize silage or maize silage intercropped with Caucasian clover on silt loam with 8 to 15% slope which received simulated rainstorms of 70 mm per hour at Lancaster, Wisconsin.

Simulation date and cropping treatment	Time to runoff min.	Runoff volume l ha^{-1} (×1000)	Suspended sediment g l^{-1}	Total soil loss kg ha^{-1}	Total P loss kg ha^{-1}	Total N loss kg ha^{-1}
April, 2010						
Maize	7b	251a	7.40a	1,872a	0.92a	15.86a
Maize in clover	16a	94b	2.30b	209b	0.02b	1.26b
June, 2010						
Maize	8a	270a	9.68a	3,326a	1.12a	22.42a
Maize in clover	26b	59b	0.35b	29b	0.31b	0.83b
September, 2010						
Maize	3a	457a	11.50a	5,187a	1.24a	37.97a
Maize in clover	6b	335b	5.40b	1,816b	0.41b	11.93b
October, 2010						
Maize	5a	383a	6.53a	2,519a	0.49a	9.52a
Maize in clover	8b	248b	2.83b	688b	0.10b	3.50b
May, 2011						
Maize	5a	372a	3.00	1,100a	0.93a	9.77a
Maize in clover	19b	129b	3.55	450b	0.08b	1.87b

Within simulation period and column means followed by different letters are significantly different at P=0.05 according to Fischer's protected least significant difference.

Conclusions

Maize can be intercropped in a permanent field of Caucasian clover with maize silage yield similar to conventional production in seasons when soil moisture is not limiting. The Caucasian clover intercrop provided important environmental benefits, including reduced nitrate-N leaching, reduced soil erosion, and reduced nutrient loss in runoff. Thus this intercropping system has potential to improve sustainability of whole-plant maize harvest for silage. The concern of reduced maize silage yield during dry years is being addressed by incorporating 'drought tolerant' maize hybrids into the system.

References

Affeldt R.P, Albrecht K.A., Boerboom C.M. and Bures E.J. (2004) Integrating herbicide-resistant corn technology in a Kura clover living mulch system. *Agronomy Journal* 96, 247-251.

Albrecht K.A. and Sabalzagaray A. (2006) Maize silage production in a Kura clover living mulch. *Grassland Science in Europe* 11, 59-61.

Berkevich, R.J. (2008) Kura clover used as a living mulch in a mixed cropping system. M.S. thesis. University of Wisconsin, Madison, USA.

Krueger E.S., Ochsner T.E., Baker J.M., Porter P.M. and Reicosky D.C. (2012) Rye-corn silage double-cropping reduces corn yield but improves environmental impacts. *Agronomy Journal* 104, 888-896.

Ochsner T.E., Albrecht K.A., Schumacher T.W, Baker J.M. and Berkevich R.J. (2010) Water balance and nitrate leaching under corn in Kura clover living mulch. *Agronomy Journal* 102, 1169-1178.

Zemenchik R.A., Albrecht K.A., Boerboom C.M. and Lauer J.G. (2000) Corn production with Kura clover as a living mulch. *Agronomy Journal* 92, 698-705.

Use of the Lifecorder+® sensor to assess grazing time of dairy cows

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Abstract

The Lifecorder+® is a uniaxial neck-mounted activitymeter. It was tested to assess grazing time in two French experimental automatic milking system farms (20 cows equipped on the Derval farm, 14 cows equipped on the Trévarez farm). The Lifecorder+ raw signal (from 0 to 9) was converted into a grazing yes/no information over a certain threshold. The data from the sensors were compared with visual observations as reference: trained observers recorded activity with a scanning every 10 minutes in the pastures. The recorded activities were as follows: grazing/ruminating and standing/lying/walking. Observation sessions were performed on the Derval and Trévarez farms. Finally, 20 recordings were available for the Derval farm (121 h of cumulated observation time in pasture) and 91 for the Trévarez farm (336 h of cumulated observation time in pasture). The results show a high correlation of grazing time between the visual observations of activity and the information from the sensor (R^2=0.93 on the Derval farm and 0.82 on the Trévarez farm) with a mean prediction error of 18 min (9%) for the Derval farm and 29 min (20%) for the Trévarez farm. Some slight biases related to the recording of walking in the pathways were noticed. Lifecorder+ appears to be a possible cheap, easy and precise tool to record grazing time at pasture.

Keywords: grazing time, accelerometer, Lifecorder+

Introduction

Assessing grass dry matter intake is a difficult task when cows are grazing. Many farmers would like to know if cows are really eating grass when grazing outside, even at night. A first step to reassure farmers is to assess the time spent grazing by cows, though it remains difficult to establish a relation between grazing time and grass dry matter intake. Recently, Ueda *et al.* (2011) and Delagarde and Lamberton (2015) showed that a human activitymeter, named 'Lifecorder+', could be used to assess cows' grazing time. Within the Autograssmilk European programme (http://www.autograssmilk.eu), a work package was dedicated to the of new technologies to optimize the integration of automatic milking systems (AMS) with cow grazing. Therefore, it was decided to check the possibility of using this sensor to record grazing behaviour in this situation. This paper summarizes the test of the Lifecorder+ in two French experimental AMS farms.

Material and methods

The Kenz Lifecorder+® (LC+; Suzuken Co. Ltd., Nagoya, Japan), a device for monitoring uniaxial acceleration, has recently been developed as a commercially available tool for the management of and research on human health. The LC+ not only provides a step count per minute and estimates energy expenditure, but it also records the intensity of physical activity at 4-s intervals. The raw data are summarized into 2-min average activity levels ranging from 0 to 9. To assess the grazing time of dairy cows, the sensors were mounted on neck collars on cows from two AMS experimental farms (20 cows were equipped on the Derval farm, 14 cows equipped on the Trévarez farm). The data from the sensors were then converted into grazing time by an MS Excel tool when the activity level exceeded a certain threshold (configurable – different thresholds were tested on the Derval farm). Intra-meal intervals

(≤4 min) are included in the grazing time and inter-meal parasite activities (≤4 min) are excluded from grazing time (see Figure 1 of Rook and Huckle (1995)). The sensor data when the cows are in the barns are also excluded. After treatment, the data from the sensors were compared with visual observations as reference: trained observers recorded activities with a scanning every 10 min in the pastures. The recorded activities were as follows: grazing/ruminating and standing/lying/walking. One observation session was performed on Derval and 12 observation sessions were performed on Trévarez on 7 days. Finally, 20 recordings were available for the Derval farm (121 h of cumulated observation time in pasture) and 91 for the Trévarez farm (336 h of cumulated observation time in pasture). The accuracy of the LC+ device was studied by calculating the coefficient of determination of the regression between observed and predicted (LC+) grazing time and the mean prediction error (MPE), which is the square root of the mean squared prediction error (MSPE).

Results and discussion

The results of the comparison between measured and observed grazing time are presented in Table 1. The average grazing times observed were 196 min on the Derval farm (65 h of cumulated time) and 147 min on the Trévarez farm (222 h of cumulated time), which represent, respectively, 50 and 66% of the observed access time to pasture. For Trévarez farm, this rate is higher than is usually observed (Kaufmann *et al.*, 2009), mostly because one part of the observation sessions was done just after a paddock change. The results show a high correlation of grazing time between the visual observations of grazing activity and the information from the sensor. For the Derval farm, the best correlation was found when the activity level of 0.3 was used as the threshold ($R^2=0.93$). In this case, the average bias was 3 min (1.5% of the observed grazing time) and the MPE was 18 min (9%). For the Trévarez farm, with a threshold of 0.3, the R^2 of the correlation was 0.82, the average bias was 6 min (4.1%) and the MPE was 29 min (20%). The positive biases were mostly related to walking in the pathways that sometimes generated a signal on the LC+ sensors (Figure 1). For the Derval farm, the correlations were lower and the MPE higher with higher thresholds (0.5, 0.7 or 1). These results confirm, with a lower accuracy, the good results obtained by Delagarde and Lamberton (2015) with the same sensor but with a threshold of 0.5. In a previous study, Ueda *et al.* (2011) observed that the best results were obtained with a threshold of 1. The differences between these studies concerning the best threshold can probably be explained by environmental effects
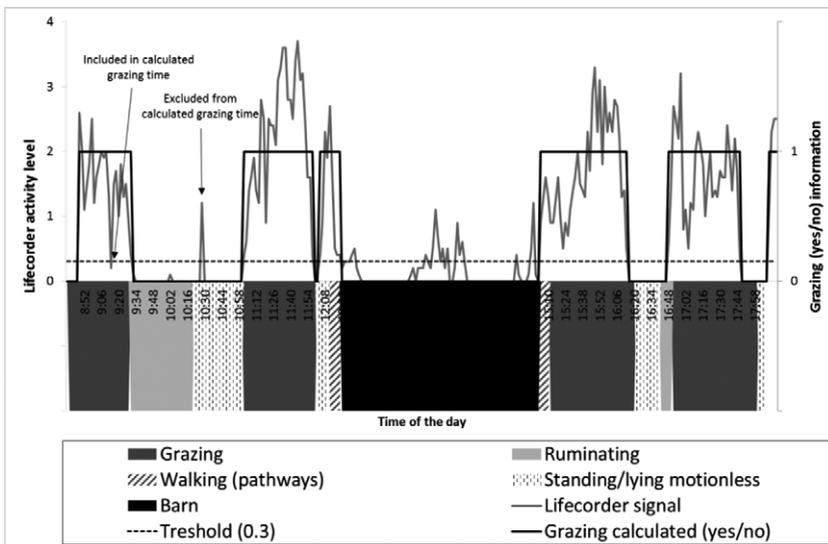
Figure 1. Example of conversion of the LC+ signal (grey line) into grazing information (black line) and comparison to observed behaviours (coloured stripes) for cow 3439 on Derval farm.

Table 1. Results of the comparison between observed and measured grazing time.

Farm	n	Threshold	Observed grazing time (min)	LC+ grazing time (min)	Ave. bias [a] (min)	R[2 b]	MPE [c]	
							min	% obs
Derval	20	0.3	196	199	3	0.93	18	9
		0.5		188	-8	0.84	27	14
		0.7		177	-19	0.75	37	19
		1		162	-34	0.69	49	25
Trévarez	91	0.3	147	153	6	0.82	29	20
All data	111	0.3	155	161	5	0.84	27	17

[a] Average bias = observed − LC+ grazing time

[b] R[2] = coefficient of determination of the regression.

[c] MPE = mean prediction error in min and % of the observed grazing time.

and especially the position of the neck collar. This involves that the use of the LC+ sensor to record grazing time needs an adjustment to each farm situation.

Conclusions

LC+ appears to be a possible cheap, easy and precise tool to record grazing time at pasture for applied research purposes. In the scope of AutoGrassMilk project, the LC+ will be used to establish grazing kinetics in order to describe grazing behaviours of cows on AMS farms. However, the approach is still a long way from being able to assess dry matter intake.

References

Delagarde R. and Lamberton P. (2015) Daily grazing time of dairy cows is recorded accurately using the Lifecorder Plus device. *Applied Animal Behaviour Science*, in press.

Kaufmann L.D., Muenger A., Rerat M., Junghans P., Goers S., Metges C.C., Dohme F. (2009) Dépense énergétique, activité physique et comportement alimentaire de vaches laitières au pâturage ou consommant la même herbe à la crèche. *Rencontre de la Recherche sur les Ruminants*, 2009, 16.

Rook A.J. and Huckle C.A. (1995) Criteria for identifying meals from continuous recordings of the behaviour of grazing dairy cows. *Annales de Zootechnie* 44 Suppl., 105-105.

Ueda Y., Akiyama F., Asakuma S. and Watanabe N. (2011). Technical note: the use of a physical activity monitor to estimate the eating time of cows in pasture. *Journal of Dairy Science* 94, 3498-3503.

Yield and nutritive value of binary legume-grass mixtures under grazing

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Abstract

Legume-grass mixtures generally provide more consistent forage yield than monocultures. We studied 18 binary mixtures of one legume and one grass species for dry matter (DM) yield, neutral detergent fibre (NDF) concentration and *in vitro* digestibility (NDFD), and estimated milk production per hectare. Cocksfoot (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pratensis* L.), meadow bromegrass (*Bromus biebersteinii* Roemer & J.A. Schultes), meadow fescue (*Festuca elatior* L.), tall fescue [*Schedonorus phoenix* (Scop.) Holub], and timothy (*Phleum pratense* L.) were seeded with birdsfoot trefoil (*Lotus corniculatus* L.), lucerne (*Medicago sativa* L.) or white clover (*Trifolium repens* L.). Frequent clipping at two sites, simulating grazing, and cattle grazing at one site were imposed on the 18 binary mixtures in this 3-year study conducted in eastern Canada. Legume and grass species significantly affected seasonal herbage DM yield, NDF concentration, and NDFD of the mixtures averaged over three production years. Birdsfoot trefoil in mixtures with meadow bromegrass or timothy resulted in the largest estimated milk production per hectare under frequent clipping, whereas white clover with meadow bromegrass or tall fescue provided the best results under cattle grazing. Frequent clipping and cattle grazing affected differently the performance of the mixtures, primarily for the legume component. Meadow bromegrass performed very well with the three legume species and under both frequent clipping and cattle grazing.

Keywords: frequent clipping, grazing, digestibility, simple forage mixtures

Introduction

Legume-grass mixtures generally provide more consistent forage yield across a wide range of environments than grass or legume monocultures (Sleugh *et al.*, 2000; Sturludóttir *et al.*, 2013). Forage legumes also fix atmospheric N thereby reducing the need for N fertilization. Cocksfoot, Kentucky bluegrass, meadow fescue, tall fescue, timothy, and meadow bromegrass are forage grass species that are well adapted to the cool seasons of eastern Canada. Lucerne, white clover, and birdsfoot trefoil are perennial legume species recommended in eastern Canada but their performance and nutritive value in mixtures with grasses and under grazing are not well documented. Little information exists in eastern Canada on what species to use in mixtures and on the nutritive value of those mixtures. Our objective was to identify binary legume-grass mixtures with high forage yield and nutritive value under both frequent clipping and cattle grazing.

Materials and methods

The experiment was conducted in eastern Canada with frequent clipping to a 7-cm sward height with a self-propelled flail forage harvester at two sites (Lévis and Normandin, QC) to simulate grazing or with cattle grazing at Nappan (NS). Plots were clipped or grazed when timothy reached about 25 cm in height. Binary legume-grass mixtures (18) of one of six grass species (cocksfoot, Kentucky bluegrass, meadow bromegrass, meadow fescue, tall fescue, and timothy) were seeded in 2010 with birdsfoot trefoil, lucerne or white clover. Binary mixtures were replicated three times in a split-plot layout, with legume species as main plots set out as a Latin square and grass species randomized to the subplots. Herbage yield, neutral detergent fibre (NDF) concentration, and *in vitro* digestibility (NDFD) were measured at

each clipping or grazing event, and potential milk production per hectare was estimated with MILK2006 (Undersander *et al.*, 2006) for three production years (2011, 2012, and 2013). MILK2006 calculates the total digestible nutrient concentration and milk produced per Mg of alfalfa-grass forages based on NDFD and NRC (2001) equations using an Excel spreadsheet. Data were assessed across treatments by analyses of variance (ANOVA) using the GENSTAT 14 statistical software. Treatments and harvest methods (frequent clipping and cattle grazing) were considered fixed effects.

Results and discussion

Legume and grass species significantly ($P<0.01$) affected seasonal herbage DM yield, NDF concentration, and NDFD of the mixtures averaged over three production years (Table 1). The effect of the legume and grass species, however, varied with the harvest method as indicated by a significant ($P<0.01$) interaction of the legume and grass species with the harvest method for seasonal dry matter (DM) yield and NDF concentration. Among the 18 binary mixtures, seasonal DM yields ranged from 4.48 to 6.94 Mg ha^{-1} with frequent clipping and from 5.57 to 7.62 Mg ha^{-1} with cattle grazing. Significant variations in NDF concentrations (392-484 and 471-554 g kg^{-1} DM) and NDFD (693-756 and 599-718 g kg^{-1} NDF) were also observed among the 18 binary mixtures under frequent clipping and cattle grazing, respectively.

The estimated milk production per hectare integrates both the DM yield and nutritive value of the herbage. Birdsfoot trefoil-based mixtures (11.7 Mg ha^{-1}) generally resulted in greater estimated milk production than lucerne-based (9.4 Mg ha^{-1}) and white clover-based mixtures (8.8 Mg ha^{-1}) under frequent clipping, but in lower estimated milk production under cattle grazing (11.1 vs 12.1 and 12.4 Mg ha^{-1}, Figure 1). Timothy- and meadow bromegrass-based mixtures generally resulted in greater estimated milk production (10.5 and 11.0 Mg ha^{-1} under frequent clipping; 12.0 and 12.7 Mg ha^{-1} under cattle grazing) than the other grass species-based mixtures. These differences in estimated milk production are due more to differences in DM yield than to differences in nutritive value (Table 1). Overall, birdsfoot trefoil mixed with either meadow bromegrass or timothy resulted in the largest estimated milk production per hectare under frequent clipping, whereas white clover with meadow bromegrass or tall

Table 1. Main effects of legume and grass species on herbage seasonal dry matter (DM) yield, neutral detergent fibre (NDF) concentration, and *in vitro* NDF digestibility (NDFD) of the mixtures under frequent clipping and cattle grazing. Values are averages over three production years.

Mixtures	DM yield (Mg ha^{-1})		NDF (g kg^{-1} DM)		NDFD (g kg^{-1} NDF)	
	Frequent clipping	Cattle grazing	Frequent clipping	Cattle grazing	Frequent clipping	Cattle grazing
Legumes						
Birdsfoot trefoil	6.13	6.14	428	522	726	677
Lucerne	5.17	6.71	435	511	711	665
White clover	4.74	6.72	462	505	746	698
SEM[1]	1.21		7.1		11.6	
Grasses						
Meadow bromegrass	6.03	6.75	449	484	732	690
Timothy	5.39	6.36	402	508	729	697
Tall fescue	5.37	7.05	471	529	737	696
Kentucky bluegrass	5.22	6.81	430	529	696	619
Meadow fescue	5.08	6.20	445	525	744	704
Cocksfoot	4.99	5.97	454	502	728	675
SEM	1.22		8.0		11.8	

[1] SEM = standard error of the mean.
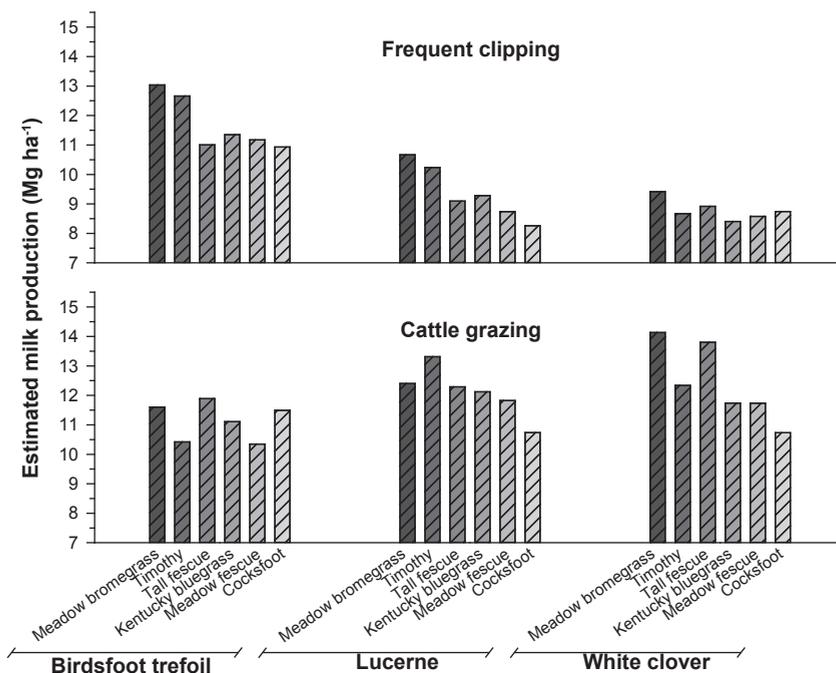
Figure 1. Estimated milk production per hectare for 18 binary grass-legume mixtures under frequent clipping and cattle grazing. Values are averages over three production years (standard error of the mean = 2.28 Mg ha^{-1}).

fescue provided the best results under cattle grazing. With cattle grazing, animal preference for birdsfoot trefoil might have reduced its DM yield and persistence over the three years of the study.

Conclusions

Frequent clipping and cattle grazing affected differently the performance of the mixtures, primarily for the legume component. Meadow bromegrass performed very well with the three legume species and under both frequent clipping and cattle grazing.

References

NRC (2001) *Nutrient requirement of dairy cattle*. 6th revised ed. National Academy of Sciences, Washington, DC, USA.

Sleugh B., Moore K.J., George J.R. and Brummer E.C. (2000) Binary legume-grass mixtures improve forage yield, quality, and seasonal distribution. *Agronomy Journal* 92, 24-29.

Sturludóttir E., Brophy C., Bélanger G., Gustavsson A.-M., Jørgensen M., Lunnan T. and Helgadóttir Á. (2013) Benefits of mixing grasses and legumes for herbage yield and nutritive value in northern Europe and Canada. *Grass and Forage Science* 69, 229-240.

Undersander D., Combs D., Shaver R. and Hoffman P. (2006) University of Wisconsin alfalfa/grass evaluation system – MILK 2006. UW Extension. Available at: http://www.uwex.edu/ces/dairynutrition/documents/milk2006alfalfa-grassprotected.xls.

Farm-level phytodiversity of dairy farms is related to within-farm diversity of grassland management types

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Abstract

We analysed 163 vegetation relevés from grassland plots of 24 conventional dairy farms in Lower Saxony, NW Germany. The sample covered farms with a different magnitude of the contribution of pasture to the roughage ration of the dairy cows: zero-grazing, grazing for <6 h d^{-1}, or >14 h d^{-1}. At each farm, the sward botanical composition of two plots per existing grassland management type was determined in one quadrat of 25 m^2 per plot. Average plot-level species numbers was distinct among types of plot management (P<0.001) and ranged from 10.6 in intensively managed meadows to 15.0 in plots managed according to agri-environmental schemes. The species number of dairy cattle pastures did not differ significantly among farms implementing different daily grazing periods. The total species number at the whole farm-level ranged from 10 to 39 and increased significantly (P=0.001) with the number of grassland management types implemented on the farms. Our results emphasize the importance of farm-level organizational structures for regional phytodiversity.

Keywords: farm scale, γ diversity, management intensity, pasture, species number, sward botanical composition

Introduction

The majority of experimental and observational studies on sward phytodiversity–management relationships in permanent grassland have focussed on the plot level and linked phytodiversity to management and site conditions prevalent immediately on the studied plot. In contrast, few studies have so far examined the scale level of the whole farm to investigate phytodiversity–management relationships.

In Central and North-Western Europe, the total productive area of grassland-based dairy farms is usually divided into parcels (fields or paddocks) which are subjected to various management types like (a) meadows for silage or cut-grass production, (b) dairy cow pastures, eventually mown, (c) pastures for young stock, bulls or non-lactating cow, or (d) meadows or pastures managed extensively according to agri-environmental schemes. The respective plots feature swards of distinct phytodiversity: species richness is generally higher in pastures than in intensively managed meadows. Implementation (present/absent) and relevance (area share of the total grassland area of a farm and proportion in total roughage production) of each of these management types depend on the overall farm-level organisation and the production targets of the farmer.

The aim of the present study was to quantify the phytodiversity of conventional, intensive dairy farms in NW-Germany at several scale levels and to determine interrelations between farm organisation structures and phytodiversity. We considered α diversity in terms of the plant species number at the plot level and γ diversity in terms of the respective farm-level plant species number. We examined the relationship between phytodiversity and the farm-level structure of grassland management. The sample of farms for this study was designed to cover a range of models of farm organization with a varying importance of pasture for the roughage ration of the dairy cows. We hypothesised (I) that plot-level phytodiversity of dairy cattle pastures would be lower in farms with a larger contribution of pasture to the roughage ration,

on the basis that the composition of the sward would be managed more intensively in favour of high-value species in settings where pasture forage holds a more important share of the ration, and (II) that farms implementing a higher number of grassland management types would feature a higher γ diversity, on the basis that they would comprise a higher number of plots bearing a comparatively high α diversity.

Materials and methods

This study is based on a total of 163 botanical relevés from 24 conventional dairy farms in Lower Saxony, NW Germany. The farms were selected to represent three groups differing with regard to the contribution of grazing to the roughage ration of the dairy cows: zero-grazing (n=5), farms with a minor contribution of pasture (grazing for <6 h d^{-1}; n=7), and farms with a large contribution of pasture to the roughage ration of the dairy cows (grazing for >14 h d^{-1}; n=12). This classification was chosen in order to represent a wide range of models of farm organization. At each farm, the total number and the identity of grassland management types implemented – e.g. dairy cow pasture, meadow (cutting only), young stock pasture, mown pasture – was obtained by asking the farmers, and the sward botanical composition was determined on two parcels per existing grassland management type by recording the yield proportions of the individual species in one quadrat of 25 m^2 per parcel.

We used linear models to analyse (a) the effects of grassland management type and farm organisation structure on α diversity (plot-level species number) and (b) the effect of the number of grassland management types per farm on γ diversity (farm-level species number).

Results and discussion

As expected, the plots of different grassland management types featured a significantly ($P<0.001$) distinct α diversity. Altogether, α diversity was comparatively low. The average species number ranged from 10.6 in intensively managed meadows to 15.0 in parcels managed according to agri-environmental schemes (Figure 1). The latter, as well as young-stock pastures, featured a higher number of both common grassland species and species indicative of extensive management. The α diversity values of dairy cow pastures and of intensively managed meadows were close to equal. Alpha diversity of dairy cow pastures was not affected by the implemented daily grazing period; this finding therefore fails to support our hypothesis (I).

The three groups of dairy farms which had been defined with regard to the contribution of pasture to the roughage ration of the dairy cows differed significantly, both regarding the number of implemented grassland management types ($P<0.001$) and regarding γ diversity ($P=0.001$) (Figure 2). The total farm-level species number increased significantly with the number of grassland management types present
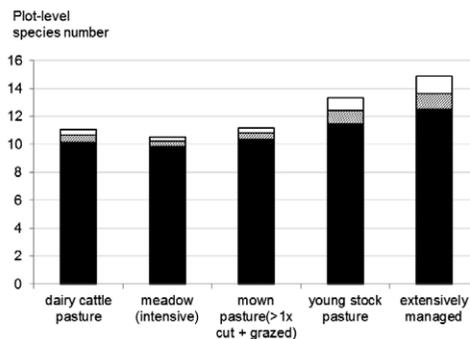
Figure 1. Species number (α diversity, plot-level) of grassland swards in parcels of different management type. Colour of bar sections: black: species common to farmed grassland in general; shaded: grassland weeds (unpalatable species or indicators of excess N supply); white: species indicative of extensive management or target species listed for result-oriented agri-environment schemes.
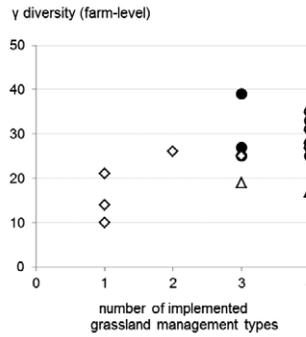
Figure 2. Relationship between γ diversity (farm-level species number) and the number of grassland management types implemented on the farm. Symbols represent farms differing with regard to the contribution of pasture to the dairy cow roughage ration: diamonds – zero-grazing; triangles – grazing <6 h d^{-1}; dots – grazing >14 h d^{-1}.

on the farm, which is supportive of our hypothesis (II). Zero-grazing dairy farms in most cases merely implemented one grassland management type – intensive cutting – which yields the lowest α diversity. Additional implementation of pasture for non-lactating cows or young stock enhanced farm-level phytodiversity due to the higher α diversity of these plots. The farms which included pasture in the roughage ration of the dairy cows in general implemented a higher number of grassland management types, and therefore also featured a higher γ diversity. This interrelation appears to be independent of the magnitude of the contribution of pasture to the roughage ration of dairy cows (Figure 2).

Our study follows the approach of relating phytodiversity of grassland-based farms with farm-level organisation structures, which is innovative in the way that farm-level structures have, so far, seldom been taken into account in studies on grassland biodiversity. We recommend that consideration should be given to the factor 'intensity of grassland management' at a larger number of scale levels for understanding regional phytodiversity; in addition to the plot-scale (the immediate site management), the farm-scale appears to be of major importance. This includes the production targets and decisions of the farmer and the resulting within-farm diversity of grassland management types. An approach of this kind may be crucial to analysing the effects of the ongoing shift in dairy farm organisation (Van den Pol-van Dasselaar *et al.*, 2008) on ecosystem services. Yet, we acknowledge that further research is required to strengthen the robustness of our findings. In particular, this encompasses the mining of data from a larger number of farms, the inclusion of plot size into the analysis of phytodiversity in order to take account of species-area relationships, and the consideration of socio-economic factors governing the implementation (presence/absence and intensity level) of individual grassland management types.

Conclusions

Our study highlights the relationship between within-farm organisation structures and farm-level phytodiversity. We deem that our results emphasize the importance of considering farm-level processes in the analysis of ecosystem services at the regional scale.

References

Van den Pol-van Dasselaar A., Vellinga T.V., Johansen A. and Kennedy E. (2008) To graze or not to graze, that's the question. *Grassland Science in Europe* 13, 706-716.

Improved potassium fertiliser recommendation for grasslands in the Netherlands

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Abstract

Optimal potassium (K) fertilisation stimulates grassland production. In 2011 and 2012 fertiliser trials on grassland were executed to update the 40-year-old recommendations. Farm field trials were executed on 24 locations on sand, clay and peat soils with varying K-availability and buffering capacity. There were three treatments on each site: with or without cattle slurry application, two nitrogen (N) levels (60 and 120 kg N ha^{-1}) and two K fertiliser levels (0 and 60 kg K$_2$O ha^{-1}). Uptake of K in the first and second cut (to account for any residual effect) was determined to derive the optimal K-application rate. In parallel there was a seasonal trial with different N and K levels to test the interaction of K with N. Fertilisation with 60 kg K$_2$O ha^{-1} resulted in extra yield of the first cut of 200 to 650 kg DM ha^{-1}. The fertiliser increased the yield in the seasonal trials up to 2 tons DM ha^{-1} year^{-1}. The experimental data were used to develop a new recommendation system based on the soil parameters of cation exchange capacity and available K determined in 0.01 M CaCl$_2$. The new recommendation results, on average, in a lower K application rate than the previous recommendation.

Keywords: potassium, fertilization, soil fertility, CEC, herbage yield, recommendation

Introduction

Optimal grass growth requires an adequate supply of potassium (K) at the right time. The Dutch K fertiliser recommendation system is to a large extent based on trials from 60-80 years ago (Van der Paauw, 1943) at a time when heavy first cuts (5-7 Mg DM ha^{-1}) were common. In later years these results were extrapolated to the actual grassland management system with first cuts taken at a much earlier growth stage (3-4 Mg DM ha^{-1}). The soil K status in the current recommendation system is provided as a K-index (derived from a soil extraction with 0.1 M HCl and corrected for the amount of soil organic matter) though it is known that this is not the best method to predict the K supply by the soil. Measuring available K via an extraction with 0.01 M CaCl$_2$ in combination with the cation exchange capacity (CEC) seems a promising method as was shown by Van Rotterdam (2010). Therefore, in 2011 a two-year K-fertiliser trial on multiple locations was performed to implement the findings of Van Rotterdam. This paper summarises some of the results leading to a new recommendation system, which was introduced in autumn 2014.

Materials and methods

The trial consisted of two sub-tests: farm field trials on 24 locations (11 in 2011 and 13 in 2012) during the first and second cut, and a detailed seasonal trial at three locations (see also Holshof and Van Middelkoop, 2014). Farm field trials were executed on different soil types with 2 sites per location varying in K-availability and buffering capacity. There were three treatments on each site: without and with cattle slurry application (30 m^3 ha^{-1} on average), two nitrogen (N) fertiliser levels (60 and 120 kg ha^{-1}) and two K fertiliser levels (0 and 60 kg K$_2$O ha^{-1}). This setup resulted in K-levels of: 0, 60, 90 and 150 kg K$_2$O ha^{-1}. On every plot superphosphate was applied to ensure an adequate supply of phosphorus and sulphur. In total there were respectively 20, 14 and 14 sites on sand, clay and peat grassland with a large variation in soil characteristics (Table 1). The second cut was used to measure the residual K effect and received only N-fertiliser at a rate of 30 kg N ha^{-1}. Herbage dry matter (DM) yield and K uptake of both cuts were determined to derive the optimum K-application rate. The seasonal trials were conducted

Table 1. The soil analysis results of the 54 sites used in the trials: the minimum, mean and maximum value.

	clay	OM[1]	CEC[1]	NLV[1]	SLV[1]	pH[2]	K[2]	Mg[2]	Na[2]	P[2]	PAL[1,2]
	g kg^{-1}	g kg^{-1}	mmol+ kg^{-1}	kg N ha^{-1}	kg ha^{-1}		mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg kg^{-1}	mg 100 g^{-1}
min	10	11	46	61	6	4.6	32	23	5	0.3	17
mean	148	116	205	181	16	5.9	114	272	35	2.1	45
max	490	257	442	250	32	7.3	317	510	90	9.3	116

[1] OM denotes organic matter; CEC the cation exchange capacity; NLV the N supply of the soil; SLV the sulphur supply of the soil; and PAL the amount of P extracted with ammonium lactate.

[2] Measurement based on extraction 0.01 M CaCl$_2$.

on sand, clay and peat grassland with a relatively low K-status and with different sites in 2012 than in 2011. In total, five cuts were harvested annually. Fertilisation took place with only mineral fertiliser. The setup was a randomized block trial (in duplicate) with three N levels: 0, 180 and 360 kg ha^{-1} yr^{-1} and four K levels for the first cut: 0, 60, 120 and 180 kg K_2O ha^{-1}. The 60 and 180 K-treatments were setup in triplicate. After the first cut these treatments received respectively 0, 40 and 80 kg K_2O ha^{-1} per cut. The 120 K_2O ha^{-1} treatment received the same amount in every cut. This resulted in a total annual application of between 0 and 600 kg K_2O ha^{-1}. The grass yield data were statistically analysed with GenStat® Release 16 (Payne *et al.*, 2010) using Restricted Maximum Likelihood with as random factor location×year. The derived model contained 18 soil and fertiliser application parameters and relevant two-way interactions. Data were log transformed before the analysis for homogeneity.

Results and discussion

In the farm field trials yield levels varied largely between locations. The average yield for the first cut in 2011 and 2012 was 4.9 and 5.2 Mg DM ha^{-1}, respectively. The second cut had an average yield of 2.3 Mg DM ha^{-1}. The yield of the first cut was mainly controlled by the first application of 60 kg K_2O ha^{-1} (Table 2). The variation in K content and herbage uptake was high but on average at an adequate level; 80% was above the critical level of 20 g K kg^{-1} DM (Whitehead, 2000). The farm field trials clearly demonstrated yield responses to the level of N and K fertilisation, which were dependent on soil conditions. The effects of the first cut were also measured in the second cut, but treatment effects were less than in the first cut. As in the farm-field trials, the seasonal trials also showed that with 60 kg K_2O ha^{-1} in the first cut a yield increase was obtained of about 650, 350 and 200 kg DM ha^{-1} on sand, peat and clay grassland, respectively. A higher K-level yielded almost no additional response. On an annual basis the yield increase was, respectively, 2, 1.5 and 0.3 Mg DM ha^{-1} when 500 kg K_2O ha^{-1} was applied. Higher N-levels gave a higher dry matter yield at all locations. The treatments that received K fertiliser in the first cut and no K during the rest of the year, gave also a higher DM yield in all cuts compared to the treatments without any K fertiliser.

Table 2. Grass yield (kg DM ha^{-1}) in the first and second cuts for the treatments with and without mineral K_2O fertiliser and cattle slurry for two N fertiliser levels (in parenthesis the relative compared to the maximum yield).

K_2O fertiliser	Cattle slurry	First cut		Second cut[1]	
		60 kg ha^{-1}	120 kg ha^{-1}	60 kg ha^{-1}	120 kg ha^{-1}
0	no	4,586 (83)	5,118 (93)	2,128 (85)	2,282 (91)
0	yes	4,947 (90)	5,453 (99)	2,346 (94)	2,449 (98)
60	no	4,799 (87)	5,249 (95)	2,205 (88)	2,284 (91)
60	yes	5,213 (95)	5,507 (100)	2,279 (91)	2,501 (100)

[1] The applied amount for the 2nd cut was 30 kg N ha^{-1}.

Crop yield was satisfactorily explained by the included soil and fertilizer parameters (R^2_{adj}=87%). The effective amount of applied N from fertiliser and cattle slurry (N_{eff}) and K_2O (K_2O_{eff}) were used as explanatory variables. The applied amounts of N_{eff} and K_2O_{eff} were highly significant ($P<0.001$) as well CEC and the potassium content of the soil (K). The interaction between K_2O_{eff} and CEC, and between K_2O_{eff} and K were also significant ($P<0.05$). Organic matter and clay content were not significant. There was no interaction between K_2O_{eff} and N_{eff}. This pattern was observed also for K-uptake. The derived statistical relationship for yield was used to develop a new K-recommendation. The relationship was simplified to:

$$\ln(Yield) = C + \ln(K_2O_{eff}) + \ln CEC + \ln K + \ln(K_2O_{eff}).\ln CEC + \ln(K_2O_{eff}) \times \ln K \qquad (1)$$

Without any K_2O fertilisation, this relationship reduced to:

$$\ln(Yield_0) = C + \ln CEC + \ln K \qquad (2)$$

For different combinations of CEC and K, the constant c was calculated for target yields of 1,700, 3,500 and 5,000 kg DM ha^{-1}. Combining Equation 1 and Equation 2 under the assumption that the amount of K_2O_{eff} should result in 4 kg extra DM ha^{-1} per kg K_2O_{eff} resulted in the relationship:

$$K_{crit} = 4 = EXP(\ln(Yield) - \ln(Yield_0))/K_2O_{eff} \qquad (3)$$

which was iteratively solved for the same combinations as Equation 2, including the corresponding C. This resulted in a dataset of optimum K_2O_{eff} rates for different target yields, CEC and K. To compare the previous recommendation with the improved recommendation, analysis of a large dataset of 2,800 soil samples showed that for a normal (3,500 kg DM ha^{-1}) and a heavy (>4,500 kg DM ha^{-1}) first cut, applications of 42 and 66 kg K_2O ha^{-1} fertilizer were needed to obtain the desired crop yield. These fertiliser rates are much lower than those recommended in the previous system.

Conclusions

An improved K fertiliser recommendation for grasslands in the Netherlands has been developed based on two-year trials on multiple grassland locations. It is based on the soil parameters CEC and $CaCl_2$ extractable soil K. The recommended amounts of K_2O for the first cut are much lower than in the previously recommended system.

References

Holshof G. and Van Middelkoop J.C. (2014) Towards a new potassium fertilization recommendation in the Netherlands. In: EGF at 50: the future of European Grassland. *Grassland Science in Europe,* 19, pp. 245-247.

Payne R.W., Murray D.A., Harding S.A., Baird D.B. and Soutar D.M. (2010) *Introduction to GenStat® for Windows™.* VSN International, Hemel Hempstead, UK.

Van der Paauw F. (1943) Grondonderzoek naar fosfaat- en kalitoestand op grasland. *Verslag Landbouwkundig Onderzoek 49 (17A)*, 958-1012.

Van Rotterdam-Los A.M.D. (2010) *The potential of soils to supply phosphorus and potassium; processes and predictions.* PhD thesis Wageningen University, Wageningen, the Netherlands.

Whitehead D.C. (2000). *Nutrient Elements in Grassland: Soil-Plant-Animal Relationships.* CABI publishers, Wallingford, UK.

How much milk is produced from pasture? Comparison of two calculation methods

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Abstract

The sustainable use of grassland resources is a good way to produce cheap fodder of adequate quality with usually short transportation pathways. However, many farmers do not know how much fodder they produce on grassland and how much milk is produced from this fodder, especially on pastures. The commonly used calculation method attributes milk production mainly to the energy taken up in the stable and only the remainder (plus the complete energy expenditure for maintenance) to pasture, probably leading to an underestimation of the contribution from pasture. Here, we compared this conventional method to another one attributing the energy expenditure for maintenance and milk according to the energy contributed by each fodder type. As a database, six years of data from a pasture trial carried out at House Riswick, Germany, have been used, with three years of full grazing and three years of half-day grazing plus silage and concentrates provided in the stable. In contrast to the alternative method, the conventional method underestimated pasture performance, especially at small shares of pasture in the ration. Adapting the alternative method in extension services may lead to a better appraisal of grass as a basis for milk production.

Keywords: pasture production, roughage, full grazing, concentrates, energy corrected milk

Introduction

For a sound judgement of the competitiveness of dairy farms, a proper estimation of milk performance is needed. Lately, this estimation has tended to shift from performance per animal to performance per area (Thomet and Reidy, 2013). To judge the latter, it is essential to have a good idea of the milk production from grassland. Especially for pastures, this is complex as the quantity and quality of fodder taken up by the animals is often unknown. In Germany, the common calculation method for milk production per pasture area therefore subtracts the amount of milk produced from fodder taken up in the stable (concentrates and silage) from the total amount of milk. Any fodder taken up on pastures then covers the remainder of the milk plus the energy needed for maintenance. According to a new method suggested by Leisen *et al.* (2013), the milk production from pasture can also be calculated by multiplying the total amount of milk produced with the share of energy supplied by pasture, thus splitting the energy needed for maintenance over all fodder types according to their share in the ration. In this paper, we compared both methods using data from two grazing systems of an experimental farm. This is the first comparison of the methods with real farm data. We hypothesized that the new method gives better results for pasture performance, and that the difference between the methods would be larger the smaller the share of pasture grass in the ration. Furthermore, we hypothesized that there is no difference in pasture performance calculated per hectare between a full and a half-day grazing system if the area is adapted according to the uptake of the animals.

Materials and methods

Grazing experiments were carried out at House Riswick, Chamber of Agriculture, Germany, between 2009 and 2014. In the first three years, full grazing was practised to a compressed sward height (CSH) of

5-6 cm (short-lawn pasture). The animals were managed in two herds where one was fed on pasture but received concentrates according to performance in 2009 while the other received supplementary silage (in 2009 only) and/or concentrates (fixed amounts in 2010; according to performance in 2009 and 2011). From 2012 to 2014, all animals were on pasture for half a day (6-7 cm CSH) and received a mixture of concentrates and silage in the stable and additional concentrates according to milk performance. No mineral fertilizer was used during the duration of the pasture trial with the exception of 450 kg kainite ha^{-1} applied in spring 2011 on some of the areas. Slurry was only applied in spring on areas used for cutting.

Data on the composition and amount (dry mass) of stable fodder as well as its energy content (literature data for wheat, grain maize) were collected on a daily basis. This was used to calculate the net energy lactation (NEL) provided by the stable fodder. Two times per month, data from milk inspection on the amount and quality of milk were received. This yielded the NEL needed for milk production (based on energy corrected milk). The average live weight of the herd was measured once a month to calculate energy needs (in NEL) for maintenance. Energy requirements for growth or activity were not taken into account. The NEL from stable fodder divided by the NEL needed for milk production and maintenance gave the contribution of stable fodder, or – by subtracting this number from one – that of pasture to the NEL of the total ration.

Calculation of pasture performance was done as follows:
- Method 1 (conventional method): Milk from pasture = total milk – milk from stable fodder
- Method 2 (Leisen *et al.*, 2013): Milk from pasture = total milk × contribution of pasture to NEL of ration

Statistical evaluation of the results was done using SPSS 20.0. The three years per grazing method were considered as replicates and data were analysed with ANOVA after testing for normality and homogeneity of variances.

Results and discussion

Table 1 shows the average pasture productivity per grazing system calculated using the two different methods. As expected, Method 1 led to significantly smaller values than Method 2. The difference was much larger for the half-day grazing system than for full grazing. This can be attributed to the energy expenditure for maintenance that remains similar for full and part-time grazing but takes a larger share of a smaller pasture uptake if assumed to be derived fully from pasture (Method 1). Table 1 also indicates that there are large and significant differences calculated in the milk yield per hectare with Method 1, but not with Method 2. As the available pasture area was adapted to the animals' requirements, we hypothesized that the outcome per area should be similar. Thus, Method 2 seems to deliver more realistic results under the tested circumstances. A difference in outcome would only be expected if pasture was managed less efficiently, if animals differed in selectivity between systems, or if the quality of the herbage on offer

Table 1. Pasture productivity (energy-corrected milk, kg ECM ha^{-1} a^{-1}) in a full grazing and a half-day grazing system with additional feeding, evaluated by two methods.[1]

	Method 1	Method 2	*P*-value between methods
Full grazing	7,754 (651)	9,337 (340)	0.020
Half-day grazing	1,921 (550)	8,438 (1,638)	0.003
P-value between grazing systems	<0.001	0.405	

[1] Methods are explained in the text. Shown are means and standard deviations (within brackets) of values collected over three years. *P*-values are the result of an ANOVA analysis.
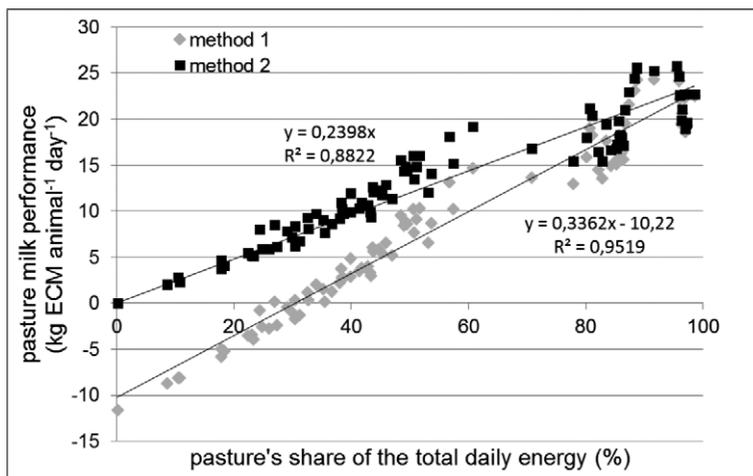
Figure 1. Pasture performance in terms of kg energy corrected milk (ECM) animal⁻¹ day⁻¹ versus the share of the total daily energy provided by pasture fodder.

differed. Larger standard deviations for the half-day grazing system were due to weather conditions in 2013 causing a shorter grazing period and more supplementary feeding in summer due to drought. If this year was left out of the calculation, the outcome for Method 2 was even more similar.

Figure 1 indicates the influence of pasture's share of the total ration's energy on the calculated pasture milk performance. It clearly shows that the deviation between the calculation methods is larger the smaller the share of pasture grass in the ration. This is in line with our hypothesis.

Conclusions

The miscalculation of pasture performance following the conventional method increases with a decreasing share of pasture feeding, suggesting even a negative pasture performance at shares below 30%. To enable sustainable and realistic management decisions regarding pastures, it is essential to change the conventional method for calculating pasture performance.

References

Leisen E., Spiekers H. and Diepolder M. (2013) Notwendige Änderungen der Methode zur Berechnung der Flächenleistung (kg Milch/ha und Jahr) von Grünland- und Ackerfutterflächen mit Schnitt oder Weidenutzung. In: *Annual Meeting of the Arbeitsgemeinschaft Grünland und Futterbau*, pp. 181-183.

Thomet P. and Reidy B. (2013) Entwicklung von neuen Effizienzparametern zur Charakterisierung von Milchproduktionssystemen. In: *Annual Meeting of the Arbeitsgemeinschaft Grünland und Futterbau*, pp. 70-76.

Exploitable yield potential of grasslands in the Netherlands

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Abstract

The Dutch dairy sector is leading in production efficiency with research and innovation achieving great improvements by focussing on the cow as the central production factor. Grass and soil, while also being essential production factors, have received much less attention. Recent developments mark a turning point for attention to grass production and grazing. While increased focus on grass production and grazing is generally considered as sustainable development, it is centred around the dimensions of people or planet; the profit dimension is under-represented. This paper builds the economic case for an increased focus on grass production and grazing by modelling the exploitable yield of grass production in the Netherlands. The current dry matter (DM) production is assessed at 6.0×10^6 Mg. The potential production is modelled at 9.3×10^6 Mg, thus leading to an exploitable net yield of 3.3×10^6 Mg. This is over 1.5 times the current grass production. Financially, the additional production implies a gain of 500 million euros when taking into account the market price for grass DM. When considering the feed value profits may rise to 750 million euros.

Keywords: dairy, grassland, grazing, yield gap analysis

Introduction

In the past decades, the Dutch dairy sector has made great improvements in production efficiency. The underlying research and innovation agenda shows a focus on the cow as the central production factor. While the cow is undeniably essential, grass and soil are also essential production factors. Forage is the main feed for dairy cattle and grasslands are predominantly grazed (Van den Pol-van Dasselaar *et al.*, 2012), making grass the major – and if grazed, the cheapest (O'Donovan *et al.*, 2011) – source of raw material for milk production. Despite this, research and innovation agendas gave grass production fewer and fewer attention. In addition, a decline of grazing, a lack of knowledge and craftsmanship especially among young dairy farmers (Reijs *et al.*, 2013), and a stagnant yield of dry matter (DM) (Aarts *et al.*, 2008; Remmelink and Hilhorst, 2013) is seen.

Recent developments mark a turning point; the signing of the Covenant Outdoor Grazing (Duurzame Zuivelketen, 2012) and the introduction of a legislative system after the milk quota abolishment (Eerste Kamer der Staten-Generaal, 2014). While increased focus on grass production and grazing is generally considered as sustainable development, drivers mostly represent the people or planet dimensions of the triple bottom line, but ignore the profit dimension. In other words, the choice for grass production and grazing is made because of social, environmental or ethical reasons, but not for economic reasons. There is a need to build an economic case around grass production and grazing in order to fully attain its sustainability promise. This paper models the exploitable yield gap of grass production based on published data and on expert opinions, and translates this into an economic case.

Actual yield

Aarts *et al.* (2008) calculated an average DM yield of 10.2 Mg ha^{-1}. This figure is represented as a net yield taking into account the uptake of grass by grazing and the exportation of silage. It does not, however, include losses during conservation and feeding of silage. Since on average 72% of grass is used as silage

(Aarts *et al.*, 2008) and over this part losses are 20% (Remmelink *et al.*, 2013) the yield calculated by Aarts *et al.* multiplied by 0.856 leads to a net yield including grazing, conservation and feeding losses of 8.73 Mg DM ha^{-1}. Dutch dairy farms together own 688,331 hectares of grassland [Statline CBS]. Multiplying this with the yield per hectare results in an annual total gross DM production of 7.0×10^6 Mg or a total net DM production of 6.0×10^6 Mg.

Yield potential of grass production and exploitable yield

Crop simulation modelling research performed during the 1960s reports a gross yield potential of 20 Mg ha^{-1} yr^{-1} under optimal conditions (Alberda and Sibma, 1968). More recently, gross yields of up to 18 Mg ha^{-1} were reported in research the authors are involved in. Van Ittersum *et al.* (2013) argue that crop simulation modelling is the most reliable way to estimate yield potential in the context of a specific crop within a defined cropping system. However, since the Netherlands has a wide variety of growing conditions, and since the recent data reflect data covering a variety of conditions, the method of maximum farmers' yield (Van Ittersum *et al.*, 2013) is chosen. The maximum gross yields reported are 18 Mg DM ha^{-1} yr^{-1}, which is a net yield potential of 15.4 Mg DM ha^{-1} yr^{-1}.

This potential indicates a maximum, which will not be achievable on the whole area of grassland due to local growth defining, limiting and reducing factors. Based on expert opinion, the total area of grassland in the Netherlands is divided into five types:
- G1: grassland for cultivation of cow feed and thus with optimal conditions, estimated at 50% of total land area (TLA) and a potential of 100% of exploitable yield (EY);
- G2: grassland under fertilization restrictions, 12.5% TLA and 90% EY;
- G3: grassland under drought limitations, 12.5% TLA and 80% of EY;
- G4: grassland with poor drainage conditions, 12.5% TLA and 70% EY;
- G5: grassland that serve other purposes next to agricultural production, 12.5% TLA and 60% EY.

Exploitable yield gap

Table 1 shows the net exploitable yield of grass production in the Netherlands at 9.3×10^6 Mg. Given the current yield of 6.0×10^6 Mg, the net exploitable yield gap is 3.3×10^6 Mg.

Feed values

The extra DM production represents additional feed value. Grazed grass represents 0.938 kVEM (net energy lactation (NEL) according to Dutch standards) and 0.083 kDVE (true protein digested in the small intestine according to Dutch standards), whereas silage represents 0.891 kVEM and 0.062 kDVE (Vermeij, 2013). Since about 72% of grass production is used as silage (Aarts *et al.*, 2008), one kilogram DM (gross) represents 0.904 kVEM and 0.068 kDVE. Thus, the total gross exploitable yield gap of 3.8×10^6 Mg DM represents 3.5×10^6 kVEM and 2.6×10^5 kDVE.

Table 1. Total exploitable yield of grass production in the Netherlands.

Type	Land area proportion[1]	Gross exploitable yield		Net exploitable yield	
		(Mg ha^{-1})	(10^6 Mg)	(Mg ha^{-1})	(10^6 Mg)
G1	0.5	18.0	6.2	15.4	5.3
G2	0.125	16.2	1.4	13.9	1.2
G3	0.125	14.4	1.2	12.3	1.1
G4	0.125	12.6	1.1	10.8	0.9
G5	0.125	10.8	0.9	9.2	0.8
Totals			10.8		9.3

[1] Estimated proportion of the total 688,331 hectares of grassland.

Financial impact of exploitable yield gap

Current market value of grass (gross) is € 0.13 kg^{-1} DM (Vermeij, 2013). The financial gain for the dairy sector based on this alone would be almost 500 M €. If, however, we focus on the feed value of the extra production, the profits would be higher. One kVEM is worth € 0.13 and one kDVE € 1.03 (Vermeij, 2013). If farms produce this themselves, they would not need to buy it externally, leading to a potential cost savings of a little over 750 M €.

Conclusions

Based on modelling of current and potential grass production, this paper concludes that dairy farmers in the Netherlands can potentially produce over 1.5 times of current grass production. Financially this would imply a gain of 500 to 750 million euros. While this is an enticing prospect, it entails quite a challenge. It implies the need bring and keep grass and soil at the attention of farmers and on research and innovation agendas. This would need coherent and collectively directed interventions in terms of awareness building and education, management modifications, precision fertilization, genetic improvements and innovation.

References

Aarts H.F.M., Daatselaar C.H.G. and Holshof G. (2008) *Bemesting, meststofbenutting en opbrengst van productiegrasland en snijmaïs op melkveebedrijven*, Report 208, Plant Research International B.V., Wageningen, the Netherlands, 50 pp.

Alberda T. and Sibma L. (1968) Dry matter production and light interception of crop surfaces. IV. Maximum herbage production as compared with predicted values. *Netherlands Journal of Agricultural Science* 16, 142-153.

Duurzame Zuivelketen (2012) *Convenant Weidegang*. Available at: http://tinyurl.com/q8ysuwh.

Eerste Kamer der Staten-Generaal (2014) *Wet verantwoorde groei melkveehouderij aangenomen*. Available at: http://tinyurl.com/paz7jeh.

O'Donovan M., Lewis E. and O'Kiely P. (2011) Requirements of future grass-based ruminant production systems in Ireland. *Irish Journal of Agricultural and Food Research* 50(1), 1-21.

Reijs J.W., Daatselaar C.H.G., Helming J.F.M., Jager J. and Beldman, A.C.G. (2013) *Grazing dairy cows in North-West Europe; Economic farm performance and future developments with emphasis on the Dutch situation,* Report 2013-001, LEI Wageningen UR, The Hague, the Netherlands, 124 pp.

Remmelink G.J. and Hilhorst G.J. (2013) *Voeding, voer-en melkproductie op De Marke: 2009 t/m weideperiode 2011,* Report 71, Koeien & Kansen, Lelystad, the Netherlands, 43 pp.

Remmelink G.J., Dooren H.J.C van, van Middelkoop J.C., Ouweltjes W. and Wemmenhove H. (2013) *Handboek Melkveehouderij 2013*, Wageningen UR Livestock Research, Lelystad, the Netherlands, 391 pp.

Van den Pol-van Dasselaar A., de Vlieger A., Hennessy D. and Peyraud J.L. (2012) *Innovations in grazing. Proceedings 2nd meeting EGF Working Group Grazing,* Report 644, Wageningen UR Livestock Research, Lelystad, the Netherlands, 15 pp.

Van Ittersum M.K., Cassman K.G., Grassini P., Wolf J., Tittonell P. and Hochman Z. (2013) Yield gap analysis with local to global relevance-A review. *Field Crops Research* 143, 4-17.

Vermeij I. (2013) *KWIN Kwantitatieve Informatie Veehouderij 2013-2014*, Wageningen UR Livestock Research, Lelystad, the Netherlands, 407 pp.

Undersown tall fescue as a cover crop after forage maize in 2014

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Abstract

Grass cover crops installed following the harvest of forage maize often develop poorly due to the late sowing date. Undersowing of grasses is an alternative, provided the undersown grass does not compete too much with the maize crop. This trial evaluated the competition of undersown tall fescue (*Festuca arundinacea* Schreb.) in forage maize. Differences in competition were obtained by using 6 contrasting herbicide treatments that affected tall fescue differently. The yield of forage maize without undersown grass (control: 21,688 kg DM ha^{-1}) was significantly higher compared to maize with undersown grass that was not inhibited by herbicides (17,887 kg DM ha^{-1}). A significant negative relationship was found between the maize yield and the grass biomass after maize harvest. At the beginning of the winter, the biomass of Italian ryegrass sown immediately after the maize harvest was at the same level of the undersown tall fescue. Our results indicate the necessity using the right herbicide treatment to combine good maize yields with the benefits of the undersown grass.

Keywords: *Festuca arundinacea*, *Zea mays*, herbicides

Introduction

Grass cover crops installed following the harvest of forage maize often develop poorly due to the late sowing date, resulting in a low nitrate-uptake potential. Dam (2006) found that under Dutch weather conditions, the simulated capacity of a catch crop to take up N is over 200 kg N ha^{-1} if it is sown in the first half of August. For winter rye, it decreases on average by 3.3 kg N ha^{-1} per day of postponement of sowing. Hence, cover crops sown after forage maize, harvested from mid-September till the end of October, have a low potential to take up nitrate. In addition, it is often not possible to sow a cover crop in wet autumn due to soil structural damage. Undersowing may resolve these problems provided the undersown grass does not compete too much with the maize crop. Liedgens *et al.* (2004) found that the yield of maize sown in a living mulch of Italian ryegrass was reduced to one-quarter of the normal yield. Therefore, the grass understorey is preferentially sown when the maize has reached the 3-4 leaf stage. Undersowing the grass when the maize has already emerged is not convenient for farmers. Late sowing jeopardizes the early grass growth due to an increased incidence of drought periods. The ideotype of a grass species for undersowing in forage maize on one that has low early vigour but good autumn growth. Such a grass can be sown at the same time as the maize without competing for water and nutrients while also having a good potential to take up N in the autumn. Tall fescue has the right ideotype (Cougnon, 2014). We evaluated the use of a commercial tall fescue seed mixture (Proterra maize, Barenbrug, the Netherlands) for undersowing in forage maize. Our research questions were:

1. How much is the maize yield affected by the undersown grass?
2. How large is the yield advantage of an undersown sward of tall fescue compared to a newly installed sward of Italian ryegrass immediately after the maize harvest?

Materials and methods

A field trial was established on a sandy loam soil in Melle in a randomized complete block design with three replicates. Each block consisted of a strip of 70 m long and 6 m wide (8 rows of 0.75 m). Each block was divided in seven plots of 10×8 m. On 28 April 2014, forage maize was sown at a density of 114,000 seeds ha^{-1} and six of the seven plots in each block were oversown on the same day with tall fescue (20 kg ha^{-1}) using a 2.5 m wide conventional seed drill.

Prior to the establishment of the trial, the land had been fertilized with 170 kg N ha^{-1}, 28 kg P ha^{-1} and 123 kg K ha^{-1} from cattle slurry and with 100 kg N ha^{-1} from mineral fertilizer. When the maize had reached the 3-4 leaf stage, 6 different herbicide treatments were applied on the plots, resulting in seven treatments (T1-T7) (Table 1). The applied herbicide treatments were either recommended in the technical sheet of 'proterra maize' (T1, T2) or recommended by agronomic advisers (T3, T4, T6 and T7). T5, a treatment affecting only dicot weeds, was included to see the effect of unsuppressed grass growth on the maize yield. Harvesting took place on 23 September with a field harvester. DM yield of forage maize was determined based on 8 m^2 per plot, a subsample of 10 plants was chopped and dried for 16 h at 75 °C. On the T1 plots (no undersown grass), a seed bed was prepared on 26 September to sow Italian ryegrass (*Lolium multiflorum* cv. 'Melquattro') at a density of 40 kg ha^{-1} on 29 September. On 28 October, 25 November (2014) and 6 January (2015), the aboveground biomass of the cover crops in all plots was determined. On each plot, 1.8 m^2 grass was harvested by cutting the seedlings above the soil surface. The harvested biomass was washed with water to remove soil and dried for 16 h on 75 °C. ANOVA, multiple comparison of means and regression was performed in R using the *aov(), TukeyHSD()* and *lm()* functions respectively.

Results and discussion

The average maize yield was 20,559 kg DM ha^{-1}. The highest yields were found on the control treatment T1 (21,688 kg DM ha^{-1}) and on the treatment T7 (21,275 kg DM ha^{-1}). The maize yield on T5 (17,887 kg DM ha^{-1}) was significantly lower than the yield on the other treatments except T3 (19,933 kg DM ha^{-1}) ($P<0.001$). Although maize yields in the other herbicide treatments were not significantly different from the control (T1), a negative relationship was found between the maize yield and the grass biomass harvested on 28 October (y=21,326 – 2.1x; R^2=0.62; Figure 1a). The yield of the Italian ryegrass sown after the maize harvest increased faster compared to the undersown tall fescue (T1, Figure 1b). At the end of October (28-10-2014), the yield of the Italian ryegrass was 167 kg DM ha^{-1}; at the beginning of the winter (6-1-2015), it was 1,131 kg DM ha^{-1} and at the same level of the yield of T3 (907 kg DM ha^{-1}) and T4 (698 kg DM ha^{-1}). Only the tall fescue on T5 had a higher grass yield (2,035 kg DM ha^{-1}) than the Italian ryegrass (T1) ($P<0.01$) at that moment.

This quick development of Italian ryegrass was related to a high plant density and a dense ground cover, whereas herbicide treatments, competition of the maize and damage of the forage harvester resulted in heterogeneous swards of the undersown tall fescue. Also, the autumn of 2014 offered marvellous conditions for the development of Italian ryegrass. First, maize harvest was rather early due to the good summer. Second, soil conditions were good at harvesting, allowing the sowing of Italian ryegrass immediately after the maize harvest. Third, the autumn was very mild: the average temperature for the months September till November was 13.0 °C compared to 10.9 °C normally.

Table 1 Treatments in trial.

Treatment	Grass undersowing	Herbicide treatment
1	0 kg ha^{-1}	88 g ha^{-1} tembotrion + 625 g ha^{-1} S-metolachloor + 375 g ha^{-1} terbuthylazin
2	20 kg ha^{-1}	88 g ha^{-1} tembotrion + 625 g ha^{-1} S-metolachloor + 375 g ha^{-1} terbuthylazin
3	20 kg ha^{-1}	44 g ha^{-1} tembotrion + 280 g ha^{-1} dimethamide-P 250 g ha^{-1} terbuthylazin + 33.6 g ha^{-1} topramezon
4	20 kg ha^{-1}	66 g ha^{-1} tembotrion + 420 g ha^{-1} dimethamide-P + 375 g ha^{-1} terbuthylazin + 50.4 g ha^{-1} topramezon
5	20 kg ha^{-1}	900 g pyridate
6	20 kg ha^{-1}	720 g ha^{-1} dimethamide-P + 300 g ha^{-1} sulcotrion + 21 g ha^{-1} nicosulfuron
7	20 kg ha^{-1}	560 g dimethamide-P + 500 g ha^{-1} terbuthylazin + 100 g ha^{-1} mesotrion + 21 g ha^{-1} nicosulfuron
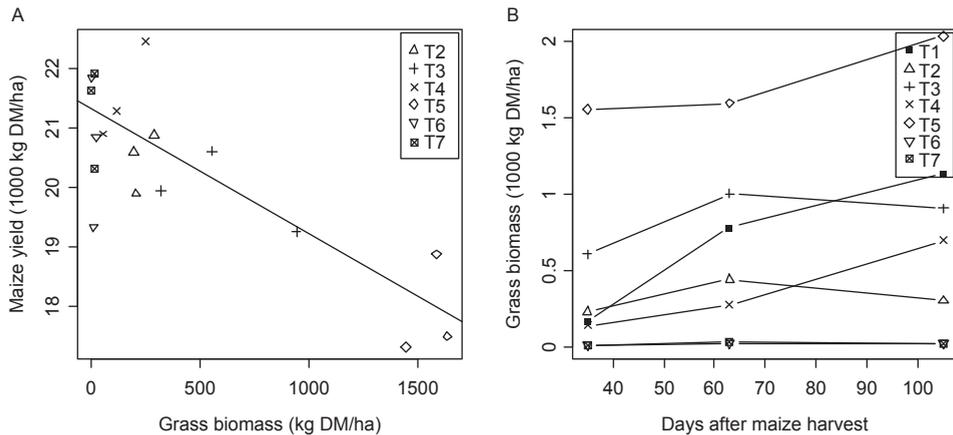
Figure 1 (a). Regression of maize yield on yield of undersown tall fescue on 28 October treated with different herbicide mixtures (T2 – T7; see Table 1) (y= 21,326 – 2.1x). (b) Evolution of the dry matter yield of Italian ryegrass sown after maize harvest (T1) and undersown tall fescue treated with different herbicide mixtures (T2 – T7).

Conclusions

Regarding our research questions, we conclude that:

1. Forage maize lost 2.1 kg DM ha^{-1} per kg DM undersown tall fescue (harvested one month after the maize harvest).
2. Sowing Italian ryegrass after the maize harvest was the better option in the exceptional mild autumn of 2014.

References

Cougnon M., Baert J. and Van Waes C. (2014) Dry matter yield and digestibility of five cool season forage grass species under contrasting N fertilizations. *Grassland Science in Europe* 19, 175-177.

Dam M. (2006) *Understanding the reduction of nitrogen leaching by catch crops*. PhD Thesis, Wageningen University, Wageningen, the Netherlands, pp 171.

Liedgens M., Soldati A. and Stamp P. (2004) Interactions of maize and Italian ryegrass in a living mulch system: (1) Shoot growth and rooting patterns. *Plant and Soil* 262, 191-203.

Yield comparison of Italian ryegrass and winter rye sown as cover crops after forage maize

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Abstract

Italian ryegrass (*Lolium multiflorum* L.) and winter rye (*Secale cereale* L.) sown as cover crops after forage maize, may produce an early cut before a new (maize) crop is installed. We report on the performance of a diploid and a tetraploid variety of both crops sown in early, mid and late October 2012. Aboveground and belowground biomasses were determined at regular intervals from December till April 2013. Aboveground biomass (cut to ground level) was significantly affected by time of sowing: at any moment, the yield of the cover crops sown early October was at least four times higher than that of the cover crops at the end of October. Similar results were found for belowground biomass. Total biomass of rye was always significantly higher than that of ryegrass, regardless of the time of sowing. By the end of April 2013, the DM yields (above 5 cm) of early sown winter rye and Italian ryegrass were 2,504 and 1,393 kg DM ha^{-1} respectively. The ploidy of the crops did not affect biomass. This study suggests that winter rye as a cover crop is clearly more productive than Italian ryegrass, sown in October after forage maize harvest.

Keywords: belowground biomass, *Secale cereale*, *Lolium multiflorum*

Introduction

Cover crops can contribute to a more sustainable forage maize production: nitrate leaching and soil erosion are decreased and soil organic matter is increased (Zavatarro *et al.*, 2012). Eventually the cover crop can be harvested as feed before growing a next (forage maize) crop. When the forage maize is harvested, at the end of the summer or at the beginning of the autumn in NW Europe, day length is too short for dicot cover crops to allow a successful development. Crops like Italian ryegrass (*Lolium multiflorum*; Lm) and winter rye (*Secale cereale*; Sc) can still be sown successfully at that time of the year (Vos *et al.*, 1997). As both crops are frost tolerant under NW European conditions and both are characterized by an early regrowth after winter, they are particularly suited for an early spring cut, e.g. for forage or for feedstock in biogas installations. Although the use of Italian ryegrass as a cover crop is more common in NW Europe, some winter rye varieties bred for biomass production have been shown to have a higher potential biomass production (Verhelst, 2011). The aim of this trial was to answer the following research questions:
1. Which crop has the highest biomass production in winter?
2. How large is the influence of sowing?
3. Which crop produces most forage in spring?

Materials and methods

A trial was established in October 2012 on a sandy loam soil in Merelbeke, Belgium comparing a diploid and a tetraploid variety of Lm ('*Meroa*', Lm2 and '*Melchior*', Lm4 respectively) and a diploid and a tetraploid variety of Sc ('*Protector*', Sc2 and '*Jobaro*', Sc4 respectively) sown on three different days (1 October, S1; 22 October, S2 and 31 October, S3). The selected varieties were the highest yielding varieties in former research (Verhelst, 2011). The trial was a split plot design with three replicates; individual plot size was 30 m^2. Sowing date was the main plot factor and the four cover crop varieties formed the subplot factor. Lm and Sc were sown at densities of 1,500 and 340 germinable seeds per m^2 respectively using a 3-m wide conventional seed drill. On five occasions (Table 1) during autumn and winter, the

aboveground biomass was measured by hand cutting the seedlings in a square of 1.5 m^2 per plot just above the soil surface. The harvested biomass was washed with water to remove soil. In the beginning of April, all plots were fertilised with 90 kg N ha^{-1}. On 25 April, the cover crops were cut at 5 cm height using an Agria cutting-bar mower. Dry matter yield was determined by drying samples for 16 h at 75 °C.

Because of their labour-intensive requirements, measurements of root biomass were limited to three occasions (Table 2) and to the tetraploid varieties. A soil cube with an edge of 0.2 m was dug out up to a depth of 20 cm using a steel mould. Samples were washed on a sieve with mesh 0.8 mm and dried for 16 h at 75 °C.

ANOVA for the dry matter yield was performed using the *aov()* function in R. The hierarchy of the split plot design and the nesting of the varieties within species were taken into account in the model. Multiple comparisons of species averages within the N levels were performed using the TukeyHSD() function.

The period October till December was very wet, with 318 mm of rain instead of the normal 231 mm. The period from January till March was colder than usual. Especially in March the average temperature was only 2.9 °C instead of 6.8 °C normally.

Results and discussion

No significant differences between the varieties of a species were found at any harvest date, so results are presented as average values per species (Table 1). Irrespective of harvest date, aboveground DM yield was at least 4 times lower ($P<0.001$) when crops were sown at S3 compared to S1. The development of the cover crops sown on S3 was so slow that the seedlings were too small to harvest on the first harvest date. On all harvest dates, Sc significantly outyielded Lm ($P<0.001$), with the gap in DM yield between Sc and Lm increasing with later sowing dates. Only on 04/02/2013 was there a significant interaction sowing date × cover crop ($P=0.03$).

Results for root dry matter yield were similar: significantly lower yield ($P<0.01$) on later sowing dates, Sc significantly outyielding Lm on the first two harvest dates ($P<0.05$) (Table 2). Total biomass yield (above ground biomass + root biomass) on 11 April 2013 was between 1,860 kg DM ha^{-1} for Sc sown on S1 and 289 kg DM ha^{-1} for Lm sown on S3. Except for Sc sown on S1, root biomass had a higher contribution than aboveground biomass to total biomass.

From the biomass yield, it can be expected that the potential reduction of nitrate leaching is higher with Sc compared to Lm. But as shown by Dam (2006), sowing date has a greater influence on the potential nitrate uptake than the sown species.

Table 1 Above ground biomass (kg DM ha^{-1}) of winter rye (Sc) and Italian ryegrass (Lm) sown on 1/10/2012 (S1), 22/10/2012 (S2) and 31/10/2012 (S3), harvested on several occasions during the winter and spring 2012-2013.

Harvest date	S1		S2		S3	
	Sc	Lm	Sc	Lm	Sc	Lm
18/12/2012	288	137	88	27	-[1]	-
04/02/2013	434	221	126	53	75	28
28/02/2013	614	340	176	74	127	44
21/03/2013	734	435	220	125	160	72
11/04/2013	1,030	652	295	211	219	110

[1] - = not harvestable.

Table 2. Root (0-20 cm) biomass (kg DM ha^{-1}) of winter rye (Sc) and Italian ryegrass (Lm) sown on 1/10/2012 (S1), 22/10/2012 (S2) and 31/10/2012 (S3), harvested on several occasions during the winter and spring 2012-2013.

Harvest	S1		S2		S3	
	Sc	Lm	Sc	Lm	Sc	Lm
04/02/2013	224	209	165	78	75	37
21/03/2013	269	269	190	104	96	46
11/04/2013	829	785	361	405	332	179

Forage yield, measured at the end of April (25/04/2013) was still negatively influenced by late sowing (*P*=0.025) and higher for rye than for Italian ryegrass (*P*<0.001), but there was interaction between sowing date and cover crop (*P*=0.045). When sown on S1, the highest and lowest yields were obtained with Sc2 (2,750 kg DM ha^{-1}) and Lm4 (1,229 kg DM ha^{-1}), respectively. When sown on S3, the highest and lowest yields were obtained with Sc4 (800 kg DM ha^{-1}) and Lm2 (314 kg DM ha^{-1}), respectively.

According to Maraval *et al.* (1978), winter rye has a slightly lower feed value than Italian ryegrass when harvested at a similar physiological stage. In a trial similar to ours, harvested on 19/04/2012, De Vliegher (pers. comm.) found DM yields of 3,244 (Sc) kg DM ha^{-1} and 2,703 (Lm) kg DM ha^{-1} with corresponding net energy content for lactation of 6,951 kJ (kg DM)$^{-1}$ and 7,138 kJ (kg DM)$^{-1}$. As Sc is heading earlier, it can be harvested earlier than Lm providing the bearing capacity of the soil is sufficient; this allows an earlier sowing of the following maize crop, which is an important advantage on soils prone to drought.

Conclusions

Regarding our research questions, we can conclude that:
1. Winter rye produced more biomass than Italian ryegrass in winter. Particularly the aboveground biomass of rye was higher.
2. Delaying the sowing of the cover crops by one month resulted in a four-times lower DM yield. Rye yielded more than Italian ryegrass on every sowing date.
3. In spring, just before maize sowing, rye had a DM yield that was about 2.5 times higher than that of Italian ryegrass.

References

Dam M. (2006) *Understanding the reduction of nitrogen leaching by catch crops*. PhD Thesis, Wageningen University, Wageningen, the Netherlands, pp. 171.

Maraval B., Morhain B. and Blanchet G. (1978) Le seigle en culture dérobée: utilisation en ensilage par les vaches laitières. *Fourrages* 73, 81-101.

Verhelst J. (2011) Winterrogge en Italiaans raaigras voor groenbedekking (in Dutch). Master thesis. Ghent University, Ghent, Belgium, pp 74.

Vos J. and Van der Putten P.E.L. (1997) Field observations on nitrogen catch crops. 1. Potential and actual growth and nitrogen accumulation in relation to sowing date and crop species. *Plant and Soil* 195, 299-309.

Zavattaro L., Monaco S, Sacco D. and Grignani C. (2012) Options to reduce N loss from maize in intensive cropping systems in Northern Italy. *Agriculture, Ecosystems and Environment* 147, 24-35.

Can lactobacilli producing ferulate esterase improve the nutritive value of grass and maize silage?

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Abstract

Pioneer® has patented a silage inoculant containing *Lactobacillus* strains of which *L. buchneri* produces ferulate esterase. The product is claimed to improve silage quality and aerobic stability as well as cell wall digestibility. The effect of the inoculant added to grass and whole-plant maize was studied using micro-silos during two years. Each year, grass was mown at 4 growth stages and maize was harvested at 2 maturity stages. Compared to the grass silage without additive, in the treated silage more sugars were fermented to lactic and acetic acid, resulting in a lower pH, less dry matter (DM) and protein degradation and a better aerobic stability. The inoculant lowered neutral detergent fibre (NDF) content of the grass silage from the early cuts, but not that from the late cuts. *In situ* rumen degradability of NDF (NDFD) was not affected, whereas *in vitro* organic matter digestibility tended to be better for the treated grass silage. In the early harvested maize, treatment resulted in less lactic and more acetic acid, a higher pH and higher DM-losses; the aerobic stability was better. Silage quality of the late-harvested maize was not affected. The additive did not affect chemical composition nor NDFD of the maize silage. It appears that the ferulate esterase in the inoculant is only able to affect less-lignified cell walls.

Keywords: *Lactobacillus buchneri*, grass silage, maize silage, nutritive value

Introduction

Sustainable dairy farms rely on the production and the preservation of high quality forage. There are various preservatives that may be used in case ensiling conditions are unfavourable. Pioneer® has an inoculant on the market which would not only improve silage quality and aerobic stability of grass and maize, but also improve cell wall digestibility. The product 11GFT (used for grass silage) consists of three *Lactobacillus* strains: *L. casei, L. plantarum* and *L. buchneri*, whereas 11CFT (used for maize) contains *L. casei and L. buchneri*. The latter ferments sugars not only to lactate but also to acetate known to inhibit yeasts and moulds (Holzer *et al.*, 2003). Further, *L. buchneri* is able to produce ferulate esterase, an enzyme which breaks down the linkages between (hemi)cellulose and lignin (Donaghy *et al.*, 1998). The objective was to study the claimed effects of the inoculant with grass cut at different growth stages and with maize harvested at a moderate and a late maturity stage by using micro-silos.

Materials and methods

A first cut of perennial ryegrass (*Lolium perenne*) was mown in 2010 and 2011 at 4 growth stages between the end of April and the beginning of June. The grass was wilted to about 35% dry matter (DM) and chopped at a length of 24 mm. Whole-plant maize (*Zea mays* L., cv PR39A98) was harvested in 2010 and 2011 at about 30 and 40% DM and chopped at a length of 8 mm. Half of the wilted grass and half of the maize was treated (T) with 11GFT and 11CFT respectively at the recommended dose of 1 g per ton, whereas the other half was not treated (Control, C). Plastic tubes of 2.75 l were filled with forage (for each stage: 5 tubes C and 5 T) at a density of 180 kg m^{-3} DM and provided with a CO_2-lock. The micro-silos were weighed and stored at ambient temperature in an unheated barn for 60 d. Aerobic stress was induced during 24 h at 18 d before opening. At opening, tubes were weighed again and 4 of the 5 tubes per treatment were selected for further study. From each tube, 100 g sample was extracted with water and

analysed for pH, lactic acid, volatile fatty acids, alcohols and ammonia. DM, crude protein (CP), neutral detergent fibre (NDF), crude ash, sugars for grass silage and starch for maize silage were analysed using EU/ISO methods. The degradability of NDF (NDFD) was determined *in situ* by incubating nylon bags in the rumen of two cannulated cows (Tamminga *et al.*, 2007). Organic matter digestibility (COMD) was determined *in vitro* with the cellulase technique (De Boever *et al.*, 1986).

The results were analysed using ANOVA to study the effect of the inoculant as well as the interaction between treatment and growth/maturity stage. If treatment effect was significant ($P \leq 0.05$), C and T means within stage were compared by a t-test.

Results and discussion

The use of 11GFT for wilted grass had a significant effect on silage quality and chemical composition in both years (Tables 1 and 2). Treatment resulted in less DM losses, a lower pH, more lactic and acetic acid, less alcohols and a lower ammonia fraction. A better aerobic stability was only observed in year 1. Although there was a significant interaction with growth stage for most parameters, the better silage quality of treated grass was clear at all stages. Treated grass silage contained more DM and clearly less sugars, less NDF and also somewhat less CP. The reduced NDF content was only significant at the early growth stages. Treatment had no effect on NDF degradability in the rumen, whereas COMD tended to be better.

The use of 11CFT for maize only showed effects at the first but not at the second maturity stage (Table 3). Treatment resulted in higher DM loss and pH, lower lactic acid and more acetic acid and alcohols, indicating a moderate silage quality. On the other hand, aerobic stability was better. Treatment did not affect NDF and starch content, nor NDFD or COMD.

Table 1. The effect of 11GFT (control C versus treatment T) on silage quality, chemical composition and nutritive value of grass silage mown at 4 growth stages – year 1.[1]

Harvest date	28/04/10		17/05/10		25/05/10		2/06/10		SEM	Significance[2]	
	C	T	C	T	C	T	C	T		T	S×T
DM (g kg^{-1})	387	397**	342	362**	370	380**	359	365**	2.9	**	**
DM loss (%)	1.6	0.8**	1.4	1.2^{ns}	1.9	1.4**	2.2	1.5**	0.08	**	**
pH	4.93	3.93**	4.60	3.84**	4.41	3.93**	4.42	4.04**	0.07	**	nd
Lactic acid (g kg^{-1} DM)	32	87**	40	83**	46	71**	45	52^{ns}	3.5	**	**
Acetic acid (g kg^{-1} DM)	26	24^{ns}	11	32**	11	27**	11	34**	1.6	**	**
Alcohols (g kg^{-1} DM)	38	21**	27	21*	34	22**	42	26**	1.4	**	**
NH$_3$-N/N (%)	4.5	2.7**	6.3	3.8**	7.6	6.3**	8.3	5.5**	0.32	**	**
Aerobic stability (h)	30	127*	24	153**	31	150**	32	>170**	12.0	**	ns
NDF (g kg^{-1} DM)	344	317**	397	377**	491	484^{ns}	513	506^{ns}	15.3	**	**
CP (g kg^{-1} DM)	231	226	169	167	141	138	135	129	13.5	*	nd
Sugars	119	70	153	38	58	17	52	14	16.1	*	nd
NDFD (%)	67.3	65.2^{ns}	63.0	61.0^{ns}	53.1	53.9^{ns}	52.2	50.7^{ns}	1.30	ns	ns
COMD (%)	91.8	92.4	88.8	88.1	76.9	79.1	73.1	74.6	2.64	ns	nd

[1] DM = dry matter; NDF = neutral detergent fibre; CP = crude protein; NDFD = NDF degradability; COMD = cellulase digestibility of organic matter; SEM = standard error of the mean.
[2] Significance of treatment effect (T) and of interaction between treatment and growth stage (S×T); nd = not determined; ns = not significant ($P>0.05$); * significant at $P \leq 0.05$; ** significant at $P \leq 0.01$.

Table 2. The effect of 11GFT (control C versus treatment T) on silage quality, chemical composition and nutritive value of grass silage mown at 4 growth stages – year 2.[1]

Harvest date	26/04/11		23/05/11		30/05/11		8/06/11		SEM	Significance[2]	
	C	T	C	T	C	T	C	T		T	S×T
DM (g kg^{-1})	322	335**	337	343**	403	414**	348	353**	5.6	**	**
DM loss (%)	0.4	0.7**	1.8	0.9**	2.5	1.0**	2.1	0.8**	0.34	**	**
pH	4.42	3.95*	4.51	3.87**	4.31	3.90**	4.45	3.80**	0.05	**	**
Lactic acid (g kg^{-1} DM)	74	118**	60	105**	58	87**	48	85**	4.1	**	*
Acetic acid (g kg^{-1} DM)	21	28^{ns}	20	20^{ns}	12	18**	14	15^{ns}	0.9	**	*
Alcohols (g kg^{-1} DM)	14	24**	32	20*	38	16*	32	17**	1.6	**	**
NH$_3$-N/N (%)	8.1	3.1**	11.1	3.0**	7.9	3.4**	12.5	4.5**	0.64	**	**
Aerobic stability (h)	43	32^{ns}	40	34^{ns}	37	60**	38	71^{ns}	3.5	ns	*
NDF (g kg^{-1} DM)	397	384**	494	485^{ns}	nd	nd	578	581^{ns}	23.3	*	*
CP (g kg^{-1} DM)	238	216^{ns}	146	133*	nd	nd	110	103*	15.5	**	*
Sugars	71	15**	65	66^{ns}	nd	nd	11	32**	7.6	*	**
NDFD (%)	55.5	55.4^{ns}	45.0	47.3^{ns}	nd	nd	35.6	37.9^{ns}	2.34	ns	ns
COMD (%)	86.5	86.7^{ns}	74.8	75.6^{ns}	nd	nd	58.3	61.5**	3.31	**	**

[1] DM = dry matter; NDF = neutral detergent fibre; CP = crude protein; NDFD = NDF degradability; COMD = cellulase digestibility of organic matter; SEM = standard error of the mean.
[2] Significance of treatment effect (T) and of interaction between treatment and growth stage (S×T); nd. = not determined; ns = not significant ($P>0.05$); * significant at $P≤0.05$; ** significant at $P≤0.01$.

Table 3. The effect of 11CFT (control C versus treatment T) on silage quality, chemical composition and nutritive value of maize silage harvested at 2 maturity stages during 2 years.[1,2]

Year	2010							2011						
	Stage 1		Stage 2		SEM	Significance[2]		Stage 1		Stage 2		SEM	Significance[3]	
	C	T	C	T		T	T×S	C	T	C	T		T	T×S
DM (g kg^{-1})	303	297*	406	389**	12.6	**	*	307	312^{ns}	421	421^{ns}	14.5	ns	ns
DM loss (%)	0.6	1.1^{ns}	0.9	0.8^{ns}	0.05	**	**	0.5	0.6*	0.5	0.5^{ns}	0.01	*	*
pH	3.81	4.00**	3.92	3.92^{ns}	0.02	**	**	3.77	3.79^{ns}	3.88	3.87^{ns}	0.01	ns	ns
Lactic acid (g kg^{-1} DM)	53	31**	54	50^{ns}	2.5	**	**	60	55*	47	46^{ns}	1.5	*	ns
Acetic acid (g kg^{-1} DM)	18	39**	15	13*	2.7	**	**	18	25**	15	15^{ns}	1.2	**	**
Alcohols (g kg^{-1} DM)	12	20**	17	14^{ns}	0.8	*	**	12	14*	12	12^{ns}	0.2	*	**
NH$_3$-N/N (%)	4.9	4.8^{ns}	4.7	4.4**	0.06	*	ns	4.6	4.4^{ns}	4.6	4.6^{ns}	0.05	ns	ns
Aerobic stability (h)	97	220**	104	70^{ns}	15.4	**	**	36	200**	91	123^{ns}	16.5	**	**
NDF (g kg^{-1} DM)	347	379*	377	381^{ns}	6.0	ns	ns	359	353^{ns}	347	352^{ns}	3.6	ns	ns
Starch (g kg^{-1} DM)	321	294	317	320	6.3	nd	nd	325	332^{ns}	366	358^{ns}	7.2	ns	ns
NDFD (%)	28.4	29.2^{ns}	28.6	28.7^{ns}	0.61	ns	ns	24.7	27.4^{ns}	nd	nd	3.9	nd	nd
COMD (%)	75.7	72.2	72.2	72.0	0.89	nd	nd	72.1	72.2^{ns}	72.2	71.8^{ns}	0.30	ns	ns

[1] DM = dry matter; NDF = neutral detergent fibre; NDFD = NDF degradability; COMD = cellulase digestibility of organic matter; SEM = standard error of the mean.
[2] Growth stage 1: 30% DM; growth stage 2: 40% DM.
[3] Significance of treatment effect (T) and of interaction between treatment and growth stage (S×T); nd. = not determined; ns = not significant ($P>0.05$); * significant at $P≤0.05$; ** significant at $P≤0.01$.

Conclusions

Treatment of wilted grass with 11GFT clearly gives a better silage quality, tends to improve aerobic stability and organic matter digestibility, but has no effect on cell wall digestibility. The use of 11CFT in maize silage only showed a positive effect on aerobic stability.

References

De Boever J.L., Cottyn B.G., Buysse F.X., Wainman F.W. and Vanacker J.M. (1986) The use of an enzymatic technique to predict digestibility, metabolizable and net energy of compound feedstuffs for ruminants. *Animal Feed Science and Technology* 14, 203-214.

Donaghy J., Kelly P.F. and McKay A.M. (1998) Detection of ferulic acid esterase production by *Bacillus* spp. and lactobacilli. *Applied Microbiology and Biotechnology* 50, 257-260.

Holzer M., Mayrhuber E., Danner H. and Braun R. (2003) The role of *Lactobacillus buchneri* in forage preservation. *Trends in Biotechnology* 21, 282-287.

Tamminga S., Brandsma G.G., Dijkstra J., Van Duinkerken G., Van Vuuren A.M. and Blok M.C. (2007) Protein evaluation in ruminants: the DVE/OEB 2007 system. *CVB Documentation report nr. 53*, Centraal Veevoederbureau, Lelystad, the Netherlands. 58 pp.

Grass-clover under cutting conditions: a highly productive system of intensive, high quality forage production

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Abstract

In this experiment, we compared grass in pure stand (300 $N_{available}$ ha^{-1}) and grasses mixed with red and white clover (150 $N_{available}$ ha^{-1}) under cutting conditions. The experiment was conducted on a sandy loam soil (Merelbeke, Belgium) in 2011-2014. Perennial ryegrass (*Lolium perenne* – Lp), tall fescue (*Festuca arundinaceae* – Fa) and *Festulolium* (Fe) in pure stands were sown with and without clover. Grass-clover with 150 N ha^{-1} produced more dry matter (+ 1.11 Mg ha^{-1} year^{-1}) with a higher protein content in terms of crude protein % (+4.5%) and true protein digested in the small intestine (+13 g kg^{-1} dry matter (DM)), but lower energy concentration (-15 VEM (fodder unit milk) g kg^{-1} DM) compared to grass with 300 N ha^{-1}. The energy content of Lp cv Meloni and Fe cv Lifema was lower in the grass-clover 150 N management than in the grass 300 N and did not change for the other grasses. Barolex (Fa), Callina (Fa) and Hykor (Fe) had significantly higher DM production, but significantly lower energy and protein content in comparison with Lp. Lifema (Fe) was less productive than the other varieties/species but had a better quality compared to Hykor (Fe) and Fa.

Keywords: *Lolium perenne*, *Festuca arundinaceae*, *Festulolium Trifolium pratense*, *Trifolium repens*, grass-clover

Introduction

Nitrogen fertilization on grassland is restricted in Flanders (Belgium) in accordance with the EU Nitrate Directive. Grasses are thus prevented from reaching their full potential for dry matter and protein yield. Could red and white clover in the sward under cutting conditions compensate for the decrease in dry matter yield and protein content caused by using lower N inputs? In addition, the Flemish Government encourages farmers by means of subsidies to cultivate clover and grass-clover to produce more farm-grown proteins and to reduce the use of mineral fertilisers. *Lolium perenne* (Lp), *Festuca arundinacae* (Fa) and *Festulolium* (Fe) all have a high yield potential under cutting conditions (Cougnon, 2013), but Lp is the only grass commonly used and it is considered as a reference.

Materials and methods

In April 2011 a trial comparing the yield and quality of single grass species and the same species in combination with clover was established under cutting at ILVO in Belgium. The grass species were Lp cv. Meloni, Fa cv. Barolex and Callina, and Fe cv. Hykor and Lifema. The grasses were sown in pure stands or in combination with a mixture of *Trifolium pratense* (Tp) cv. Lemmon and *Trifolium repens* (Tr) cv. Merwi. (Mixtures of Lp and Fa varieties and/or Lp with Fe varieties were also sown with and without clovers but the results will not be discussed here.) Grasses and red clover were sown at 1000 germinating seeds per m^2 and white clover at 500 seeds per m^2 in field plots of 1.4×6 m. The trial design was a split plot design with 4 replicate blocks with presence of clover as main plot factor and the varieties as subplot factor. Mineral N fertilization was 300 kg N ha^{-1} for the pure grass and 150 kg N ha^{-1} for the grass-clover plots. Three, five, five and six cuts were harvested with a Haldrup forage harvester at a cutting height of 6 cm in 2011, 2012, 2013 and 2014, respectively. At each cut dry matter (DM) yield was measured and a grab subsample was separated into the individual sown species and unsown species (collectively). Samples were analysed by near-infrared spectometry for chemical composition and digestibility after

which energy (fodder unit milk – VEM) and protein content (true protein digested in the small intestine – DVE and rumen degraded protein balance – OEB) were calculated. DVE and OEB are parameters of protein quality developed by Taminga *et al.* (1994).

Results and discussion

The average dry matter yield of grass at 300 N and grass-clover at 150 N was 13,990 kg ha^{-1} and 15,100 kg ha^{-1}, respectively (Table 1). A mean difference in dry matter yield of 1,110 kg ha^{-1} in favour of grass-clover was observed; saving 150 N ha^{-1} year^{-1} and about 150 euro ha^{-1} year^{-1}. These results confirmed earlier results under intensive management in Flanders (De Vliegher and Carlier, 2008). There was a yield increase for every single variety when mixed with clover: the effect varied between 280 kg ha^{-1} (Barolex) and 2,000 kg ha^{-1} (Lifema).

The statistical analysis was done with 5 varieties and 7 mixtures but only results of the single varieties are reported here. The interaction between the two factors was significant. As a result the statistical analysis was done separately for grass 300 N and grass-clover 150 N and a comparison of the varieties was performed within each group.

Sown without clover, DM-yields of Fe cv. Hykor (15,860 kg DM ha^{-1}) and Fa cv. Barolex (15,210 kg DM ha^{-1}) and Callina (14,400 kg DM ha^{-1}) were significantly higher, while Fe cv. Lifema (11,850 kg DM ha^{-1}) was significantly lower in comparison with Lp cv. Meloni (12,610 kg DM ha^{-1}). When sown with clover a similar ranking of the varieties was observed but differences between the single varieties were smaller and Fe cv. Lifema (13,850 kg DM ha^{-1}) was significantly lower in DM yield in comparison with Lp cv. Meloni (13,940 kg DM ha^{-1}). The average content of clovers (red+white) was about 50% of the dry matter (40% red + 9% white) and clover content of Lp cv. Meloni (57%) was significantly higher

Table 1. Dry matter yield (2011-2014, Mg ha^{-1}), clover content (2011-2014, % in dry matter (DM)) and forage quality (2011-2013, per kg DM[-1]) of grass species and varieties in pure stand and in mixtures with red + white clover. Three, five, five and six cuts were harvested at a cutting height of 6 cm in 2011, 2012, 2013 and 2014, respectively.[1,2]

Species	Cultivar	Clover content		Yield	Protein content[3]			Energy content[3]
		T. pratense	T. repens	DM	CP	DVE	OEB	VEM
		% in DM	% in DM	kg ha^{-1}	g kg^{-1} DM	g kg^{-1} DM	g kg^{-1} DM	kg[-1] DM
Grass species 300 N ha^{-1} year^{-1}								
Lolium perenne	Meloni			12,610c[(2)]	153ab	83a	-4	914a
Festuca arundinaceae	Barolex			15,210a	150bc	73c	2	828c
	Callina			14,400b	147c	72c	1	823c
Festulolium	Hykor			15,860a	144d	71c	-3	827c
	Lifema			11,850d	153a	77b	-2	853b
Average				13,990	149	75	-1	849
Grass species + red and white clover 150 N ha^{-1} year^{-1}								
Lolium perenne	Meloni	45	12	13,940c	203a	94a	42	859a
Festuca arundinaceae	Barolex	35	10	15,490b	196b	88b	40	829c
	Callina	40	10	15,400b	193b	87b	38	824cd
Festulolium	Hykor	38	7	16,830a	187c	85c	33	821d
	Lifema	43	7	13,850c	193b	88b	36	838b
Average		40	9	15,100	195	88	38	834

[1] DM = dry matter; CP = crude protein; DVE = true protein digested in the small intestine; OEB = rumen degraded protein balance; VEM = fodder unit milk.

[2] Data with the same letter in the same column within a group are not significantly different ($P<0.05$).

[3] Forage quality is determined on the dataset 2010-2013.

than the others (Table 1). The average CP content of grass at 300N and grass-clover at 150 N was 149 g kg^{-1} DM and 195 g kg^{-1} DM respectively (Table 1). There was a mean difference in CP of 46 g kg^{-1} DM in favour of grass-clover. There was an increase of CP for every single variety when mixed with clover: the effect varied between 40 g kg^{-1} DM (cv. Lifema) and 50 g kg^{-1} DM (cv. Meloni). For forage evaluation even more attention is paid to true protein digested in the small intestine (DVE). When clover was used, the average DVE content was considerably higher: 88 g kg^{-1} (grass-clover) versus 75 g kg^{-1} (grass). Lp cv. Meloni with and without clover had a significant higher DVE content in comparison with the other varieties, but in grass-clover the range between the grass varieties decreased because the effect of clover was higher on the Fa and Fe varieties with the lowest DVE concentration (Table 1). The OEB value is a measure for the amount of protein that will be degraded in the rumen and can be transformed to microbial protein if enough energy is available in the rumen. If not, considerable N losses might occur to the environment. In grass-clover with150 N the content of this unstable protein was considerably higher in comparison with grass 300 N. Differences in OEB between grass varieties within a species were small. The average energy content of grass at 300 N and grass-clover at 150 N was 849 VEM and 834 VEM respectively (Table 1) and was in favour of grass 300 N. With or without clover Lp cv. Meloni and Fe cv. Lifema had significantly higher energy content compared with the others. When sown with clover the energy content decreased for grasses with a high energy content such as Lp cv. Meloni and Fe cv. Lifema (Table 1); for the other grasses the energy content was about the same.

Conclusions

Grass clover at 150 N ha^{-1} produced more dry matter (+ 1.11 Mg ha^{-1}) with a higher protein concentration in terms of CP (+45 g kg^{-1} DM), DVE (+13 g kg^{-1} DM) and OEB (+ 37 g kg^{-1} DM) but with a lower energy concentration (-15 VEM g kg^{-1} DM) compared to grass at 300 N ha^{-1}. The energy content of Lp cv. Meloni and Fe cv. Lifema was lower in the grass-clover 150 N management than in the grass 300 N management and did not change for the other grass varieties. Barolex (Fe), Callina (Fe) and Hykor (Fe) had a significant higher DM production, especially in pure stands with 300 N ha^{-1} but were significantly lower in terms of energy and protein content in comparison with Lp cv. Meloni. Lifema (Fe) had lower DM yield in comparison with the other varieties/species but with better quality herbage than Hykor (Fe) and Barolex (Fa) and cv. Callina (Fa) but lower quality compared to Meloni (Lp). Fa and Fe have a high yield potential, but especially for Fe there were substantial varietal differences.

Acknowledgements

References

Cougnon M. (2013) *Potential in mixed swards and breeding of tall fescue*. PhD thesis, University Ghent, Ghent, Belgium, pp. 257.

De Vliegher A. and Carlier L. (2008) Potential of fodder legumes under intensive farming conditions in Flanders. *Grassland Science in Europe* 13, 236-238.

Tamminga S., Van Straalen W.M., Subnel A.P.J., Meijer R.G.M., Steg A., Wever C.J.G. and Blok M.C. (1994) The Dutch protein evaluation system: the DVE/OEB-system. *Livestock Production Science* 40, 139-155.

Type of grass influences clover proportion and production of grass-clover leys

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Abstract

Inclusion of red clover (*Trifolium pratense*) in grasslands improves productivity. However, poor persistence, particularly under high fertilization rates, is a major limitation for wider utilization. Earlier observations indicated that the type of grass may influence the grass-clover balance, besides, e.g. cutting strategy. In a field experiment we investigated clover proportions and production of five different grass mixtures in combination with red and white clover (*T. repens*): (1) *Lolium perenne*; (2) *L. boucheanum* + *L. perenne*; (3) *Festulolium* + *L. perenne* + *L. boucheanum* + *Phleum pratense* subsp. *pratense*; (4) *L. perenne* + *Festulolium*; (5) *Festuca arundinacea* + *P. pratense*. The experiment was carried out for three years at two locations (sandy and clay soil) at high fertilization levels (254 and 306 kg N-total ha^{-1} year^{-1} from animal manure). Results indicate that red clover can be relatively persistent, with an average of 43% red clover in the DM-production in both the second and third year. Mixtures containing *L. boucheanum* showed significantly lower clover proportions. Protein production per hectare was strongly and positively related to the red clover proportion in the sward. These results show that grass species influence the productivity and clover proportions in grass-clover swards. The best performing mixtures under the given conditions include *Festulolium* or *F. arundinacea*.

Keywords: red clover, persistence, grass mixture, high input systems

Introduction

In Dutch agriculture red clover (*Trifolium pratense*) is recently becoming more popular because of its high yield potential under cutting regimes. However, rapid decline of red clover proportions and poor persistence are major limitations for its wider utilization. Besides the clover variety (Boller *et al.*, 2008) cutting strategy also influences the proportion of clover and persistence of red clover (Eriksen *et al.*, 2013; Søegaard, 2013). Incidental observations with hybrid ryegrass (*Lolium boucheanum*) and tall fescue (*Festuca arundinacea*) have indicated that the type of grass might also have a major effect on the proportion of clover and the persistence of red clover in grass-clover swards. To investigate this effect five different grass mixtures were sown in combination with red and white clover (*T. pratense* and *T. repens* respectively).

Materials and methods

In early September 2011 grass-clover mixtures were sown on two commercially managed fields, on sandy soil and clay soil, as part of a larger trial to compare pure grass and grass-clover (Rietberg *et al.*, 2015). Swards were fertilized three times per year with 254 (sand) and 306 (clay) kg N-total ha^{-1} year^{-1} from injected dairy cattle slurry. Mixtures comprised 7 and 3 kg ha^{-1} of red and white clover, respectively, and were sown together with the five grass mixtures (specifically selected for cutting regimes) at commercially advised seeding rates (Table 1). The mixtures were sown in duplicate per location.

Due to financial limitations in 2012 only dry matter (DM) yield was measured and on only one location (clay soil). In 2013 and 2014, in the 2nd and 3rd years of the experiment, the plots were harvested for silage four and five times, respectively. DM yield was determined by cutting a strip of 0.81×5 m with a two-wheel tractor per plot. After weighing the fresh biomass, two sub-samples of ca. 300 g were taken for the analysis of nutritive value by near infrared spectrometry at a commercial lab and for botanical

composition (hand separation and subsequent drying at 70 °C for 24 h). Results were tested by analysis of variance (ANOVA with location as block; least significant differences) and regression analysis (generalized linear model procedure with n=40) using GenStat 13.3.

Results and discussion

All mixtures were well established at the beginning of the first production year. Mean clover proportions in the sward and yields of the next two years are summarized in Table 1. The proportions of red and white clover were significantly affected by the grass mixture, with lowest proportions in the mixtures with hybrid ryegrass. This tall-growing grass negatively affected the red clover proportion, particularly on the clay location, where the first two cuts of mixture B were very heavy (>6 Mg DM ha^{-1} cut^{-1}) in 2012, due to unfavourable weather conditions that delayed the cuts. Particularly in mixture B, the hybrid ryegrass also prevented white clover from spreading more effectively in the plots with lowest clover proportions, even though grass production seemed sometimes limited by low N-availability (reflected in crude protein contents of less than 130 g kg DM^{-1} of some cuts in 2013). The proportion of red clover was highest in mixture E, possibly due to the near disappearance of *Phleum pratense* from all plots during the first growing season.

The proportions of clover were similar in the two years of measurement, with 43% of red clover and 8-9% white clover, and no general interaction between grass mixture and year was apparent. However, while in most mixtures the proportions of clover increased slightly, the proportion of red clover decreased significantly in the mixture E (-16% in DM; $P<0.05$), due to the spread of grasses, partly by hybrid ryegrass which spontaneously seeded itself into the very open sward of these plots.

Yields and nutritive values were all higher for the clay location compared with the sand location (e.g. 1 Mg DM, 281 kg crude protein and 137 kg available intestinally digestible protein ha^{-1} year^{-1}), while clover proportion in the sward was lower (-16% in DM). Due to favourable weather conditions, yields were higher in 2014 than in 2013 (+3.2 Mg DM, +304 kg of available intestinally digestible protein and +830 kg crude protein ha^{-1} year^{-1}), but no interaction between grass mixture and year was apparent. Yields were significantly affected by the grass mixtures, with highest yields for the mixtures including *Festulolium* or tall fescue.

Regression analysis showed a significant effect of the red clover proportion on protein yields (+ 19.3 kg ha^{-1} year^{-1} crude protein and +4.7 kg ha^{-1} year^{-1} of available intestinally digestible protein per percent of red clover; $P<0.001$, n=40). The proportion of red clover explained 24 and 11% of the total variance for crude protein and intestinally digestible protein, respectively. Year had a large effect explaining 59 and 66%, respectively, while the location effect was relatively small with 1 and 7% of the total variance

Table 1. Grass seed rates in mixtures with red and white clover, clover proportions, dry matter yields, protein content and protein yields. Means of two locations and two years (2013 and 2014).

Treat-ment and seed rate of grass (kg ha^{-1})	Proportion in seed (weight %)					Red clover (% of DM)	White clover (% of DM)	DM yield (Mg ha^{-1} y^{-1})	CP content (g kg DM^{-1})	CP yield (kg ha^{-1} y^{-1})	DVE yield (kg ha^{-1} y^{-1})
	Lp	Lb	Fest	Fa	Pp						
A (40)	100					45 ab	11 a	12.2 c	211 ab	2,588 c	1,012 b
B (50)	40	60				26 c	3 b	12.4 bc	175 d	2,187 d	909 c
C (40)	30	25	35		10	37 b	5 b	13.1 ab	198 c	2,612 cb	1,037 b
D (40)	65		35			49 a	8 ab	13.4 a	210 b	2,810 ab	1,071 ab
E (60)				85	15	54 a	11 a	13.7 a	217 a	2,972 a	1,115 a

[1] Lp = *Lolium perenne*; Lb = *Lolium boucheanum*; Fest = *Festulolium*; Fa = *Festuca arundinacea*; Pp = *Phleum pratense*; DM = dry matter; CP = crude protein; DVE = Dutch measure for available intestinally digestible protein. Values with different letters within each column are significantly different (least significant difference, $P<0.05$).

explained, and no interactions were apparent. The effect on DM yield was not significant, mainly due to mixture A in which perennial ryegrass and white clover dominate, both having a relatively modest production capacity but high nutritive value.

Conclusions

The companion grass mixture affects protein production and clover proportion of grass-clover mixtures. Highest protein production is obtained with productive grass mixtures which can still support sufficiently high red clover proportions under the given agro-ecological conditions. Results indicate that red clover can be relatively persistent in the first three years, even under high fertilization rates. Mixtures containing highly productive, tall-growing hybrid ryegrass negatively affect clover proportions in the sward. These results show that selecting appropriate grass species can be an important strategy to increase the productivity and clover proportions in grass-clover swards. The choice for a specific grass mixture depends on the objective but under given agro-ecological conditions the best performing mixtures include *Festulolium* or tall fescue.

Acknowledgements

References

Boller B., Tanner P. and Schubiger F.X. (2012) Pastor: ein neuer, für die Weide geeigneter Rotklee. *Agrarforschung Schweiz* 3(1), 20-27.

Eriksen J., Askegaard M. and Søegaard K. (2013) Red clover inclusion in ryegrass-white clover swards for grazing and cutting. *Grassland Science in Europe 18*, 183-188.

Rietberg, P., De Wit J. and Van Eekeren N. (2015) Performance of red clover mixtures in high output dairy systems: an agro-economical comparison. This book, pp. 478-480.

Søegaard K. (2013) Cutting strategy as a tool for manipulating the seasonal nutritive value and production in grass-clover. *Grassland Science in Europe 18*, 216-218.

Pastur'Plan: a dynamic tool to support grazing management decision making in a rotational grazing system

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Abstract

Efficient grazing management requires anticipation and flexibility and would be greatly facilitated by the development of dynamic tools with the capability to simulate different scenarios based on regular measurement of grass supply on the farm. Pastur'Plan, built on a spreadsheet within a partnership between INRA and a livestock management advisory association (Orne Conseil Elevage), combines two complementary concepts. The first is inspired by the Grass Wedge method adapted to French grazing conditions to highlight the distribution and coherence of grass supply on the paddocks on a farm and the requirements for grass based on the grazing rules and objectives. The second concept allows us to describe the evolution of the balance between grass growth and demand according to various grazing simulations on a paddock-by-paddock basis. This paper describes the hypothesis and calculations implemented, and subsequently the simulation method used and the illustrations dedicated to help support decision-making by grazing managers.

Keywords: grazing management, dynamic tools, dairy cows, grass wedge

Introduction

Feeding dairy cows at grazing is of interest as a means to provide a low-cost and well-balanced diet. In continental Europe, however, the contribution of grazed grass in the total annual diet of dairy cows is declining. Various different reasons such as small accessible areas for grazing, grass growth sensitivity to climate and the difficulties to manage grazing systems efficiently are often mentioned in surveys of farmers. In contrast to indoor feeding, feed supply and quality in grazing systems is more variable and grazing management requires frequent adjustment to ensure consistency between animal requirements and grass growth. The art of grazing is to anticipate variations and imbalances between grass supply and demand and to implement essential adjustments promptly to manage the dynamic grazing system efficiently. Many methods and tools have been developed in the recent past to help farmers and advisers to implement grazing systems more efficiently. Such tools are often based on a weekly measurement of grass availability and the projection of the change in grass availability in the immediate future based on predicted grass growth and demand. One such tool used in France, named Herb'aVenir (Defrance *et al.*, 2005), is based on the calculation of grazing days ahead. Similarly, another tool proposed in New Zealand and Ireland is the grass wedge method (Dillon and Kennedy, 2009) based on a graphic comparison of the actual and ideal grass supply profiles on a paddock-by-paddock basis. In both cases, these tools are static, and do not give the farmer an anticipated grazing plan. Consequently, such tools require expertise of the farmer to analyse the grass supply profile and make the right decisions. The objective of this paper is to describe Pastur'Plan, a new decision support tool based on the grass wedge concept adaptation and on the possibility of dynamic simulations of anticipated future grazing outcomes.

Concepts and calculation methods implemented in Pastur'Plan

The grass wedge concept (Dillon and Kennedy, 2009) compares the actual biomass of each paddock drawn on a histogram graph with an ideal line joining two points corresponding to the pre- and post-grazing biomass. The lowest point corresponds to the post-grazing biomass objective. The highest point

is the target pre-grazing grass yield (kg dry matter (DM) ha^{-1}) calculated as the product of the stocking rate (cows ha^{-1}) by the grass demand (kg DM cow^{-1} day^{-1}) by the rotation length (days) plus the target residual grass yield (kg DM ha^{-1}). In fact, mathematically, the line between these two points is straight only if the paddock area and grass growth potential is identical for every paddock and this is frequently not the case. In Pastur'Plan, to be more universal, we have chosen to draw a breaking line (Figure 1) where each point is the ideal height at which each paddock should be, taking account of (1) the pre- and post-grazing heights defined by the farmer, (2) the area of each paddock, (3) the predicted grazing duration of the previous paddocks and (4) the future grass growth during the simulated period.

To propose a predicted grazing calendar and to facilitate the evaluation of different scenarios of grazing management, Pastur'Plan calculates the grazing days available and duration of grazing for each paddock according to animal requirements and the grass offered. Animal demand depends on the herd size, the grass-intake capacity of the individual animal (nine categories are proposed depending on the type of animal) and the level of forage or concentrate supplementation. As a consequence of the substitution rate law (Faverdin *et al.*, 2010), we have considered a grass intake decrease of 1 kg and 0.5 kg of DM for each 1 kg of forage or concentrate intake, respectively. The grass provided is calculated daily, paddock-by-paddock, and also by cow according to an annual standard grass growth curve which is modifiable and updatable by the user according to local grass growth measurements.

Among the most original aspects of Pastur'Plan is the capability to test different options (levels of supplementation, excess grass ensiling, changing weather conditions, etc.) and to simulate the consequences in terms of likely future grazing outcomes. For each paddock chosen by the user as the next paddock to graze, Pastur'Plan calculates the paddock grazing duration and applies grass growth curves to all other paddocks of the platform. The calculations are done at a half-day scale. For each half day, Pastur'Plan calculates the total grass intake according to the animal demand, changes the biomass consumed into grass height used (with a modifiable sward density grid included in the software) and calculates the residual grass height. If the residual grass height calculated exceeds the post-grazing height objective, the herd stays in the paddock for another half day and Pastur'Plan simulates a new grazing sequence. At the end of each grazing, a summary table is created with a new grazing profile taking into account the new state of the grazing platform to facilitate analysis by the user.

How to use Pastur'Plan

Pastur'Plan has been developed on Microsoft Excel and allows the possibility to simulate grass supply change for 42 days or up to 28 paddocks ahead. As often with grazing decision support tools, the Pastur'Plan user starts by inputting the farm structure components (paddocks, herds, feeding supplementation, grazing conditions). Subsequently, paddock heights from each paddock measured with a platemeter are recorded. The actual grass supply profile (Figure 1) and an associated table display the current actual grass supply including the relationship between grass supply and demand. Then the user selects the grazing paddock order and has access, sheet by sheet, to the evolution of the grazing situation. The user can change assumptions and create alternative simulations to evaluate the consequences of alternative management decisions. Finally, the farmer has access to a forecast grazing calendar with some illustrations to help interpret the future grazing simulation. The user can compare the pre- and post-grazing height objective with what is likely to happen, based on the chosen management decisions to reflect the coherence (or not) of the paddock-by-paddock grazing management. The figure of the dynamic evolution of grass demand and growth expressed per cow (not illustrated) permits the user to evaluate the adequacy of the actual stocking rate and supplemental feeding practices on future grass availability. Finally, Figure 2 describes the evolution of grass availability per animal, translated into grazing days ahead. This highlights the likely evolution of grazing in the near future and permits the grazing manager
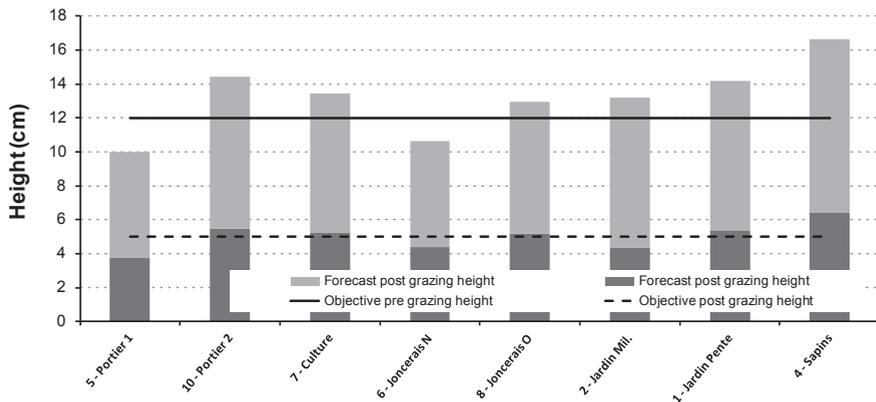
Figure 1. Example of grazing profile in Pastur'Plan.
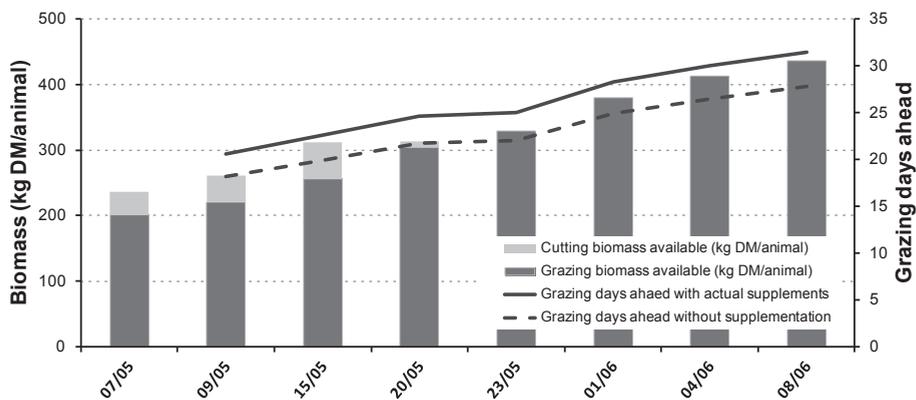
Figure 2. Evolution of grass available and grazing days ahead.

to examine alternative options with advisors and other colleagues before finally deciding on the best grazing plan for the next period.

Conclusions

Developed in association with an advisory company and based on practical grazing management concepts, Pastur'Plan will facilitate anticipation and decision making for advisers and grazing managers. This tool should provide more confidence in grazing systems and improve the efficiency of the dairy production systems based on better grass utilisation.

References

Defrance P., Delaby L. and Seuret J.M. (2005) Herb'aVenir, a simple decision support tool for grazing management. *Rencontres Recherches Ruminants* 12, 80.

Dillon P. and Kennedy J. (2009) Grazing notebook. Teagasc and Irish Farmer Journal, Ireland; 56 p. Available at: http://tinyurl.com/m9dzaw6.

Faverdin P., Delagarde R., Delaby L. and Meschy F. (2010) Alimentation des vaches laitières. In: Alimentation des bovins, ovins et caprins. INRA, Quae, Paris, Paris, pp. 23-58.

Accuracy of the FeedPhone device for recording eating and rumination times in dairy cows

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Abstract

Several commercially available devices automatically record feeding behaviour of dairy cows on farm, but independent validation studies are often not available. The objective of this study was to determine the accuracy of the FeedPhone® device, developed in France by Medria, to record eating and rumination activities of dairy cows. The FeedPhone is based on a tri-axial accelerometer placed on a collar, data being radio-transferred and processed automatically. The main activity (eating, rumination, or rest) is recorded every 5 min. Validation was performed on 7 lactating dairy cows fed on maize silage and concentrates for a total of 89 full day records. The actual times were determined by a reference method, by recording continuously the weight of the trough and the jaw movements at the minute scale. At the day level, the mean prediction error was 11.5% for eating time and 11.1% for rumination times, with low mean and slope biases (error mainly random). Eating and rumination activities are clearly distinguishable. This precision enables the detection of between-day variations of both eating or rumination times of 20, 10, and 5%, at cow level, small-herd level (4-7 cows) and larger herd level (>20 cows), respectively. This accuracy makes the FeedPhone valuable for studying relative variations of both eating and rumination times of dairy cows fed on total mixed ration.

Keywords: cattle, behaviour, methodology, accelerometer, accuracy

Introduction

Ruminant feeding behaviour has been recorded for a long time for scientific purposes to better understand and predict animal-feed relationships. More recently, advanced technologies allow continuous recording of on-farm dairy cow feeding behaviour and oestrus activity while also detecting health or nutritional events such as acidosis periods, either at cow or herd levels. This involves, however, accurate recording of eating and/or rumination activities. Several devices have been developed recently, most of them being based on biaxial or tri-axial accelerometers (Nielsen, 2013; Umemura, 2013). The objective of this work was to determine the precision and accuracy of the FeedPhone®, a new device for automatically recording eating and rumination times and the daily pattern of these events, which can be used on-farm for dairy herd management but also in ruminant research studies.

Materials and methods

Seven mid-lactating Holstein dairy cows were fed *ad libitum* during several weeks on a total mixed ration which comprised 59% maize silage, 39% concentrates and 2% minerals. After several days of adaptation, feeding behaviour was recorded continuously during 20 days from December 2013 to January 2014 by two independent methods: (1) the INRA reference method for measuring actual eating and rumination times, and (2) the Feedphone device developed by Medria for measuring predicted eating and rumination times. The INRA method consists of combining data from automatic weighing troughs and from bite meters. The bite meter is made up of a small balloon filled with foam rubber placed on the lower jaw and connected by a silicone tube to a pressure recorder (Baumont *et al.*, 2004). Feeding activity is interpreted each minute and classified as eating, rumination, or resting. The FeedPhone uses the Axel® sensor placed on a properly fitted collar on the cow's neck. The sensor consists of a micro-electromechanical tri-axial accelerometer that measures and continuously analyses the changes of inclination and lateral and vertical

accelerations. A set of nine statistical data is recorded every 5 min, automatically transmitted to the Box Medria by a radio link and thereafter to the data centre by a GPRS radio or internet connection. In the data centre, the processing algorithms on servers convert the raw data into new standardised data. The algorithms determine the main activity (here also classified as rumination, eating, or rest) for every 5 min period. They also determine if the animal is standing or lying down, and distinguish between eating at the barn or at grazing.

The accuracy of the FeedPhone in estimating eating and rumination time was investigated by calculating the mean prediction error (MPE, in min or in proportion to actual mean value), and the proportional contribution of mean bias, line bias and random variation to the mean-squared prediction error (MSPE) (Bibby and Toutenburg, 1977). Accuracy was investigated per day or per hour, by summing activities recorded at 5 min periods (FeedPhone) or at every 1 min period (INRA). Short unclear behaviour periods from the INRA reference system were not considered.

Results and discussion

The validation study involved a total of 89 complete cow × day recordings, for a total of 2,212 h of validation. At the day scale, the mean prediction error was 11.5% (42 min d^{-1}) for eating time and 11.1% (59 min d^{-1}) for rumination time, when the FeedPhone is compared to the INRA reference method used as the 'gold standard'. As no 'gold standard' is perfect (the INRA method is also an indirect method), it may be hypothesized that true accuracy should probably be greater. For eating time, part of the error comes from an under-estimation of low actual eating times (Figure 1), leading to a small overall under-estimation of eating time (-18 min d^{-1}, 18% of MSPE; Table 1). For rumination time, error is mainly random (97% of MSPE) with low mean and slope biases but greater dispersion (Figure 1). At the hour scale, mean prediction error is of 39% (5.7 min h^{-1}) for eating time and 35% (7.5 min h^{-1}) for rumination
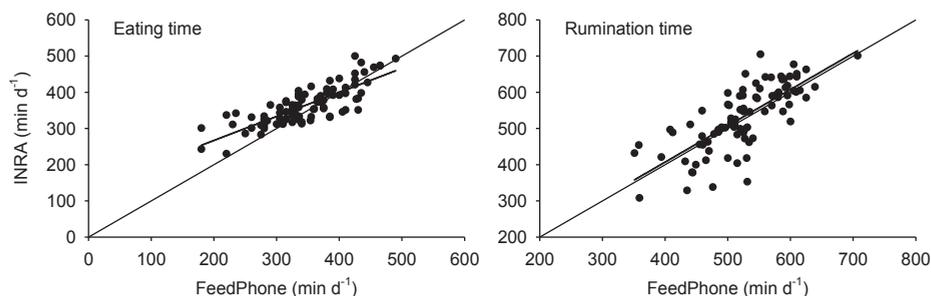
Figure 1. Daily eating and rumination times estimated by the FeedPhone or by INRA reference method on 7 cows during 20 days (total of 89 recordings).
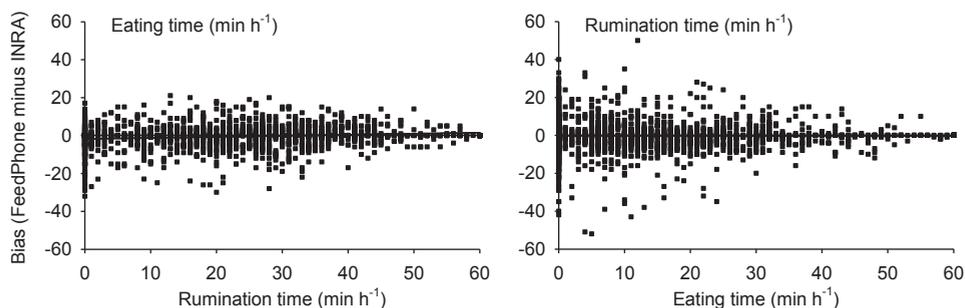
Figure 2. Relationship, for each of the 2,212 h of validation, between the bias (FeedPhone minus INRA) in eating or rumination time and the other feeding activity time (rumination for eating, and eating for rumination).

Table 1. Accuracy of the FeedPhone to record eating and rumination time in lactating dairy cows fed on a total mixed ration based on maize silage (89 d and 2,212 h of validation).

Scale	Activity	INRA	FeedPhone	MPE[1]		MSPE[1]		
		min	min	min	% mean	% mean	% slope	% random
Day	eating	364	346	41.8	11.5	18	27	55
	rumination	531	523	58.8	11.1	2	0	98
Hour	eating	14.6	13.9	5.7	39.2	2	1	97
	rumination	21.4	21.1	7.5	35.2	0	3	97

[1] MPE = mean prediction error; MPSE = mean square prediction error.

time, with no mean or slope biases, 97% of MSPE being random (Table 1). At the hour scale, there was no significant relationship between eating time bias and rumination time, nor between rumination time bias and eating time (Figure 2). It is noticeable that when a cow is engaged in a feeding activity (>40 min h^{-1}), there are only very small biases in the other feeding activity (Figure 2). This clearly shows the ability of the processing algorithms to classify feeding activities into either eating or rumination activity.

From mean prediction error observed at the day scale, it can be extrapolated that at individual cow scale, at small herd size scale like in this study (4-7 cows), or at larger herd size scale (>20 cows), the accuracy of the FeedPhone seems sufficient to detect between-day variations of eating and rumination times of about 20, 10 and 5%, respectively. Additional validation studies are needed to determine accuracy of the FeedPhone on cows fed on pasture silage, hay and/or under grazing.

Conclusions

At the day level, the FeedPhone is able to record automatically the eating and rumination time of dairy cows fed on a maize silage-based diet with a precision of 89 to 90% for both activities. Data analysis at the hour scale shows that algorithms are specific enough for clearly identifying the eating and rumination activities. This overall accuracy is good enough to make the FeedPhone a valuable tool for studying relative variations of both eating and rumination times of dairy cows.

References

Baumont R., Chenost M. and Demarquilly C. (2004) Measurement of herbage intake and ingestive behaviour by housed animals. In: Penning P.D. (ed) *Herbage intake handbook*. British Grassland Society, UK, pp. 121-150.

Bibby J. and Toutenburg H. (1977) *Prediction and improved estimation in linear models*. Wiley, London, UK.

Nielsen P.P. (2013) Automatic registration of grazing behaviour in dairy cows using 3D activity loggers. *Applied Animal Behaviour Science* 148, 179-184.

Umemura K. (2013) Monitoring grazing bites and walking activity with pedometers. *Journal of Dairy Science* 96, 1090-1093.

Phosphorus concentration and export by silage maize and cut grassland under temperate climate

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Abstract

Algal blooming caused by phosphorus (P) losses from agricultural soils to ground- and surface water is a major problem as P is typically the limiting factor for eutrophication in freshwater systems. To fine-tune the advice on P fertilisation and increase P-use efficiency, it is important to have up to date information on amounts of phosphate (P_2O_5) exported by crops. We re-analysed Flemish nitrogen fertilisation experiments on silage maize (*Zea mays*) and cut grassland (*Poaceae*) to derive their quantities of exported P_2O_5. The median P_2O_5 export by silage maize increased significantly from 78 kg P_2O_5 ha^{-1} in the last decade of the 20th century to 94 kg P_2O_5 ha^{-1} in recent years (median of 2.1 g P kg^{-1} dry matter (DM)). This increase is due to the higher crop yields. The median P_2O_5 export for cut grassland remained at approximately 110 kg P_2O_5 ha^{-1} with a median of 4.1 g P kg^{-1} DM.

Keywords: phosphorus, export, fertilisation advice, best management practice

Introduction

Long term phosphorus (P) overfertilisation has resulted in a large acreage of P-saturated soils and increased P losses to ground- and surface waters. In some European countries agriculture has become the main P source in water bodies (Bogestrand *et al.*, 2005) and is a major factor in eutrophication of surface waters as P is typically the limiting factor for algal blooming in freshwater systems (Sterner, 2008). One of the most commonly followed strategies to reduce P losses from agricultural soils is a rational P-fertilisation rate. To fine-tune the P fertilisation advice, it is important to have up to date information of the phosphate (P_2O_5) export of silage maize (*Zea mays*) and cut grassland (*Poaceae*), as scientifically sound fertilisation advice takes both optimal crop yield and quality and environmental impact into account.

Material and methods

We re-analysed 26 and 14 Flemish nitrogen (N) fertilisation experiments (1996-2013) on silage maize and cut grassland without clover, respectively, to derive their P_2O_5 export. To preclude an effect of N fertilisation rate, only plots receiving the maximum allowed N fertilisation norm of the Flemish fertilisation legislation (MAP IV, 2011-2014) ±25%, meaning that plots with 100-200 and 225-375 kg of applied effective N ha^{-1} for silage maize and cut grassland, respectively, were included in the analysis (Anonymous, 2011). Phosphorus application rates were based on fertilisation advice dependent on the expected yield. Total fresh and dry matter (FM and DM) yields were determined and P concentration of harvested plant parts was measured colorimetrically after digestion and acid decomposition. Phosphorus content of the upper soil layer was determined with the ammonium lactate method (P-AL).

Results and discussion

The P_2O_5 export by silage maize in Flanders (1996-2013) had a median of 86 kg P_2O_5 ha^{-1} with a median 0.7 and 2.1 g P kg^{-1} on a FM and DM basis, respectively. Regression analysis showed no correlation between P_2O_5 export by silage maize and soil P-AL content and/or P_2O_5 fertilisation rate. There was a significant correlation (R^2=0.47) between P_2O_5 export and yield. The median P_2O_5 export by silage maize increased significantly (P<0.001 nonparametric Mann-Witney U-test). The increase of the median

P$_2$O$_5$ export from 78 in 1996-1997 to 94 kg P$_2$O$_5$ ha^{-1} in 2003-2013 can be explained by the higher yield (median of 16.8 and 18.9 Mg DM ha^{-1}, respectively) as the P concentration did not change (Table 1).

The P concentration in Flanders falls within the range of other temperate-climate areas, i.e. 1.8 g P kg^{-1} DM in the Netherlands and France (Ehlert *et al.*, 2009; Gloria, 2012) and 2.2-2.3 g P kg^{-1} DM (2008-2013) in northern Germany (Egert, 2014). Fotyma and Shepherd (2001) measured in northern and eastern Europe on average 0.6±0.009 g P kg^{-1} FM (or 2.0 g P kg^{-1} DM). The median Flemish P$_2$O$_5$ export (86 kg P$_2$O$_5$ ha^{-1}) is higher than in other regions under temperate climates. In France and Saskatchewan (Canada) fertilisation advice is based on an export of 60 (Gloria, 2012) and 64 to 78 kg P$_2$O$_5$ ha^{-1} (Anonymous, 2012), respectively. In the UK, the maintenance fertilisation advice is 55 kg P$_2$O$_5$ ha^{-1} (Defra, 2010). Aarts *et al.* (2008) calculated an average export of 69 kg P$_2$O$_5$ ha^{-1} from fields of representative Dutch dairy farms (1998-2006) based on an average 2.0 g P kg^{-1} DM measured by BLGG (http://blgg.agroxpertus.nl).

The median P$_2$O$_5$ export by Flemish cut grassland was about 110 kg P$_2$O$_5$ ha^{-1} with a median P concentration of 4.1 g P kg^{-1} DM (Table 1). Regression analysis showed no correlation between P$_2$O$_5$ export and soil P-AL content and/or P$_2$O$_5$ fertilisation rate. There was a significant correlation (R^2=0.50) between P$_2$O$_5$ export and yield. The limited data from recent years suggest that the lower P$_2$O$_5$ fertilisation rate (90 compared to 116 kg P$_2$O$_5$ ha^{-1}) has resulted in a non-significant decrease of the average P concentration (P=0.06 T-test). The median P concentration decreased from 4.2 g P kg^{-1} DM to 3.9 g P kg^{-1} DM. The average P concentrations of Dutch grass silage measured by BLGG decreased from 4.4 in 1998 to 4.0 g P kg^{-1} DM in 2007, which was also explained by the stricter legislation (Aarts *et al.*, 2008). Although the median N fertilisation rate was 50 kg of effective N ha^{-1} less in 2003-2008 than in 1997-1998, DM grass yield remained constant.

The Flemish P concentration is within the range of measurements from intensively managed grassland under temperate-climates: i.e. 3.3-3.6 g P kg^{-1} DM in northern Germany (2008-2013) (Egert, 2014),

Table 1. Average (av.), median (med.) and standard deviation (std.) of phosphorus and effective nitrogen fertilisation rate, phosphorus content in the soil, dry matter (DM) yield, phosphorus concentration and phosphorus export by silage maize and cut grassland in Flanders.

	Silage maize								
	119 plots (1996-2013)			73 plots (1996-1997)			46 plots (2003-2013)		
	Av.	Med.	Std.	Av.	Med.	Std.	Av.	Med.	Std.
P$_2$O$_5$ fertilisation (kg ha^{-1})	67	65	25	66	69	21	67	60	30
Effective N fertilisation (kg ha^{-1})	140	138	26	141	138	28	138	135	22
P-AL (mg 100g^{-1} soil)	34	30	15	35	33	11	32	29	21
DM yield (Mg ha^{-1})	18.1	17.7	2.7	17.4	16.8	2.6	19.3	18.9	2.5
Phosphorus (g kg^{-1} DM)	2.1	2.1	0.4	2.1	2.1	0.4	2.1	2.1	0.3
P$_2$O$_5$ export (kg ha^{-1})	87	86	21	83	78	23	95	94	14

	Cut grassland								
	56 plots (1997-2008)			44 plots (1997-1998)			12 plots (2003-2008)		
P$_2$O$_5$ fertilisation (kg ha^{-1})	114	116	24	119	116	23	98	90	20
Effective N fertilisation (kg ha^{-1})	289	296	42	296	300	43	262	250	24
P-AL (mg 100g^{-1} soil)	28	27	11	29	37	12	23	22	8
DM yield (Mg ha^{-1})	12.0	11.9	2.1	11.8	11.9	1.5	12.9	12.3	3.5
Phosphorus (g kg^{-1} DM)	4.0	4.1	0.6	4.1	4.2	0.6	3.7	3.9	0.4
P$_2$O$_5$ export (kg ha^{-1})	111	111	26	111	111	27	110	109	21

3.1-4.1 g P kg^{-1} DM in UK (Defra, 2010) and 3.5-4.4 g P kg^{-1} DM in the Netherlands (Aarts *et al.*, 2008; Ehlert *et al.*, 2009). Fotyma and Shepherd (2001) measured on average 0.6 g P kg^{-1} FM (or 3.0 g P kg^{-1} DM) in grassland with and without clover. The median Flemish P_2O_5 export is higher due to higher yields. In the UK, maintenance fertilisation advice is 90 kg P_2O_5 ha^{-1} (Defra, 2010). Aarts *et al.* (2008) calculated an average export of 89 kg P_2O_5 ha^{-1} from fields of representative dairy farms (1998-2006).

Conclusions

Phosphorus concentration of silage maize and cut grassland remained similar, independent of yield. The median P_2O_5 export by silage maize increased significantly from 78 kg P_2O_5 ha^{-1} in the last decade of the 20th century to 94 kg P_2O_5 ha^{-1} in recent years (with a median of 2.1 g P kg^{-1} DM) due to the increased yield. The median P_2O_5 export by cut grassland was about 110 kg P_2O_5 ha^{-1} with a median of 4.1 g P kg^{-1} DM. In order to obtain optimal yield and taking into account the environmental impact, legislation and P_2O_5 fertilisation advice should envisage an equilibrium maintenance P_2O_5 fertilisation rate per crop for fields with an optimal soil P content, with differentiation for other fields depending on their soil P content.

Acknowledgements

References

Aarts H.F.M., Daatselaar C.H.G. and Holshof G. (2008) *Bemesting, meststofbenutting en opbrengst van productiegrasland en snijmaïs.* PRI, Wageningen, Nederland, 49 pp.

Anonymous (2011) Decreet houdende wijziging van het Mestdecreet van 22 december van 2006. *Belgisch Staatsblad*, 27876-27894.

Anonymus (2012) *Phosphorus fertilization in crop production.* Available at: http://www.agriculture.gov.sk.ca.

Bogestrand J., Kristensen P. and Kronvang B. (2005) *Source apportionment of nitrogen and phosphorus inputs into the aquatic environment*. European Environment Agency, Copenhagen, Denmark, 48 pp.

Defra (2010) *Fertiliser manual (RB209)*, Department for Environment, Food and Rural Affairs (Defra), London, UK, 249 pp.

Egert M. (2014) *Mineralstoffgehalte in silagen*. Available at: http://tinyurl.com/pflxdy3.

Ehlert P.A.I., Dekker P.H.M., Schoot J.R, Visschers R., Middelkoop J.C, Maas M.P, Pronk A.A. and Dam A.M. (2009) *Fosforgehalten en fosfaatafvoercijfers van landbouwgewassen: eindrapportage*. Alterra, Wageningen, Nederland, 125 pp.

Fotyma G. and Shepherd M. (2001) *Sustainable nutrient management.* MAINTAIN, Pulawy, Poland, 88 pp.

Gloria C. (2012) *La recherche s'active sur le phosphore*. Available at: http://tinyurl.com/k45hlzp.

Sterner R.W. (2008) On the phosphorus limitation paradigm for lakes. *International Review of Hydrobiology* 93(4-5), 433-445.

Competitive forbs in high-producing temporary grasslands with perennial ryegrass and red clover can increase plant diversity and herbage yield

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Abstract

In highly productive temporary grasslands in Europe, plant diversity is usually low. Some non-leguminous species have shown a high competitive ability in temporary grasslands and can increase plant diversity without compromising yields. In an experiment, the competitiveness and productivity of three forb species: chicory (*Cichorium intybus*), ribwort plantain (*Plantago lanceolata*) and caraway (*Carum carvi*), grown in different proportions in mixtures including traditional sown grassland species, perennial ryegrass and red clover, were examined with slurry application as an additional factor. Dry matter (DM) yield and botanical composition were measured during one complete growing season. Annual DM yields were mostly similar when forbs were included in the grassland mixture. A three-species mixture (perennial ryegrass, red clover and ribwort plantain) had the highest yield potential, especially for the slurry application treatment. Chicory and ribwort plantain were highly competitive in the mixtures. The response in the DM yield of perennial ryegrass to slurry application was considerable, but no consistent trend was found in the forbs. In conclusion, forbs contributed to increased plant species diversity and herbage DM yield, and fertilisation had positive effect on herbage yield of grassland mixtures.

Keywords: plant diversity, forb, dry matter yield, competitiveness, fertilisation

Introduction

There is growing interest in increasing biodiversity in European agriculture to make a contribution towards increasing the sustainability of cropping systems. However, most high-producing grasslands are dominated by traditional sown grass and clover species. With the inclusion of forbs in high-producing grasslands, there is a potential for increasing biodiversity without decreasing the dry matter (DM) yield (Søegaard *et al.,* 2011), but high competitiveness is required to secure better establishment and productivity of the forbs. Therefore, a field experiment was established with high-diversity temporary grassland including three highly competitive forb species. The aim was to generate more knowledge on the competitiveness of forbs, including the herbage yield response to the application of fertiliser (slurry).

Materials and methods

Sixteen seed mixtures, composed of chicory (*Cichorium intybus*), ribwort plantain (*Plantago lanceolata*), caraway (*Carum carvi*), perennial ryegrass and red clover (Table 1), were established in plots of 1.5×8 m in spring 2013 in three replicates. Seed rates in pure stands were 15, 4 and 12 kg ha^{-1} for perennial ryegrass, red clover and the three forbs, respectively. The plots were supplied with two levels of cattle slurry, 0 or 200 kg total N ha^{-1}. Herbage mass was harvested twice in 2013 and four times in 2014 during the growing season between May and October to determine DM yield. Botanical composition was determined by hand separation of sub-samples. Results from 2014 are presented and discussed.

Results and discussion

Red clover had the highest DM yield in pure stands. The DM yield in mixtures, composed of perennial ryegrass, red clover and forbs (mixtures 6-15), ranged between 13.2 and 16.1, and 14.3 and 17.7 Mg ha^{-1}, without and with slurry application, respectively (Table 1). The majority of the mixtures, except the

Table 1. Annual dry matter (DM) yield and weighted botanical composition.[1,2]

Seed mixture	Proportion of seed mixtures					Yield (Mg DM ha^{-1})	Proportion of DM yield					
	GR	RC	CI	PL	CA		GR	RC	CI	PL	CA	Weeds
Without slurry												
1	1.00					9.1[g]	0.54[a]					0.46[a]
2		1.00				15.4[abc]		0.94[a]				0.06[c]
3			1.00			8.8[g]			0.85[a]			0.15[b]
4				1.00		11.2[f]				0.79[a]		0.21[b]
5					1.00	8.0[e]					0.51[a]	0.49[a]
6	0.20	0.20	0.60			13.8[de]	0.07[ef]	0.42[de]	0.48[b]			0.03[c]
7	0.40	0.40	0.20			14.1[cde]	0.19[c]	0.46[de]	0.28[cd]			0.06[c]
8	0.20	0.20		0.60		15.7[ab]	0.06[f]	0.53[cd]		0.38[b]		0.03[c]
9	0.40	0.40		0.20		16.1[a]	0.12[de]	0.63[bc]		0.24[c]		0.01[c]
10	0.20	0.20			0.60	13.2[e]	0.25[b]	0.56[cd]			0.14[b]	0.05[c]
11	0.40	0.40			0.20	14.2[bcde]	0.26[b]	0.63[bc]			0.08[bc]	0.03[c]
12	0.50	0.50				15.6[abc]	0.25[bc]	0.73[b]				0.02[c]
13	0.40	0.40	0.07	0.07	0.07	15.6[ab]	0.13[d]	0.61[bc]	0.12[e]	0.11[d]	0.02[c]	0.02[c]
14	0.20	0.20	0.20	0.20	0.20	14.9[abcd]	0.10[de]	0.44[def]	0.19[de]	0.20[cd]	0.03[c]	0.04[c]
15	0.10	0.10	0.27	0.27	0.27	14.5[bcde]	0.06[f]	0.33[e]	0.28[cd]	0.27[c]	0.02[c]	0.04[c]
16			0.33	0.33	0.33	11.2[f]			0.34[c]	0.44[b]	0.04[c]	0.19[b]
With slurry (200 kg N ha^{-1})												
1	1.00					11.9[f]	0.74[a]					0.26[b]
2		1.00				15.7[bcd]		0.95[a]				0.05[de]
3			1.00			11.3[f]			0.94[a]			0.06[de]
4				1.00		14.0[e]				0.82[a]		0.18[c]
5					1.00	9.7[g]					0.64[a]	0.36[a]
6	0.20	0.20	0.60			14.3[e]	0.14[f]	0.30[de]	0.54[b]			0.03[e]
7	0.40	0.40	0.20			16.3[bc]	0.25[de]	0.46[bc]	0.28[cde]			0.01[e]
8	0.20	0.20		0.60		17.7[a]	0.17[ef]	0.41[bcd]		0.39[b]		0.02[e]
9	0.40	0.40		0.20		15.9[bc]	0.32[cd]	0.42[bc]		0.24[c]		0.02[e]
10	0.20	0.20			0.60	15.9[bc]	0.30[cd]	0.52[b]			0.15[b]	0.03[e]
11	0.40	0.40			0.20	15.7[bcd]	0.37[c]	0.52[b]			0.09[c]	0.02[e]
12	0.50	0.50				15.1[cde]	0.49[b]	0.49[b]				0.02[e]
13	0.40	0.40	0.07	0.07	0.07	16.4[b]	0.29[cd]	0.46[bc]	0.12[e]	0.10[d]	0.02[c]	0.02[e]
14	0.20	0.20	0.20	0.20	0.20	16.6[ab]	0.19[ef]	0.35[cd]	0.23[de]	0.18[c]	0.03[c]	0.02[e]
15	0.10	0.10	0.27	0.27	0.27	14.4[de]	0.15[f]	0.20[e]	0.35[cd]	0.21[c]	0.05[c]	0.04[e]
16			0.33	0.33	0.33	12.5[f]			0.40[bc]	0.43[b]	0.06[c]	0.11[cd]

[1] GR: perennial ryegrass; RC: red clover; CI: chicory; PL: ribwort plantain; CA: caraway.

[2] Within each column, values followed by the same letter are not significantly different *(P<0.05)*.

three-species mixture of forbs (mixture 16) showed similar annual DM yields to that of the pure stand of red clover (mixture 2) and the standard mixture of red clover and perennial ryegrass (mixture 12). However, the three-species mixtures of perennial ryegrass, red clover and ribwort plantain produced relatively higher DM yields without slurry, and significantly higher yields with slurry application than the pure stand of red clover and the standard mixture (mixtures 2 and 12). The greater DM yield can be explained by the positive effect of plant species diversity on resource use (Pirhofer-Walzl *et al.,* 2013).

In mixtures, red clover contributed a higher proportion of the herbage than its proportion in the seed mixture (Table 1). The proportions of chicory and ribwort plantain were similar in the herbage and seed mixtures, and perennial ryegrass and caraway had a lower proportion in the herbage than in the seed mixtures. In the mixtures composed of one forb, perennial ryegrass and red clover, when the proportion of forbs was low (20% of seed mixture), the proportions of forbs in the herbage were higher than in the seed sown. With 60% of chicory and ribwort plantain seeds in the seed sown (mixtures 6 and 8), chicory appeared to have competed more successfully with red clover than plantain, which could be the reason for the lower DM yield with chicory and higher yield with plantain compared with the standard mixture (mixture 12), especially with slurry application. The more upright leaves of plantain might have allowed better light interception. In mixtures, slurry fertilisation (200 kg N) reduced the red clover content on average from 53 to 42%, while the grass content increased from 15 to 27% and the content of the three forbs was only slightly affected. This reflects a high ability of forbs to compete with grass for available resources. Caraway always constituted very low proportions of the DM yield in all mixtures and was a lower proportion of the herbage than in the seed mixture, demonstrating poor ability to compete for the available resources with companion species (Table 1). One explanation could be that the resources are being utilised to establish caraway's large root system and the herbage mass might be expected to be higher in subsequent years (Søegaard *et al.,* 2013). The abundance of weeds was significantly lower in mixtures, except the three-species mixture of forbs (mixture 16), compared to pure stands except the pure stand of red clover and that of fertilised chicory. It demonstrated a higher ability of mixtures to compete with weeds for better utilisation of resources and higher herbage production. White clover constituted a significant proportion of the unsown species present in the plots sown without red clover.

Slurry application increased DM yield, and was most pronounced in pure stands of perennial ryegrass and forbs, increasing the DM yield of perennial ryegrass by up to 31%; there were smaller increases for chicory, ribwort plantain and caraway. The DM yield of red clover did not increase with slurry application to the pure stand. In mixtures including red clover (mixtures 6-15), the change in DM yield varied between -3 and +20% as compared to that of the pure stand. This variation was not related to forb species or red clover content. Even in mixture 15, with the lowest red clover content, there was no effect of slurry fertilisation, indicating that the N_2-fixation of red clover was sufficient. In the mixture with all three forbs, slurry fertilisation increased yield by 12% compared to an increase of 21-28% in pure stands. This indicates better resource utilisation at a low fertiliser level.

Conclusions

The experiment demonstrated possibilities for increasing biodiversity in leys with a high content of non-leguminous forbs without a loss in DM yield. Herbage yield was increased by slurry application without affecting the competitiveness of non-legume species.

References

Pirhofer-Walzl K., Eriksen J., Rasmussen J., Høgh-Jensen H. and Søegaard K. (2013) Effect of four plant species on soil 15N-access and herbage yield in temporary agricultural grasslands. *Plant and Soil* 371, 313-325.

Søegaard K., Eriksen J. and Askegaard M. (2011) Herbs in high producing organic grasslands – effect of management. In: Neuhoff D. (ed.) *Third Scientific Conference of ISOFAR, Republic of Korea, Vol. 1,* pp. 190-193.

Søegaard K., Eriksen J. and Mortensen T.B. (2013) Species competition in multispecies grass swards. *ICROFS News* 3, 12-13.

Changes in vitamin and fatty acid contents in grass-red clover herbage after cutting

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Abstract

Fresh herbage is an important natural source of protein, fibre, fatty acids (FA) and vitamins in ruminant diets and it is desirable for farmers that they minimise losses. Thus the concentrations of vitamins and FA in herbages during the growing season as well as their fate after cutting are of interest. A study was conducted in Denmark in which a red clover (*Trifolium pratense*) – perennial ryegrass (*Lolium perenne*) sward was mown eight times during the crop growing season. Swaths were subjected to three wilting strategies, and sampled at six time intervals after cutting. Dry matter content and concentrations of α-tocopherol, β-carotene and FA were determined. Fatty acid and α-tocopherol concentrations were highest in October, followed by May, and lowest in summer. Total FA and vitamin concentrations showed a significant overall decline from freshly cut to 29 h-wilted forage. Weather conditions and swath management practices had significant effects on the drying rate of cut forage. The magnitude and rates of decline of concentrations of vitamins and FA during the wilting process were not affected by swath management or herbage drying rates. Choice of harvest date and wilting duration could be used as management tools to optimise concentrations of vitamins and FA in forage.

Keywords: α-tocopherol, β-carotene, α-linolenic acid, drying rate, fatty acids, seasonal pattern

Introduction

As N is a major limiting factor for plant growth, inclusion of legumes in grasslands contributes to sustainable intensification, as symbiotically fixed N_2 may replace fertilizer-N. Red clover (*Trifolium pratense*) is an important forage legume and perennial ryegrass (*Lolium perenne*) a major grass species. Livestock products are an important source of fat-soluble vitamins. Tocopherols and carotenoids can be transferred from feed into milk and the fatty acid (FA) profile of feed has a direct impact on the FA profile of animal products. Fresh herbage is an important natural source of protein, fibre, FA and vitamins in ruminant diets. It is desirable to optimise contents of valuable compounds in grazing animals' diets, and for zero grazing systems and conserved forage, to minimise losses after cutting. Thus the contents of vitamins and FA during the growing season, as well as their fate after cutting, were studied in perennial ryegrass-red clover herbage. Although synthetic vitamins are cheap and widely used in livestock production, there is interest in naturally occurring vitamins, particularly in organic farming systems and thus, for physiological and economic reasons, it is desirable to keep vitamin levels in conserved forages close to the initial levels in the fresh crop. Post-harvest treatments can affect FA contents in grass (e.g. Witkowska *et al.,* 2009). Following cutting, pre-wilting of herbage prior to ensiling is a widely used swath management practice. Detrimental effects of prolonged wilting and field drying on the concentrations of FA and vitamins have been reported in grass and legume species (Müller *et al.*, 2007). The aim of this experiment was to study the effects of harvest date and swath management on changes in concentrations of vitamins and FA in a gradually wilted grass-red clover mixture, in relation to wilting duration, weather conditions and herbage drying rate. We hypothesised that during wilting, concentrations of vitamins and FA would decline, and that the rate of decline would be related to herbage drying rate.

Materials and methods

A study was conducted in Denmark in which a red clover-perennial ryegrass sward was mown on eight occasions (early May until mid-October 2009). Swaths were subjected to three wilting strategies, i.e. 'narrow' (50% area cover), 'broad' (full field cover) and 'broad' swaths tedded 2 h after cutting, and sampled on six occasions (0, 3, 5, 10, 24 and 29 h after cutting). Weather parameters were measured hourly by a weather station ca. 200 m from the experimental area. of Dry matter (DM) content and concentrations of α-tocopherol, β-carotene and FA were determined as described in Elgersma *et al.* (2013). Change in DM content was calculated for each interval between two sampling times. Changes with time were evaluated with a model (ProcMixed) that included fixed effects of swath treatment, harvest date and sampling time and their two-way interactions. Across harvest dates, air temperature at cutting (at 10:00 h) ranged from 7.3 to 22.6 °C. In May, September and October, the grass was in a vegetative stage and predominantly leafy. Grass stems mainly occurred at the flowering stage in June (harvests 2 and 3). Red clover was at the flowering stage and was most stemmy in mid-summer (late July-August, harvests 4-6).

Results

In freshly cut herbage (t=1), significant effects of harvest date occurred for concentrations of vitamins, FA and DM. Fatty acid and α-tocopherol concentrations were highest in harvest 8 (October) followed by harvest 1 (May). Averaged across harvest dates and swath managements, vitamins and FA concentrations declined during wilting from sampling time t=1 to t=6, whereas DM concentration increased from 140 to 320 g kg^{-1} (Table 1). Average drying rates across the five time intervals were 0.7, 1.7 and 2.0 g 100 g DM^{-1} h^{-1} in narrow, broad and broad tedded swaths, respectively, but there was large variation in crop drying rates among the eight harvest dates in each swath type. After 19 h, in narrow swaths DM contents were lowest and ranged from 138 (harvest 1) to 324 g kg^{-1} (harvest 5) but in broad swaths, only in harvests 1, 6 and 8 the final DM content was below 320 g kg^{-1}. The highest DM contents were found in harvests 2 and 7 in broad swaths and particularly in broad tedded swaths (519 g kg^{-1} in harvest 3 and 643 g kg^{-1} in harvest 5). Despite interactions, the main effect of sampling time was highly significant ($P<0.001$). Total FA concentration showed a significant overall decline ($P<0.001$) from fresh to 29 h-wilted forage (2.13 to 1.87 g 100 g DM^{-1}) (Table 1). Regression analyses with the rate of change in FA concentration as dependent variable did not reveal significant explanatory variables. Swath management had no effect. During the wilting process, vitamins and particularly β-carotene concentrations were more variable than FA concentrations; during some time intervals contents increased and there were interactions between harvest date and sampling times. However, after 29 h, concentrations of α-tocopherol and β-carotene had declined on average from 29 to 27, and 44 to 31 mg kg^{-1}, respectively (Table 1). No relationships were found between the rates of change in vitamin concentrations from t=1-6 and crop drying rates or weather parameters. Swath management had no effect. Interrelations in concentrations of vitamins and FA were complex, and were different in fresh and wilted herbage. Weather conditions and swath management practices had significant effects on the drying rate of cut herbage. The magnitude and rates

Table 1. Concentrations of α-tocopherol, β-carotene, and fatty acids (FA) and dry matter (DM) content in perennial ryegrass-red clover herbage, cut at 10:00 h and sampled 0, 3, 5, 8, 24 and 29 h after cutting (t=1-6), respectively.[1,2]

| | t1 | t2 | t3 | t4 | t5 | t6 | SEM | Significance | | |
	0 h	3 h	5 h	8 h	24 h	29 h		Time (T)	T×S	T×H
DM (g kg^{-1})	14 [a]	17 [b]	21 [c]	24 [d]	24 [d]	32 [e]	0.61	<0.001	<0.001	<0.001
FA (mg kg^{-1})	2.13 [e]	2.06 [d]	2.03 [cd]	2.00 [c]	1.93 [b]	1.87 [a]	0.026	<0.001	NS	NS
α-tocopherol (mg kg^{-1})	29 [b]	29 [b]	31 [c]	29 [b]	28 [ab]	27 [a]	0.7	<0.001	NS	<0.001
β-carotene (mg kg^{-1})	44 [c]	45 [c]	44 [c]	41 [c]	35 [b]	31 [a]	0.2	<0.001	NS	<0.001

[1] Average values of three swath (S) treatments and eight harvest (H) dates between 18 May and 12 October 2009; n=24. SEM = standard error of the mean.

[2] Different letters within a row indicate a significant difference at P=0.05. NS = not significant.

of decline during the wilting process were not affected by swath management or herbage drying rates (*P*>0.05; not shown).

Discussion

This study provided insight into changes in concentrations of vitamins and FA and their interrelations in grass-clover herbage during wilting as affected by management, herbage drying rates and season. In general, broad swaths where cut herbage covered the ground area had a faster drying rate than narrow swaths, while tedding accelerated the drying rate. In broad swaths, the drying conditions were better as the layer was thinner and had a larger surface area. Swath management had no effect changes in concentrations of vitamins and FA. Although the decline in vitamin and FA concentrations was significantly affected by wilting time, the numerical values were small and less important than differences between harvest dates. Our hypothesis that concentrations of vitamins and FA would decline during wilting was confirmed but, contrary to our expectation, the magnitude and rates of decline during the wilting process were not affected by swath management or herbage drying rates. Choice of harvest date and wilting duration could be used as management tools to optimise contents of vitamins and FA in forage. In line with Witkowska *et al.* (2008), FA contents were highest in vegetative forage grown at low temperatures. Utilization of autumn-grown grass-clover as well as early spring growth, by either grazing or feeding freshly cut grass in zero grazing systems, could be a way to enhance vitamin and FA contents in animal diets. In conclusion, the outcome of this study suggests that shortening the post-harvest wilting period would result in reduced losses of vitamins and FA in perennial ryegrass-red clover herbage, regardless of swath treatment or crop drying rate.

References

Elgersma A., Søegaard K. and Jensen S.K. (2013) Fatty acids, α-tocopherol, β-carotene and lutein contents in forage legumes, forbs and a grass-clover mixture. *Journal of Agricultural and Food Chemistry* 61, 11913-11920.

Müller C.E., Möller J., Jensen S.K. and Udén, P. (2007) Tocopherol and carotenoid levels in baled silage and haylage in relation to horse requirements. *Animal Feed Science and Technology* 137, 182-197.

Witkowska I.M., Wever A.C. and Elgersma A. (2009) Effects of post-harvest treatments on concentrations and profile of fatty acids in fresh perennial ryegrass. *Animal Feed Science and Technology* 149, 60-69.

Witkowska I.M., Wever A.C., Gort G. and Elgersma A. (2008) Effects of nitrogen rate and regrowth interval on perennial ryegrass fatty acid content during the growing season. *Agronomy Journal* 100, 1371-1379.

Effect of different doses of an amendment and an organo-mineral fertiliser on the production of forage maize

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Abstract

Animal feed is the main cost on dairy farms. Maize can produce quality silage for dairy cattle at less cost than silage from grass, and at the same time increases milk yield and milk protein content. Moreover, supplementation with concentrates can be reduced and profitability is improved. The correct use of amendments and fertilisers could improve maize production and its nutritional content and also reduce costs. The aim of this study was to evaluate the effect on forage maize production of different application rates of an amendment (5, 15, 25 and 35 Mg ha^{-1}) and an organo-mineral fertiliser (50, 100, 150 and 200 kg N ha^{-1}) developed with organic matter from industrial wastes and with inorganic sulphur from a refinery, in comparison with the mineral fertilisation usually carried out in the area where the experiment was conducted (Spain). The results obtained did not show a significant effect of the different rates of the amendment on maize production, probably because the amount of N applied to the soil was similar. However, high rates of the organo-mineral fertiliser increased the production of forage maize, probably by the soil fertility improvement associated with this treatment.

Keywords: dairy farms, nutrition, yield, management, *Zea mays*

Introduction

On dairy farms, green fodder is the most valuable and cheapest source of animal feed. Maize occupies a key position as one of the most important fodder crops for animal consumption because of the high production of maize in comparison with other fodder crops (Muzaffar *et al.*, 2014). Moreover, maize produces quality silage for dairy cattle at less cost than silage made from grass, which reduces the need for supplementation with concentrates and improves the farm profitability (Ali *et al.*, 2012). On the other hand, the correct use of amendments and fertilisers is vital for the success of the crop because it greatly influences not only the yield of the crop and its nutritional content but also its production costs. New products developed from wastes from industries could be used as amendments and fertilisers. This could reduce the use of inorganic fertilisers at the same time as residues are recycled. Several studies have shown that the use of wastes from industries as amendments and fertilisers can increase crop yields and quality and result in significant economic returns for producers (Hue, 1992). The aim of this study was to evaluate the effect on forage maize production of different rates of application of an amendment (5, 15, 25 and 35 Mg ha^{-1}) and of an organo-mineral fertiliser (50, 100, 150 and 200 kg N ha^{-1}) developed with organic matter from industrial wastes and with inorganic sulphur from a refinery. The results obtained were compared with the mineral fertilisation usually carried out in the area of Spain where the experiment was conducted.

Materials and methods

The experiment was established in León (NW Spain) in 2013 when the soil was ploughed and the experimental plots were established. Each plot occupied 11.25 m^2 and in spring of 2013 the plots were sown with forage maize (*Zea mays* L.). The distance between plant rows was 0.55 m and the distance between plants in each row was 0.155 m. The experiment was arranged as a randomized complete block design with four replicates and nine treatments. The treatments consisted of the application of four rates of an amendment (5, 15, 25 and 35 Mg ha^{-1}) and four rates of an organo-mineral fertiliser (50, 100,

150 and 200 kg N_{total} ha^{-1}) developed with organic matter from industrial wastes and with inorganic sulphur from a refinery. The amendment was developed from compost and industrial wastes from the dairy and meat industries and the fertiliser consisted of a mixture of chicken manure and waste from the dairy industry to which was added magnesium oxide. In the amendment, the concentrations of N, P and K were 18.2 g kg^{-1}, 7 g kg^{-1} and 2.9 g kg^{-1} of the amendment on dry matter basis, respectively. In the case of the organo-mineral fertiliser, the N concentration was 20.3 g kg^{-1}, the P concentration was 14.5 g kg^{-1} and the K concentration was 6.9 g kg^{-1}. Moreover, a control mineral treatment (MIN) was also included which consisted of the mineral fertiliser usually carried out in the area: 800 kg of 8% N, 15% P_2O_5, 15% K_2O ha^{-1} and 243 kg N ha^{-1}. The mineral treatment was also applied to the amended plots. The amendment and the fertilisers were applied before sowing in 2013 and 2014 and incorporated into the soil through tillage with a disc harrow. The calculation of the required amounts was conducted according to the dry matter percentage in the amendment (36.06%) and in the organo-mineral fertiliser (47.15%) and the N_{total} concentration, considering that only around 20% was mineralised and therefore available. The maize was irrigated during the experiment. To estimate the production of forage maize, ten plants per plot were harvested and weighed fresh in November 2014. In the laboratory, the plants were separated into the components: aborted cobs, cobs without grains, stems, leaves and grains. These components were dried and weighed to estimate the dry matter production. Data were analysed using ANOVA and differences between averages were shown by the LSD test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

Results and discussion

The total production of forage maize obtained in this study when the amendment (12.98-16.45 Mg ha^{-1}) and the organo-mineral fertiliser (7.32-14.55 Mg ha^{-1}) (Figure 1) were applied was similar to the production found by Moreno-González (1982) (13.4 Mg ha^{-1}) and by Lloveras (1990) (14.07 Mg ha^{-1}) in Galicia (NW Spain). However, in the case of the mineral fertiliser, the total production of forage maize obtained (10.16 Mg ha^{-1}) was lower compared with the production found by these authors. Galicia is a region characterised by high precipitation distributed throughout the year, with the exception of the summer months, and this usually implies a higher production of maize in Galicia compared with the area in which this experiment was established. However, irrigation and the use of the amendment and organo-mineral fertiliser in our study probably implied that the maize production obtained was similar to that found by Moreno-González (1982) and by Lloveras (1990) in Galicia.

There were no significant effects of the different rates of amendment applied on the production of the different components of maize ($P>0.05$). This was probably because the amount of N applied to the soil with the different rates of amendment was similar (5: 314 kg N ha^{-1}, 15: 327 kg N ha^{-1}, 25: 340 kg N
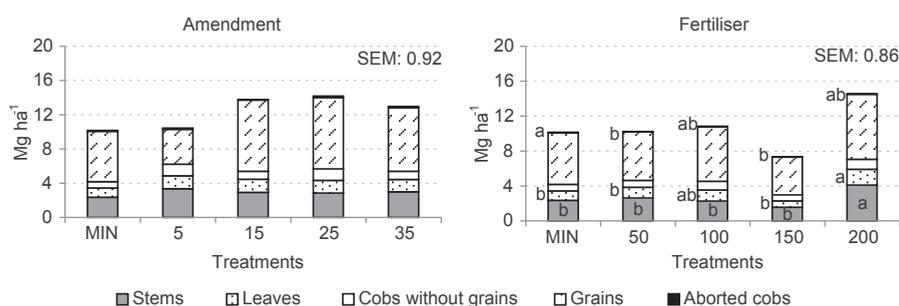
Figure 1. Production of the different components of forage maize (aborted cobs, cobs without grain, stems, grains and leaves) (Mg ha^{-1}) under the different treatments in 2014. MIN = mineral; 5, 15, 25 and 35 Mg amendment ha^{-1}; 50, 100, 150 and 200 kg N ha^{-1}; SEM = standard error of the mean. Different letters indicate significant differences between treatments.

ha^{-1} and 35: 353 kg N ha^{-1}). The application of high rates of the organo-mineral fertiliser (200 kg N ha^{-1}) increased the production of stems and leaves of the forage maize ($P<0.05$) more than the other fertiliser rates (50, 100 and 150 kg N$_{total}$ ha^{-1}) and the mineral fertilisation (MIN). This result could be explained by the higher inputs of nutrients to the soil with the high rates of fertiliser than with the low rates. Other authors, such as Černý *et al.* (2012) in studies established in Czech Republic also observed an increment of maize production when a waste as sewage sludge was used as a fertiliser, mainly with the highest rates of sewage sludge applied to the soil (240 kg N ha^{-1}). Finally, the production of aborted cobs was higher in the MIN treatment than when the low and the intermediate rates (50 and 150 kg N$_{total}$ ha^{-1}) of fertiliser were applied ($P<0.05$). This also demonstrates the advantages of the use of the organo-mineral fertiliser used in this study on the production of forage maize compared with the traditional management carried out in the area. Therefore, the use of this fertiliser could increase the production of the crop and at the same time provide a cheap source of N and decrease the environmental risks associated with mineral fertilisers.

Conclusions

Forage maize production was not significantly modified by the different application rates of the amendment, probably because the amount of N applied to the soil was similar and very high. However, the highest rate of organo-mineral fertiliser (200 N ha^{-1}) increased the production of forage maize due to higher inputs of nutrients to the soil. Therefore, the use of high rate of organo-mineral fertiliser as shown in this study should be recommended because the production of the crop increases and at the same time it provides a cheap source of N and decreases the environmental risks associated with mineral fertilisers.

References

Ali S., Sahiba Malik M.A., Hassan F. and Ansar M. (2012) Growth of rainfed fodder maize under different levels of nitrogen and phosphorus. *Pakistan Journal of Agricultural Research* 25, 196-205.

Černý J., Balík J., Kulhánek M., Vašák F., Peklová L. and Sedlář O. (2012) The effect of mineral N fertiliser and sewage sludge on yield and nitrogen efficiency of silage maize. *Plant Soil and Environment* 50, 76-83.

Hue N.V. (1992) Correcting soil acidity of a highly weathered ultisol with chicken manure and sewage-sludge. *Communications in Soil Science and Plant Analysis* 23, 241-264.

Lloveras J. (1990) Dry matter yield and nutritive value of four summer annual crops in northwest Spain Galicia. *Grass and Forage Science* 45, 243-248.

Moreno-González J. (1982) El maíz forrajero: una opción en las explotaciones ganaderas. *Pastos* 12, 157-170.

Muzaffar A., Yingying S., Waseem B., Shahbaz K., Sanaullah B., Yang Y., Abdul H., Aman J.B. and Shabeer A. (2014) Influence of integrated levels of potassium and zinc on the green fodder yield of maize (*Zea mays* L.). *Journal of Biology, Agriculture and Healthcare* 4, 162-170.

SAS (2001) *SAS/Stat User´s Guide: Statistics*. SAS Institute Inc., Cary, NC, USA, 1223 pp.

Effects of forage species and sward-lifting on compacted soil

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Abstract

Using shallow tillage (e.g. direct drilling) is one approach that farmers could use to reduce establishment costs within dairy systems, but soils are often compacted by machinery during field operations. Research has shown that different forage species may alter the physical properties of soil. An experiment investigating the effects of forage species established by direct drilling, either with or without sward-lifting, on soil compaction was established on a previously compacted area of silt loam at Trawscoed, Aberystwyth University. Treatments consisted of perennial ryegrass (*Lolium perenne*), white clover (*Trifolium repens*) or lucerne (*Medicago sativa*) established by direct drilling compared to ryegrass established by ploughing, with each of these treatments set up either with or without prior sward-lifting. The existing ryegrass sward was used as a control. Triplicate plots (17×3 m) of each treatment were sown on 17 July. Sward-lifting reduced soil penetration resistance for all treatments in all soil layers between 7.5 and 37.5 cm, but increased resistance in the 0-7.5 cm layer. Ploughing reduced soil penetration resistance in all soil layers between 0-22.5 cm. Soil penetration resistance within the 0-7.5 cm layer of soil was lower in existing ryegrass plots than lucerne plots during early establishment.

Keywords: shallow tillage, penetrometer, direct drilling, *Trifolium repens*, *Medicago sativa*

Introduction

Good soil management is fundamental to sustainable grassland-based high-output dairy systems. Using shallow tillage (e.g. direct drilling) is one approach farmers could use to reduce establishment costs whilst maintaining soil structure, biology and moisture. However, within dairy systems, soils are often compacted by machinery during field operations. Mytton *et al.* (1993) showed that different forage species may alter the physical properties of the soil, due to differences in their root architecture. Here we present the findings of an experiment investigating the effects of forages established by direct drilling compared to ryegrass established by ploughing and either with or without a sward-lifter, on soil compaction.

Materials and methods

Plots (17×3 m) were set up within a randomised block design, with 3 replicates of each treatment, on an area of silt loam at Trawscoed Farm, Aberystwyth University (52°20'29.21'N 3°57'18.33'W). The area was compacted on 5 July 2013 prior to the experiment using a wheeled tractor and half-loaded silage trailer, driven wheel-on-wheel during wet weather, immediately after a second silage harvest (90° to the alignment of the designed plots). All further mechanical operations were completed along the length of the plots. Treatments comprised: perennial ryegrass (*Lolium perenne*), white clover (*Trifolium repens*) or lucerne (*Medicago sativa*) established by direct drilling; perennial ryegrass treatment established by ploughing; and the existing ryegrass sward, with each of these treatments set up either with or without prior sward-lifting (Table 1).

Areas allocated to treatments 1-8 were treated with glyphosate (360 g l^{-1}) herbicide (Clinic Ace, Nufarm UK Ltd., Bradford, UK) at the rate of 4 l ha^{-1} on 9 July. Treatments 9 and 10 remained as the existing grass swards. Sward lifted areas were treated using a four-legged sward-lifter set at 60 cm between each leg and working to a depth of 30 cm (Erth Engineering, Seaforde, Northern Ireland) on 9 July. On 17 July, direct drilled seed was sown into slots 10 mm deep and treatments 7-8 were sown at a depth 10 mm. Lucerne (cv.

Table 1. Treatments to compare the effect of forage species, with and without the use of a sward-lifter, on soil compaction.

Treatment	Sward-lifted	Forage species	Sowing method
1	+	lucerne	direct drilling
2	–	lucerne	direct drilling
3	+	white clover	direct drilling
4	–	white clover	direct drilling
5	+	perennial ryegrass	direct drilling
6	–	perennial ryegrass	direct drilling
7	+	perennial ryegrass	ploughed
8	–	perennial ryegrass	ploughed
9	+	existing ryegrass	-
10	–	existing ryegrass	-

Timbale), white clover (cv. Aran) and perennial ryegrass (cv. Abermagic) were sown at target rates of 22.5 and 35 kg ha^{-1}, respectively using a 2.9 m wide drill (Moore Grassland Unidrill, Ballymoney, Northern Ireland). Soil chemical analysis prior to establishment was pH 6.6, phosphate 26 mg l^{-1} (index 3), potash 191 mg l^{-1} (index 2+), magnesium 203 mg l^{-1} (index 4). Plots were harvested using a Haldrup 1500 plot harvester (J. Haldrup a/s, Løgstør, Denmark) on 21 August, 24 September and on 25 November 2013 (data not shown). On 3 February 2014, soil compaction at 8 random points along the centreline of each plot was determined as penetration resistance (kPa) at 2.5 cm intervals down to 37.5 cm using a soil compaction meter (Fieldscout SC900, Spectrum Technologies, IL, USA). The area under the curve for different soil layers (0-7.5, 7.5-15, 15-22.5, 22.5-30 and 30-37.5 cm) was compared between treatments by ANOVA using GenStat® Release 13.

Results and discussion

Seven months after establishment, sward-lifted soils showed significantly lower ($P<0.01$) penetration resistance compared to intact soils in each layer evaluated between 7.5 and 37.5 cm (Table 2) but higher resistance in the 0-7.5 cm layer ($P<0.05$). In the 0-7.5 cm soil layer, soil resistance was lower ($P<0.05$) in ploughed plots compared with all other forage treatments. In the same soil layer, soil under existing sward showed lower resistance than that under direct-drilled lucerne, with direct-drilled white clover and direct-drilled ryegrass plots being intermediate. Ploughed ryegrass plots also had lower soil resistance in the 7.5-15 and 15-22.5 cm soil layers (Figure 1). There were no forage species effects below the 15-22.5 cm layer and no forage species × sward-lifting interaction in any of the soil layers. As Mytton *et al.* (1993) showed that different forage species can alter soil physical properties, further work is needed to determine if these effects change over a longer period and at different soil depths.

Conclusions

Sward lifting reduced soil penetration resistance below 7.5 cm. Ploughing significantly reduced soil penetration resistance down to 22.5 cm soil depth. Soil penetration resistance within the 0-7.5 cm layer of soil was lower in existing ryegrass than lucerne at 7 months post-establishment.

Acknowledgements
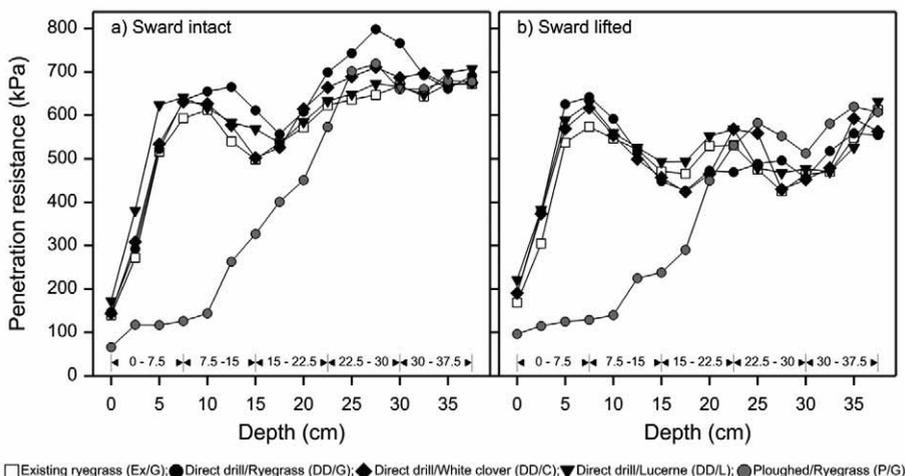
Figure 1. Effects on soil compaction of different forage species established by direct drilling compared to an existing ryegrass sward or ryegrass established by ploughing, either (a) without or (b) with the effects of sward-lifting.

Table 2. Area under penetration resistance curves within each 7.5 cm soil layer (MPa 7.5 cm^{-1}).[1]

Crop[2]	0-7.5 cm			7.5-15 cm			15-22.5 cm			22.5-30 cm			30-37.5 cm		
	Intact	Lifted	x̄	Intact	Lifted	x̄	Intact	Lifted	x̄	Intact	Lifted	x̄	Intact	Lifted	x̄
Ex/G	2.87	3.03	2.95^b	4.25	3.98	4.11^b	4.18	3.74	3.96^b	4.82	3.50	4.16	4.97	3.89	4.43
D/G	3.00	3.55	3.26^{bc}	4.86	4.13	4.50^b	4.55	3.40	3.97^b	5.69	3.62	4.65	5.21	3.96	4.58
DD/WC	3.06	3.36	3.21^{bc}	4.43	3.98	4.20^b	4.31	3.50	3.91^b	5.19	3.75	4.47	5.12	3.95	4.53
DD/L	3.49	3.49	3.49^c	4.51	4.12	4.32^b	4.31	3.94	4.13^b	4.93	3.67	4.30	5.08	3.88	4.48
P/G	0.82	0.88	0.85^a	1.58	1.37	1.48^a	3.26	2.81	3.03^a	5.09	4.14	4.62	5.02	4.40	4.71
x̄	2.37	2.56		3.93	3.52		4.12	3.48		5.14	3.74		5.08	4.02	

	SEM	Prob	SEM	Prob	SEM	Prob	SEM	Prob	SEM	Prob
Crop (C)	0.017*	<0.001	0.108	<0.001	0.192	0.006	0.132	0.077	0.191	0.857
Lifted (sL)	0.011*	0.041	0.068	<0.001	0.121	0.002	0.084	<0.001	0.121	<0.001
C × sL	0.024*	0.651	0.152	0.508	0.271	0.560	0.187	0.088	0.270	0.771

[1] Differing superscripts indicate difference between means (P<0.05; Student Newman Keuls test); SEM = standard error of the mean; Prob = probability; * Relates to means on log$_{10}$ scale.
[2] Crops: L = lucerne; WC = white clover; G = perennial ryegrass; Ex = existing ryegrass; DD = direct drilling; P = ploughed.

References

Mytton L.R., Cresswell A. and Colbourn P. (1993) Improvement in soil structure associated with white clover. *Grass and Forage Science* 48, 84-90.

Differentiation of cultivars within pasture grasses with regard to leaf tensile strength

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Abstract

The objective of this work was to analyse the differentiation of selected cultivars within five pasture grass species with regard to leaf tensile strength (LTS). The investigations were carried out in 2011-2012 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 2× and 15 4× cvs) and *Phleum pratense* (10 cvs) were analysed. LTS 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 subassemblies of the Höttinger Baldwin Messtechnik (HBM) Company. The fresh matter and dry matter weight, width and specific leaf area of leaf blades were also determined. The LTS of investigated species ranged from 4.06 N (*L. perenne* 2×) to 12.46 N (*D. glomerata*). The differentiation of cultivars within species was also high and statistically significant. Performance of precise tensile strength measurements of leaf blades could be a helpful plant breeding tool for the development of improved pasture grass cultivars and selection of appropriate components in seed mixtures, particularly in high output dairy farming systems.

Keywords: cocksfoot, meadow fescue, perennial ryegrass, tall fescue, timothy

Introduction

Tensile strength of grass leaves is equated with resistance to the pulling motion that cattle apply to the sward when grazing. It influences bite mass, biting rate, sward preference and energy used by grazing animals (MacAdam and Mayland, 2003) and consequently affects dry matter (DM) intake. Grass leaves are dominant in pasture swards and, therefore, investigations associated with leaf tensile strength (LTS) are crucial for the determination of the total energy expenditure to ingest fodder. Grass genotype variability in this regard makes possible the appropriate selection of breeding materials with the aim of improving pasture cultivars (Rogalski and Kozłowski, 1981). The objective of this work was to evaluate the differentiation of selected cultivars within pasture grasses with regard to their LTS.

Materials and methods

LTS of selected cultivars of pasture grasses was evaluated during the 2010 and 2011 growing seasons at the Brody Experimental Station of PULS (52° 26′ N, 16° 18′ E). Plant material originated from two cultivar testing experiments established in 2009 and 2010 on an Albic Luvisols soil (pH_{KCl}=5.8, N_t = 0.72%, P = 0.083, K = 0.125, Mg = 0.063 mg g^{-1}) in randomized complete block designs (r=3) on 10 m^2 (1×10 m) plots, in which *Dactylis glomerata* – Dg (10 cvs), *Festuca arundinacea* – Fa (10 cvs), *Festuca pratensis* – Fp (15 cvs), *Lolium perenne* – Lp (16 2× and 15 4× cvs) and *Phleum pratense* – Php (10 cvs) were examined. In each year the following rates of fertiliser were applied: 120 kg ha^{-1} N, 26.2 kg ha^{-1} P and 83 kg ha^{-1} K, while 4 regrowth periods were harvested. The annual mean temperature and total precipitation for 2010 and 2011 was 8.0 and 9.4 °C, and 788, 537 mm, respectively. From each regrowth and each plot, 30 youngest fully developed grass leaf blades were randomly collected from plants in the vegetative growth stage (about 20 cm height – sward target for rotational grazing systems). LTS measured as force in Newtons (N) was estimated on 12 cm-long middle section leaf blades on the day of sampling using a prototype testing stand for measuring tensile strength of biological material designed on the

basis of subassemblies (tensiometric sensors of appropriate nominal ranges, special measuring amplifiers with analogue/digital convertors) of the Höttinger Baldwin Messtechnik Company (Goliński, 2009). The fresh matter (FM) and dry matter (DM) weight, width and specific leaf area (SLA) of a leaf section of 12 cm in length taken for measuring tensile strength were also determined. The data were analysed by ANOVA. Tests of the main effects were performed by F-tests. Means were separated using the least significant difference and declared at $P<0.05$.

Results and discussion

Results on the tensile strength of grass leaves confirm that there were considerable differences between species (Table 1). When mean values for the entire period of investigations are compared, 2× cvs of Lp were characterised by the lowest LTS. The force required to break leaf blades of Fp was 20.4% higher than Lp2×. On the other hand, the force needed to break leaves of Php and 4× cvs of Lp were 69.2 and 44.8% higher, respectively, when compared with the Lp2×. The highest LTS, however, was observed in Fa and Dg, which, in comparison with that of Lp2× cvs, was found to be about 3 times higher. It is also worth emphasising the small coefficients of variation recorded for Fa (9.1%) in contrast to a much higher variation coefficient in the case of Dg (15.1%) and Lp2× (14.3%). It should also be added here that, following the performed statistical analysis, the existence of significant differences between cultivars was proved in all analysed grass species.

In addition, cultivars within individual species were also characterised by considerable variations in LTS. The greatest variability amounting to 106.5 and 88.1%, was recorded in the case of Dg and Fa cvs, respectively, whereas Php (74.5%), Fp (66.3%) and Lp4× (53.4%) cvs varied much less between one another in this regard. The lowest LTS variability (49.8%) was registered in the Lp2× cvs.

Pasture grasses differ with regard to their morphological structure and for this reason it is of interest to investigate LTS with reference to selected biological features (Zhang *et al.*, 2004). Rogalski and Kozłowski (1981) reported a correlation between LTS and length and width of leaves. In our study the leaf blade weight was also considered, because, for the same length of leaf blade section, this feature is positively correlated with leaf thickness and higher percentage of structural tissue. The negative correlation of ruminant preference with leaf strength may actually indicate a preference for grasses with a higher proportion of mesophyll tissue (MacAdam and Mayland, 2003). Data shown in Table 2 confirm that Fa and Dg cvs were characterised by the highest LTS when calculated per unit of leaf weight. With regard to 1 g of dry matter, the LTS of Fa was from 110.0 to 141.2% higher in comparison with Fp, Php and Lp cvs. Similar differences were observed in the case of Dg cvs. These results differ significantly from those reported by Rogalski and Kozłowski (1981) who found that LTS of Dg cvs was only 19.6% higher in comparison with Php cvs. The results in the present experiment used a different set of cultivars, and the considerable differences obtained here are attributed to these cultivar differences, as well as to measurement accuracy resulting from technical advances in measuring equipment. In the past, LTS

Table 1. Leaf tensile strength of cultivars within pasture grasses over the investigation period.

Species	Mean (N)	Coefficient of variation (%)	Cultivar means (N)		LSD$_{0.05}$ for cultivars based on plot error
			Minimum	Maximum	
Dactylis glomerata	12.46	15.1	8.64	17.84	2.333
Festuca arundinacea	11.25	9.1	8.07	15.18	1.618
Festuca pratensis	4.89	12.8	3.80	6.32	0.997
Lolium perenne 2×	4.06	14.3	3.27	4.90	0.750
Lolium perenne 4×	5.88	12.5	4.57	7.01	0.761
Phleum pratense	6.87	12.9	5.56	9.70	1.799

Table 2. Leaf tensile strength of cultivars within pasture grasses with regard to leaf parameters.[1]

Species	Weight[2]		Width[2]	SLA	Leaf tensile strength			
	FM (g)	DM (g)	(mm)	(cm^2)	N g^{-1} FM	N g^{-1} DM	N mm^{-1} of width	N cm^{-2} SLA
Dactylis glomerata	0.111	0.027	6.53	7.84	112.3	461.5	1.908	1.590
Festuca arundinacea	0.105	0.023	5.07	6.08	107.1	489.1	2.219	1.849
Festuca pratensis	0.064	0.021	5.01	6.01	76.4	232.9	0.976	0.813
Lolium perenne 2x	0.068	0.018	3.32	3.98	59.7	225.6	1.223	1.019
Lolium perenne 4x	0.076	0.029	4.15	4.98	77.4	202.8	1.417	1.181
Phleum pratense	0.117	0.030	6.69	8.03	58.7	229.0	1.027	0.856

[1] FM = fresh matter; DM = dry matter; SLA = specific leaf area = leaf area (width × 12 cm)/dry mass.
[2] Refers to the weight and width of a leaf blade section of 12 cm in length

investigations were conducted with the aid of simple devices operating on the principle of dynamometers (Evans, 1967; Martens and de Booysen, 1968; Rogalski and Kozłowski, 1981). With regard to the 1 mm leaf blade width, the lowest LTS was registered in the Fp and Php cultivars and the highest in Fa. For the rank order of LTS per SLA the following results were obtained: Fp, Php, Lp2×, Lp4×, Dg and Fa.

Conclusions

Leaf tensile strength of the investigated species ranged from 4.06 N (Lp2×) to 12.46 N (Dg). The greatest variability of this feature was recorded in the case of Dg and Fa cvs and the lowest in the Lp2× cvs. Intraspecific differences in leaf tensile strength in each of the analysed pasture grass species were statistically significant. Performance of precise tensile strength measurements of leaf blades could be a helpful tool in plant breeding for the development of improved pasture grass cultivars and selection of appropriate components in seed mixtures, particularly in high output dairy farming systems. The results obtained here help to provide a better understanding of the impact of plant functional traits on forage intake.

References

Evans P.S. (1967) Leaf strength studies of pastures grasses: I. Apparatus, techniques and some factors affecting leaf strength. *Journal of Agricultural Science* 69, 171-174.

Goliński P. (2009) Investigations on tensile strength of plant material using a modern measuring stand. *Grassland Science in Poland* 12, 47-59.

MacAdam J.W. and Mayland H.F. (2003) The relationship of leaf strength to cattle preference in tall fescue cultivars. *Agronomy Journal* 95, 414-419.

Martens P.O. and De V. Booysen P. (1968) A tensilmeter for the measurement of the tensile strength of grass leaf blades. *Proceedings of Grassland Society of Southern Africa* 3:51-56.

Rogalski M. and Kozłowski S. (1981) Work expenditure on leaves and stems tensile strength as characteristic of grasses varieties. *Cultivar Testing Bulletin* 9(13-14), 117-123.

Zhang J.M., Hongo A. and Akimoto M. (2004) Physical strength and its relation to leaf anatomical characteristics of nine forage grasses. *Australian Journal of Botany* 52(6), 799-804.

An alternative system for classifying earliness in maize varieties in Sweden

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Abstract

Classifying earliness, or adaptation to a certain climate, is very important in varieties of maize (*Zea mays* L.). The most common classification system is the Food and Agriculture Organization (FAO) maturity class. This study systematically explored the response of maize varieties with different earliness in the maize-growing area in Sweden and examined possible alternatives to the FAO system for classifying earliness in maize varieties in Sweden. Based on differences in maturation rate according to the FAO index, four maize varieties were selected from variety trials in Sweden 2009-2011. At four sites (56°02-59°71N), the development of these varieties was determined on four occasions, when the standard variety Avenir was at silking, milk, dough and dent. Aboveground dry matter (DM) yield, DM content and starch content were measured on the latter three occasions and at final harvest of Avenir. Ontario Corn Heat Units (CHU) were calculated for all sites. DM and starch content in the varieties Avenir and Jasmic showed a significant high linear correlation with CHU (R^2=0.79 and 0.75, respectively). It was concluded that an index based on the correlation between DM or starch concentration and CHU could be an alternative to the FAO maturity class system for ranking earliness in maize varieties in the Nordic countries.

Keywords: maize, DM-yield, starch, classification system

Introduction

Earliness, or adaptation to a certain climate, is very important in maize varieties. Earliness is most commonly categorised using the Food and Agriculture Organization (FAO) maturity class system (Zscheischler *et al.*, 1990). This gives a three-digit index, the first digit of which is the maturity class (from 1 to 9), the second the earliness and the third grain colour. A difference in index of 10 units is equal to a 1-2 day difference in earliness or a 1-2% difference in dry matter (DM) content. All varieties are compared against a group of standard varieties but characteristics can vary over time, so FAO scores are not absolute and therefore alternatives are needed, especially in marginal areas for maize growing. The aim of this study was to systematically explore the response of maize varieties with different FAO earliness scores in the maize-growing area in Sweden and suggest possible alternatives to the FAO maturity class system for classifying the earliness of maize varieties in Sweden.

Methods

Using data from variety trials in Sweden 2009-2011, four maize varieties were selected based on differences in maturation rate according to the FAO index (180, 190, 210 and 240 for Avenir, Isberi, Jasmic and Nerissa, respectively). The development of the varieties was determined on four occasions, i.e. when the standard variety Avenir was at the stages R1 (silking), R3 (milk), R4 (dough), R5 (dent) at final harvest according the MAO (Ministry of Agriculture Ontario) (2002) scale. Aboveground DM yield, DM content and starch content were measured when Avenir was at R3, R4, R5 and final harvest. This was done at four locations in 2009 and three locations in 2010 and 2011, i.e. 10 field trials in total (sites located between 56°02N and 59°71N). Only Avenir and Jasmic were represented at all 10 sites. On each sampling occasion, three plants were randomly harvested from the border rows and subdivided into cobs and leaves plus stems. Immediately after harvest, a sub-sample was dried (110°C, 10 hours) and DM

content (%) was determined. The starch content (%) in the whole aboveground biomass was measured by an enzymatic method (Bengtsson and Larsson, 1990). At the last (final) harvest, the biomass in the whole plot (1.5×12 m) was cut and weighed and the aboveground biomass (g m^{-2}), DM content and starch content were measured. Starch was determined using near-infrared spectrometry. Ontario Corn Heat Units (CHU) were calculated according to the equation:

$$CHU = (9/5(T_{min} − 4.4C)+(3.33(T_{max} − 10.0) − 0.084(T_{max} − 10.0)^2))/2$$

using daily weather data from the nearest weather station (MAO, 1997).

Results and discussion

There was a clear linear regression between maize variety development and CHU. Figure 1 shows examples for two sites in 2009. The slope of the regression line was higher at the northern site Örsundsbro (56°02N) than at the southern site Kristianstad (59°71N) and the initial recording started at a higher CHU level. This means that the maize required more CHU at the northern site to reach flowering (R1), but thereafter development was faster than at the southern site. Similarly, Mussadiq *et al.* (2012) demonstrated a site effect on the development of maize varieties with different FAO maturity classes, but the ranking in earliness between the varieties in their trials was the same as between the sites. Our linear regressions for 2009 (Figure 1) showed a significant fit, with R^2 values between 0.87 and 0.99. For Avenir to reach dough stage (R4) in 2009, it required 2,244 CHU in Örsundsbro, but 2,296 CHU in Kristianstad.

The DM and starch content in the varieties Avenir and Jasmic showed a significant high linear correlation with CHU (Figure 2). Nonlinear models were also tested, but they had lower R^2 values. The difference in slope between the varieties in terms of DM content (Figure 2a) was mainly an effect of outliers in Västerås in 2010. Jasmic had the highest correlation (R^2=0.79). To reach 30% DM, Avenir needed 2,230 CHU and Jasmic 2,408 CHU. For the starch content in Figure 2b, the slope and fit between the varieties were rather equal. To reach 300 g starch g^{-1} DM, Avenir needed 2,304 CHU and Jasmic 2,480 CHU. Because of the high correlations obtained, an earliness index based on the data in Figure 2 could be an alternative to the FAO maturity class system. However, the CHU equation, which was developed in eastern Canada, has not been fully validated for Nordic conditions. Although, as seen from the results, CHU seems to be a useful tool to relate changes in DM- and starch content in varieties with earliness.
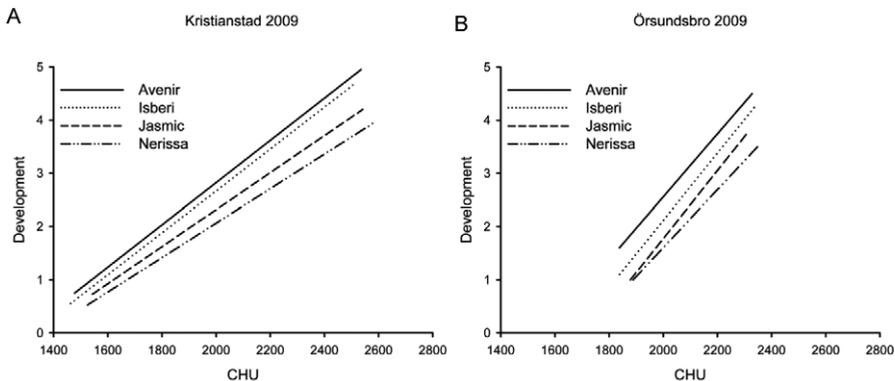
Figure 1. Linear regression between Corn Heat Units (CHU) and development stage R1-R5 (MAO, 2002) for four maize varieties grown in 2009 in (a) Kristianstad (*R^2*=0.99, n=10) and (b) Örsundsbro (*R^2*=0.87, n=9).
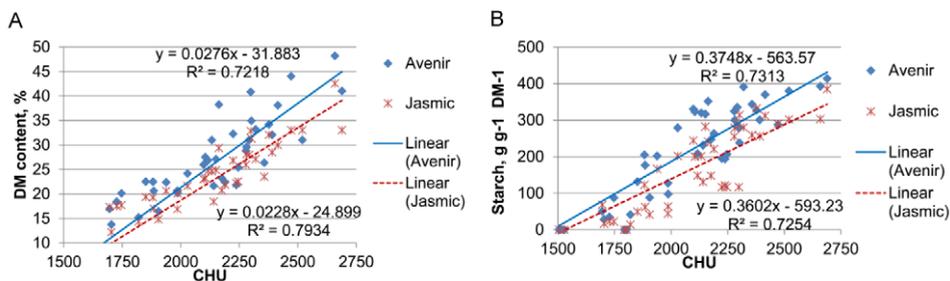
Figure 2. Linear regression between Corn Heat Units (CHU) and (a) dry matter (DM) content and (b) starch content, in all 10 trials carried out in Sweden.

Conclusions

An index based on the correlation between DM or starch content (%) and CHU could be an alternative to the FAO maturity class system when ranking earliness in maize varieties in the Nordic countries.

Acknowledgements

References

Bengtsson S. and Larsson K. (1990) Determination of starch in a flow-injection system with immobilized enzymes. *Swedish Journal of Agricultural Research* 20, 27-29.

MAO (1997) Corn Heat Units for corn and other warm season crops in Ontario. *Publication 93-119: Fact sheet*. Ministry of Agriculture Ontario, Canada.

MAO (2002) Corn development (chapter 1.4). In: *Agronomy Guide for Field Crops. Publication 811*. Ministry of Agriculture Ontario, Canada. Available at: http://tinyurl.com/o3l2yl6.

Mussadiq Z., Hetta M., Swensson C. and Gustavsson A.-M. (2012) Plant development, agronomic performance and nutritive value of forage maize depending on hybrid and marginal site conditions at high latitudes. *Acta Agriculturae Scandinavica Section B – Soil and Plant Science* 62(5), 420-430.

Zscheischler J., Estler M., Staudacher W., Gross F., Burgstaller G. and Rechmann T. (1990) *Handbuch Mais*. Umweltgerechter Anbau Wirtschaftliche Verwertung. DLGVerlag Frankfurt (Main), Germany, pp. 108-109.

PastureBase Ireland – a National Grassland database for Ireland

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Abstract

PastureBase Ireland (PBI) is a web-based grassland management tool incorporating a dual function of grassland decision support and a central database to collate grassland data. This database facilitates the collection and storage of a vast quantity of grassland data from grassland farmers in Ireland, providing infinite opportunities to increase the understanding around all aspects of grassland production and ultimately utilisation. The database spans across enterprises (dairy, beef and sheep), with grassland data recorded by all enterprise groups. Key questions that PBI can address include the quantification of seasonal and annual grass dry matter (DM) production, establishing the factors that affect production across different enterprises, including for example grassland management, region, and soil type. This database is designed to be functional at the paddock level. PBI has the potential to refocus grassland research in Ireland, while contributing to significant increases in productivity and profitability on grass-based farms. The objective of this paper is to briefly describe PBI and to demonstrate some of the outputs of the model.

Keywords: PastureBase Ireland, grassland management, yield, decision support

Introduction

Irish agriculture's ability to grow and utilise grazed grass in an efficient and economically profitable manner is widely considered to be a major competitive advantage over other food producing countries in terms of low-cost animal production (Hurtado-Uria *et al.*, 2013), while generating a sustainable, green and a highly reputable image which is marketed throughout the world. Dillon *et al.* (2005) found that for every 10% increase of grazed grass as a proportion of the overall diet of a dairy cow there was a reduction in the cost of milk production by 2.5 cents l[-1]. In a separate study by Shalloo (2009), it was shown that approximately 44% of the variation in net profit per hectare is associated with grass utilisation per hectare. Therefore, with the removal of EU milk quotas and for many farmers the freedom to expand the dairy business for the first time, their focus should centre on increasing grass growth and utilisation at farm level. As there is such a range in performance of grass growth within and between farms, the development and use of a decision support system with a centralised database has the potential to significantly increase profits at farm level through benchmarking between farms. This tool can directly affect the decision making process at farm level by providing information to the user in a usable format (grass wedge or rotation plan) while at the same time providing data that can be used to dramatically broaden the field of grassland research. The database can be used to investigate the traits contributing to dry matter (DM) yields and can identify areas where farmers, researchers and the industry can be continuously improving and innovating going forward. PastureBase Ireland (PBI) is a leader in its own class as it provides supply security of large quantities of verifiable data as well as other variables of interest, such as cultivar performance or soil fertility status. The objective of this study is to describe the functionality of a web based grassland decision support tool (PBI) by demonstrating the grass growth differences between years 2013 and 2014.

Materials and methods

PBI is a web-based system and functions by the farmer interacting with the model. The data are enriched with background paddock information and grass growth for each paddock is then linked to the external

factors. The farmer uses the web-based package to assist in the decision making process around grazing rotations, silage making, supplementation, etc. The main aspects of PBI as a decision support tool are the grass wedge, grass budget and the Spring and Autumn rotation planners (Teagasc, 2009). Through this inputted information cumulative grass growth rates are calculated for each paddock. The PBI model functions through a large series of calculations using the grass data entered by the farmer. The primary calculations that this paper concentrates on are both daily and cumulative growth rates. A daily farm growth rate is calculated as the weighted average difference in pasture herbage estimates on all paddocks with a paddock status of 'Grass' and a previous paddock status of 'Grass' with a herbage estimate greater than or equal to the previous recording between two consecutive measurement dates divided by the number of days between estimates. Cumulative growth is calculated by a further series of calculations which must be carried out to account for when paddocks are not included in daily growth rate calculations (e.g. being grazed, cut for silage, and grazed since last measurement). This information is then used for producing the paddock summary report and overall weighted farm growth for the year. In this study average grass growth for 2013 and 2014 is compared on commercial farms using PBI since 2013. The data from each farm were statistically analysed using SAS with the mean DM yield of 47 commercial farms being used for the comparison. PBI was used weekly on these farms over the two-year period.

Results and discussion

Figure 1 shows the average grass growth from the PBI system in 2013 and 2014 of the farms analysed. There was a substantial increase in DM yield in 2014 over 2013. The mean DM yield on the 47 commercial farms increased from 12,389 kg DM ha^{-1} to 14,315 kg DM ha^{-1} in the two years. The more favourable climatic conditions of 2014 had a large effect on this result as 2014 was more conducive to grass growth due to a warmer spring combined with a more even spread of rainfall throughout the year. Grazed grass yields were 10,576 kg DM ha^{-1} and 11,703 kg DM ha^{-1} in 2013 and 2014, respectively. The corresponding figures for grass silage were 1,813 kg DM ha^{-1} and 2,612 kg DM ha^{-1} in 2013 and 2014, respectively. Annual growth comprises three seasonal growth periods: spring, main season and autumn (McEvoy *et al.*, 2011). From the data studied there appears to be a trend associated with spring DM yield and annual DM yield with the highest performing farms in spring having the highest levels of annual grass growth.

Increasing grass growth on farm will allow for profitable dairy expansion on farm with less reliance on bought-in feed, thus creating a system that is more resilient to the ever changing dynamics of input and output prices. If the additional grass grown in 2014 was utilised at farm level it would result in increased
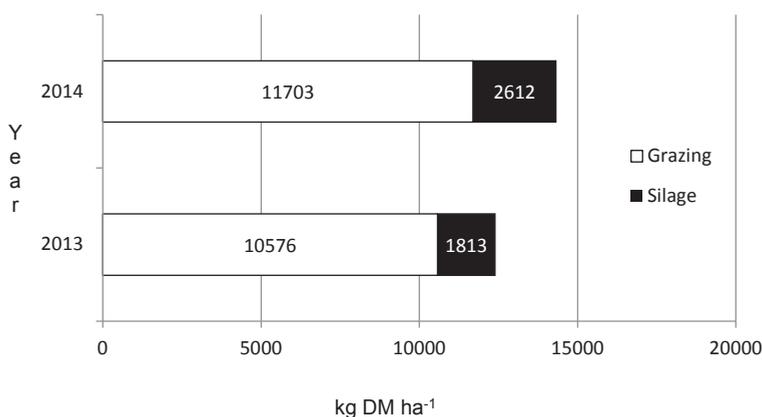
Figure.1. PastureBase Ireland dry matter (DM) yield (kg DM ha^{-1}) data for 2013 and 2014.

animal performance from grazed grass, lower production costs and increased profits, with Moorepark research showing there is an increase of € 161 in additional profit for every extra Mg of grass utilised (Shalloo, 2009). PBI will assist in realising this potential as it enables farmers to evaluate the performance of paddocks more easily through its paddock summary reports and decision support mechanisms.

Conclusions

This study has demonstrated the potential of the newly developed PBI system. For farmers the initial direct impact of PBI will come from the advancement of the decision making process. This allows farmers to more easily evaluate paddocks and cultivars on farm, which will encourage better grassland management practices and therefore increase DM yields. However, significant gains will be achieved by the research conducted from the PBI database through a new research programme which will be facilitated by the new research database.

References

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005) Optimising financial return from grazing in temperate pastures. In: Murphy J.J. (ed.) *Utilisation of grazed grass in temperate animal systems*. Proceedings of a satellite workshop of the XXth International Grassland Congress, pp. 131-147.

Hurtado-Uria C., Hennessy D., Shalloo L., Schulte R.P.O., Delaby L. and O'Connor D. (2013) Evaluation of three grass growth models to predict grass growth in Ireland. *Journal of Agricultural Science* 151, 91-104.

McEvoy M., O'Donovan M. and Shalloo L. (2011) Development and application of an economic ranking index for perennial ryegrass cultivars. *Journal of Dairy Science* 94, 1627-1639.

Shalloo L. (2009) Pushing the barriers of milk production costs/outputs. In: *Proceedings National Dairy Conference*, 18-19 November, Mulingar and Kilarney, Teagasc, Ireland, pp. 19-38.

Teagasc (2009). *Grazing notebook*. Available at: http://tinyurl.com/m9dzaw6.

Effect of cutting frequency of four red clover cultivars on forage yield and persistence

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Abstract

Red clover (*Trifolium pratense* L) is the most important perennial legume cultivated in Central and Northern Europe. Its lack of persistence is the main limiting factor which hampers its wider use in permanent grassland. Once the plants in the 2nd or 3rd harvest year disappear, the remaining grass sward needs more nitrogen fertilizing, over-seeding or renovation. The aim of this paper was to evaluate the effect of four red clover cultivars and two cutting frequencies on dry matter (DM) yield and clover persistence in mixture with grasses. The highest DM forage yield in the 3rd harvest year and persistence index was achieved by the cultivars Astur and Amos for 3- and 4-cut management, respectively (15.7 vs 16.6 Mg ha^{-1} and 0.82 vs 0.95, respectively). There was a significant interaction between cultivar and cutting frequency in the 3rd harvest year, when only cultivar Amos increased yield and persistence index under 4-cut management. The cultivar Amos, in comparison with other cultivars, demonstrated the best results under more frequent cutting management and should be recommended, in preference, for intensively harvested permanent grasslands and/or leys.

Keywords: *Trifolium pratense*, persistence index, forage yield, management

Introduction

Red clover has more tolerance than lucerne to shallow, acid and wet soils and has better complementarity to grasses. That is the reason this species is increasingly important for sustainable grassland systems, producing high dry matter yields of high quality forage without need for nitrogen fertilization. The main limiting factor that hampers its wider use in permanent grassland is its lack of persistence. Traditionally, red clover-based stands are harvested three times per year. As climate change leads to extension of the growing season and animal performance increases, four and sometimes five cuts per year are more common in some parts of Europe. Some authors (e.g. Sheldrick *et al.*, 1986) report that more frequent harvest leads to weakening of plants and their yields and persistence decline. The aim of this experiment was to compare yields and persistence index of red clover cultivars cut three and four times per year.

Materials and methods

The trial was established at the Forage Research Station in Vatín (49°15'5"N, 15° 58'15"E), Czech Republic. The site is situated at 540 m.a.s.l., mean annual precipitation and mean annual temperature is 617.5 mm and 6.9 °C, respectively. Soil is slightly acid (pH in CaCl$_2$ 5.48) sandy loam cambisol developed on orthogneiss. Plant-available P was good, K was high and Mg was good (Mehlich III method). C$_{ox}$ and N$_t$ in 0-20 cm of topsoil were 19 and 1.2 g kg^{-1} of dry soil, respectively.

Four varieties of red clover (diploids Start and Lucrum, tetraploids Astur and Amos), which had shown high persistence in a previous experiment (Hejduk and Knot, 2010), were sown on arable land by drilling in parallel rows spaced at 125 mm. The red clover varieties (14 kg seed ha^{-1}) were mixed with meadow fescue (4 kg ha^{-1}) and timothy (6 kg ha^{-1}). The trial was established on 20 June 2011 in a randomized block design with 3 replications for each cultivar and cutting frequency. The size of experimental plot was 1.25×8 m (10 m^2). During three production years the stands were harvested three or four times. The first harvests of the four-cuts treatment were performed at bud stage, whereas in the three-cut treatment it was

harvested when 50% of flower heads opened. Dry matter yields were determined after drying the samples at 55 °C. Persistence index was calculated according to Halling *et al.* (2004) as a ratio of DM forage yields in 3rd and 1st harvest years. The experiment was fertilized with 40 and 30 kg P ha-1 (Hyperkorn) applied only before the establishment of the trial and in the spring of the first production year. No other fertilizers were used, so the yield of associated grasses was dependent on rhizobial fixation of nitrogen on the roots of red clover. Statistical analyses were performed using repeated measures ANOVA (for evaluation of the whole period) or two-way Anova (for evaluation of the last harvest year) with multiple post-hoc comparisons according to Tukey (*P*-value <0.05). Software Statistica 12 (StatSoft) was used for the analysis.

Results and discussion

Ageing of stands significantly reduced yields and number of plants. There were no significant differences among cultivars and cutting frequencies in yield and plant density when all three harvest years were calculated (Figure 1). Significant interactions of cultivar × cutting frequency and year cultivar × cutting frequency were associated with the cultivar Amos. This clover produced significantly the highest yield in the 3rd harvest year under the 4-cuts treatment. Under the 3-cuts treatment the yield and persistence index were the lowest. In this experiment, the DM yield of the red clover cultivars ranged from 15.5 to 20.6 Mg ha-1 in year 1, from 11.3 to 16.9 Mg ha-1 in year 2 and from 8.9 Mg ha-1 to 17.8 Mg ha-1 in year 3.

Cultivars with the highest values of persistence index should be those with a higher persistence and better disease resistance (Halling *et al.*, 2004). Marshall *et al.* (2012) found almost identical persistence index under 3-cuts management in Wales (quite low: 0.60) for cultivar Amos as to that found in this trial. In the country of origin (Czech Republic), cultivar Amos has been suffering greatly from *Fusarium* attack in recent years. For this reason it is no longer considered as a persistent cultivar. In central Europe, dieback of red clover plants can be attributed to fungi of the genera *Fusarium*, viruses and the mammal pest *Microtus arvalis*.

Surprisingly, in the 4-cuts management, cultivar Amos demonstrated much better results than under 3-cuts management in terms of yield and persistence index. This could be attributed to a higher susceptibility to lodging or to the microclimate in the stand under three cut management.

The development of DM yields and density of plants in stands over 3 harvest years are described in Table 1. There is a consistent decrease of yield and number of plants for both harvest managements over the period of ageing of the stands.
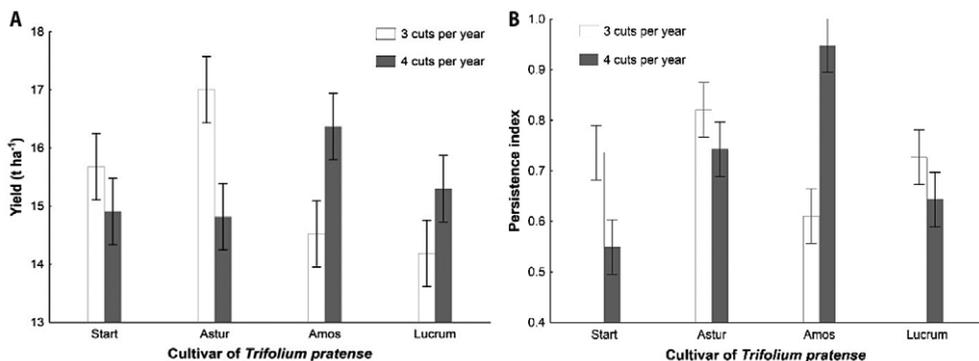
Figure 1. Effect of cultivar and cutting frequency on (A) yield and (B) persistence index. The abscisae at bars show standard deviations.

Table 1. Development of yields (Mg ha^{-1} DM) and stand density (plants m^{-2}) within three harvest years (data derived from all four cultivars).[1]

	Dry matter yield		Number of plants on 1 m^2	
	3 cuts	4 cuts	3 cuts	4 cuts
2012	18.0 a	18.3 a	158 a	149 a
2013	15.1 b	14.6 b	124 b	116 b
2014	13.0 c	13.1 c	67 c	73 c
Average	15.3	15.3	116	113

[1]Values with a different letter in a row are significantly different ($P<0.05$).

Conclusions

Increased cutting frequency of red clover stands is not directly linked to a decrease of yield and stand persistence. The cultivar Amos produced higher DM yield at higher cutting frequency in the 3rd harvest year and this variety can be used in preference for more intensive systems. There is no known explanation or specific trait connected with the interaction of this cultivar but 4-cut plots of cultivar Amos are visually greener and more vigorous than the others, even in autumn and early spring periods. Higher cutting frequency is linked with higher forage quality and lower risk of lodging. If forage DM yield is not reduced, the stand also has higher yield of protein, metabolisable energy and other nutrients per unit area.

Acknowledgements

References

Halling M.A., Topp C.F.E. and Doyle C.J. (2004) Aspects of the productivity of forage legumes in Northern Europe. *Grass and Forage Science* 59, 331-344.

Hejduk S. and Knot P. (2010) Effect of provenance and ploidity of red clover varieties on productivity, persistence and growth pattern in mixture with grasses. *Plant, Soil and Environment* 56(3), 111-119.

Marshall A.H., Lowe M. and Vale J. (2012) Improved persistence of red clover (*Trifolium pratense* L.) varieties in mixed swards. *Grassland Science in Europe* 17, 73-75.

Sheldrick R.D., Lavender R.H. and Tewson V.J. (1986) The effects of frequency of defoliation, date of first cut and heading date of a perennial ryegrass companion on the yield, quality and persistence of diploid and tetraploid broad red clover. *Grass and Forage Science* 41, 137-149.

Calibration of five rising plate meters in the Netherlands

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Abstract

To obtain good grassland management, especially under grazing, requires accurate information about grass growth. In the Netherlands several methods have been introduced to estimate herbage mass. At present the rising plate meter is the most accessible tool for Dutch farmers; it is cheap and easy to use. However, the equations for translation of grass height, as measured with the rising plate meters, into measures of herbage mass, have been developed in the countries of origin of the meters. To check the equations for the situation in the Netherlands in 2014 five rising plate meters were calibrated. Grass height was estimated with the five rising plate meters on small plots on which the grass was then cut and dried to measure the dry matter (DM) yield. For each rising plate meter a calibration curve was estimated. DM yield was estimated from ground level and from 5 cm stubble. Information about the herbage mass in the stubble was also estimated by cutting the stubble to ground level. The results show that for three rising plate meters the same equation can be used. Two rising plate meters need a different equation. The rising plate meters are relatively reliable for a measured grass sward of 20-25 cm in height from ground level. This means that a good estimate of DM yield can be made for up to 2,500 kg DM ha^{-1} above 5-cm stubble height.

Keywords: grassland management, measurement, rising plate meter, grass growth

Introduction

For good grassland management actual information on herbage mass production and farm grass cover is necessary. The rising plate meter is a simple tool to measure growth and DM yield. The quality and applicability of these meters has been proven (Earl and McGowen, 1979; Michell and Large, 1983). The use of the plate meter has retreated into the background in the Netherlands. Nowadays grazing is an issue and farmers therefore have a need for support tools to manage their grazing. By measuring all the paddocks weekly (by walking the farm), the farmer will get actual information about growth and DM yields. To obtain the right information a good calibration of the rising plate meter is needed. In the Netherlands we use DM yield measured from stubble height. The rising plate meter, however, measures from ground level. New rising plate meters have been developed during recent years, so new calibrations for Dutch circumstances probably need to be made. The questions are: which calibration is suitable for which meter? are there differences between meters ? and how to deal with the DM yield in the stubble? In 2014 an experiment was carried out in the Netherlands to get answers to these questions.

Materials and methods

In 2014 five rising plate meters were tested within an existing cutting experiment (100% *Lolium perenne*). The tested rising plate meters were the Farmworks F400 (Farmworks Precision Farming Systems Ltd, New Zealand), EC10 and JenQuip (NZ Agriworks Ltd, New Zealand, diameter 36 cm, average pressure 0.47 g cm^{-2}), Grasshopper (developmental stage) and the Styrofoam plate meter (Eijkelkamp Agrisearch Equipment, the Netherlands, diameter 48.5 cm, pressure 0.2 g/cm^{-2}). Measurements took place at different stages of growth (generative stage, vegetative stage, different percentages of heading and differences in sod density) and for different cuts. Table 1 gives an overview of the data, location, cut number and number of plots and herbage mass in the stubble.

Table 1 Overview of experiments

Date	Location[1]	Cut no.	Stubble height (cm)	DM stubble (kg ha^{-1})	Total obs.
29-4-2014	Dwingeloo	1			100
20-5-2014	Venray	1	6.8	982	100
10-6-2014	Dwingeloo	2	6.4	688	100
26-6-2014	Venray	2	6.6	1,223	100
17-7-2014	Lelystad	3	6.8	1,036	125
25-8-2014	Dwingeloo	4	7.2	925	125
Average			6.8	972	650

[1] Dwingeloo and Venray= sandy soil; Lelystad = clay soil.

The area of each experimental plot was 10×1.5 m and on every plot five measurements were carried out. The percentage of ears and sod density were estimated. Also, the herbage mass conditions (standing lodging, heading) were estimated. The results were statistically analysed with linear regression (y = ax + bx^2) to estimate a calibration line for each meter relating meter reading (height × in cm) and herbage mass above stubble (6.8 cm, y). The effects of heading and sward density and differences in regression lines were also tested. The measured height as well as height^2 were used as fixed parameters.

Results and discussion

Sod density varied between 65% (one object) and 98%. In most objects density was over 90%. The percentage of ears was between 0% and 25% and were present only on 10 June and 17 July. DM yields measured by cutting ranged from 1,232 kg DM ha^{-1} to 3,864 kg DM ha^{-1}. There was no significant effect of sod density or percentage of ears (generative or generative stage) on the relation between sward height and DM yield. Therefore in a second step, all the data were pooled to estimate a regression that could be used over the whole season. A significant difference ($P<0.001$) in calibration lines was found between the Farmworks, EC10 and JenQuip on the one hand, and the Grasshopper and Styrofoam plate on the other hand. The statistical results are shown in Table 2.

Sward height as well as sward height^2 ($P<0.001$) were significant parameters for estimating DM yield. The overall declared variance was 70%. A higher yield gave a lower amount of DM per cm (so that height^2 is negative), but the Grasshopper and Styrofoam plate had higher yields at higher swards (height^2 is positive). Earl and McGowan (1979) and Michell and Large (1983) found a much higher declared variance (92-97%) and they used an intercept. In their experiment height^2 did not improve the calibration line. Measuring from ground level does not require an intercept, so in this calibration no intercept is used. Because of the great difference in the DM yield in the stubble (Table 1) and the fact that DM yield in the

Table 2. Regressions (y = ax + bx^2) relating herbage mass y (kg DM ha^{-1}) and measured height x (cm).[1,2]

Plate meter	a (height factor)	SE	b (height^2 factor)	SE	RSD	R^2	N obs.
EC 10	181.61 [a]	10.1	-1.57 [a]	0.516	483	64.6	150
Farmworks	177.42 [a]	9.15	-1.34 [a]	0.466	435	71.2	150
Grasshopper	64.4 [b]	17.9	4.37 [b]	1.10	290	77.3	50
JenQuip	174.65 [a]	9.18	-1.29 [a]	0.464	445	69.9	150
Styrofoam	95.27 [c]	8.57	1.24 [c]	0.372	399	75.8	150

[1] SE = standard deviation; RSD = relative standard deviation.

[2] Different letters means significant ($P<0.001$) differences.

stubble was not measured on every plot (by destructive methods) means that the calibration presented in this article is the line based on DM yields from a stubble height of 6.8 cm.

The highest sward height measured was 27 cm, probably due to the weight of the plate and the weight of the leaves (herbage on some plots was lodged). The measured DM yield showed much variation in the range from 18 to 27 cm. Therefore, a rising plate meter can be used for reasonable measurements up to 2,500 kg DM ha^{-1}. The total declared variance was only 70%. The difference in sod density and amount of DM in the stubble probably caused this relatively low figure. As there was too little difference in sod density and percentages of ears (vegetative or generative stage) at one moment of measurement combined with a relatively high yield (>2,700 kg DM ha^{-1}) no effects of these parameters were estimated. Including those parameters would probably lead to a more accurate estimation. Michell and Large (1983) made a distinction in two of three periods within a season. Nakagami and Itano (2013) also estimated seasonal effects. Further research is needed to get more information about the effects of sod density, DM yield in the stubble and percentage of ears. Probably because the Grasshopper and Styrofoam plate meters have different plate pressures, these meters need a different calibration.

Conclusions

Rising plate meters can be used to measure reliable DM yields in a range up to 2,500 kg DM ha^{-1} or about 20-25 cm of sward height. Not every meter has the same calibration. Additional research is needed to get more information about effects of different sward density and effect of ears and DM yield in the stubble in order to give substantiated equations for estimating DM yield of grasslands.

References

Earle D.F. and McGowan A.A. (1979) Evaluation and calibration of an automated rising plate meter for estimating dry matter yield of pasture. *Australian Journal of Experimental Agriculture and Animal Husbandry* 19, 337-343.

Michell P. and Large R.V. (1983) The estimation of herbage mass of perennial ryegrass swards: a comparative evaluation of a rising-plate meter and a single-probe capacitance calibrated at and above ground level. *Grass and Forage Science* 38, 295-299.

Nakagami K. and Itano S. (2013) Improving pooled calibration of a rising-plate meter for estimating herbage mass over a season in cool-season grass pasture. *Grass and Forage Science* 69, 717-723.

Grazing and difficult circumstances: economic benefits depend on milk price and grazing efficiency

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Abstract

Dairy herds in the Netherlands will increase in size in the coming years, due to the imminent abolition of milk quotas. Also more farms will make use of automatic milking systems (AMS). Both trends mean less opportunity for grazing. As the grazing area itself will not increase it has become a priority to explore new ways of grazing. At Dairy Campus – a Dutch experimental farm – two distinct grazing systems were tested: strip grazing with AMS and one-day rotational grazing with a fixed paddock area and a standard growing period of 23 days. The grazing time was restricted to daytime. At night the cows were fed silage and concentrates. In the one-day rotational grazing, the grass allowance depended on what was grown in 23 days on the fixed paddock. The silage feeding was adapted to the allowed amount of grass. The total allowance of grass and roughage for both systems was 16 kg dry matter cow^{-1} d^{-1} supplemented with concentrates. The strip grazing system had a fixed allowance of 8 kg DM grass cow^{-1} d^{-1} supplemented with 8 kg TMR cow^{-1} d^{-1}. Model calculations showed a relation between grazing efficiency, milk price and income. Grazing will be more profitable than an indoor system at lower milk prices. At higher milk prices a high grazing efficiency is necessary to make a grazing system profitable.

Keywords: grazing, grazing efficiency, large herds, AMS, income, new grazing system

Introduction

Grazing provides lots of economic opportunities, including less contract work for making silage and for applying manure. Furthermore, in the Netherlands farmers can obtain a premium for grazing. Farmers, however, often consider grazing and grassland management as difficult, time consuming and less efficient. Due to the abolition of the milk quota, herd size is expected to increase as stocking density on the grazing platform. Furthermore, the number of farms with an automatic milking system (AMS) is expected to increase. Those aspects are causes for a decline in grazing. To address these challenges, a novel simple grazing system for farms with high stocking rates has been developed on the research farm 'Dairy Campus' in Leeuwarden, the Netherlands. The aim of this study is to show the effect of grazing efficiency on the economic results at different milk prices. Grazing efficiency is described as the percentage of produced grass which is actually eaten by the cows.

Materials and methods

In 2014 two grazing experiments were set up at the research farm 'Dairy Campus' in the Netherlands. The first one was a strip grazing system with 60 cows on 18 ha of grassland. This experiment was part of the European AutograssMilk project. The cows had free access to the paddock during daytime (about 12 hours), where every 6 hours a new strip was offered. The total grass allowance was 8-9 kg DM cow^{-1} d^{-1}. At 17:00 h the cows were fed 8 kg DM TMR (total mixed ration) silage (70% maize and 30% grass silage) indoors. The second experiment tested a new grazing system at high stocking rates (6 cows ha^{-1}). A 45-cow herd grazed on 7.5 ha grassland, which was divided into 24 equal paddocks. A fresh paddock was offered daily. In both experiments, grass production, feed intake and milk production were measured. The results of the grazing systems were compared with a fully housed herd with summer feeding, which was also present at the Dairy Campus experimental facility. The data from both grazing experiments and the 'indoor herd' were used in model calculations using DairyWise (Schils *et al.*, 2007) to compare

three systems. The data collected from the grazing experiments were used as inputs to parameterize the model and to extrapolate the economic results to farm level year around. The model farm was scaled up to 150 cows on 51 ha grassland and 12.8 ha maize all with an AMS. On the first model farm, the grazing platform was 25 ha for the 24 paddock system (and 26 ha grassland for cutting only) and on the second model farm 45 ha for the strip grazing system (plus 6 ha for only mowing), to compare economic effects of grazing on a small (restricted) grazing platform with grazing on a larger platform.

Results and discussion

The measured grass intake in the 24-paddock system was, on average, 4.9 kg DM cow[-1] day^{-1}, and the strip grazing system reached 5.6 kg DM. The grazing efficiency on the 24-paddock system was with 50-60% lower than on the strip system (70-80%). The milk yield was 8,000 kg milk cow[-1] year^{-1} for the 24-paddock system and 8,050 kg milk cow[-1] year^{-1} for the strip-grazing system. The year -ound indoor system had a milk yield of 8,500 kg cow[-1] year^{-1}. The net grass production was 8,870 kg DM ha^{-1} for the paddock system, 10,800 for the strip system and 10,900 for the year round indoor system. These collected data were used as input for DairyWise to calculate the economic results, based on standard prices (Vermeij, 2013) and a milk price of € 0.35. Results are presented in Table 1.

Due to the low grassland production and low grazing efficiency, especially in the 24-paddock system, a lot of roughage had to be purchased. On the other hand the costs for contract work decreased a lot. This is in accordance with former research (Van den Pol *et al.*, 2013; Reijs *et al.*, 2013). There are two main factors that strongly influence the economic balance: the net grass production (grassland production × efficiency) and the milk price. Table 2 shows a sensitivity analysis for these factors based on DairyWise calculations; the income is compared to the income at year-round summer feeding. The sensitivity for milk price is presented horizontally and varies from 25 to 40 cents kg^{-1} milk. Grazing efficiency is presented vertically and varies from 50 to 90%. Experts assume that a 24-paddock system will not reach an efficiency above 70%, so no figures are given for higher efficiencies. Strip-grazing systems can reach a higher efficiency. Changes of 10% in grazing efficiency or 5 cents in milk price have a strong effect on income. The results of the 2014 experimental design (Table 1) can be found in Table 2 (paddock

Table 1. Economic effects (€ farm[-1]) of the grazing experiments (high stocking rate on 24 paddocks and strip grazing combined, compared to year round indoor (at a milk price of € 0.35 l^{-1}), all with automatic milking systems.

	24 paddock system	Strip graze system
Milk revenues (A), incl. grazing premium	-14,250	-11,550
Direct costs (B)	+12,927	-3,459
concentrates	-4,136	-4,136
purchased roughage	+18,039	+4,975
other cattle costs	-1,275	-1,193
fertiliser costs	+299	-3,105
Indirect costs (C)	-21,454	-6,544
contract work	-19,043	-10,076
grassland equipment (fences etc)	+1,825	+3,285
fuel	-634	-518
installations (incl. selection box)	+0	+1,573
energy	-113	-101
manure disposal	-3,289	-539
diverse small costs	-201	-167
Total income (A – B – C)	-5,723	-1,547

Table 2. Effect of grazing efficiency and milk price on income for two grazing systems (calculated with DairyWise and compared to year round indoor summer feeding), € farm^{-1}.

Grazing efficiency	Milk proce – high stocking rate on 24 paddock system				Milk proce – strip grazing with AMS[1]			
	40 ct	35 ct	30 ct	25 ct	40 ct	35 ct	30 ct	25 ct
50%	-9,500	-5,723	-2,000	+1,800	X	X	X	X
60%	-3,800	-100	+3,700	+7,400	X	X	X	X
70%	+1,800	+5,600	+9,300	+13,100	-4,900	-1,547	+1,800	+5,200
80%	X	X	X	X	-1000	+2,400	+5,700	+9,100
90%	X	X	X	X	+2,900	+6,300	+9,700	+13,000

[1] AMS = automatic milking system.

system: € 5,723 less income at 50% grazing efficiency and strip grazing: €1,547 less income at 70% grazing efficiency, and a € 0.35 l^{-1} milk price).

Table 2 shows that the grazing systems of 2014 would have been profitable compared to summer feeding at lower milk prices. The 24 paddock system for example would have been profitable at a 50% grazing efficiency and a milk price of € 0.25 l^{-1}. Higher grazing efficiencies also lead to an increase in income compared to summer feeding.

Conclusions

Grazing will be more profitable than a year-round indoor system at low milk prices. At higher milk prices, a high grazing efficiency is important to make a grazing system more profitable.

Acknowledgement

References

Reijs J.W., Daatselaar C.H.G., Helming J.F.M., Jager J. and Beldman, A.C.G. (2013) *Grazing dairy cows in North-West Europe; Economic farm performance and future developments with emphasis on the Dutch situation,* Report 2013-001, LEI Wageningen UR, The Hague, the Netherlands, 124 pp.

Schils R.L.M., De Haan M.H.A., Hemmer J.G.A., Van den Pol-van Dasselaar A., De Boer J.A., Everds A.G., Holshof G., Van Middelkoop J.C. and Zom R.L.G. (2007) DairyWise, a whole-farm dairy model. *Journal of Dairy Science* 90, 5334-5346.

Van den Pol, A., Philipsen A.P. and De Haan M.H.A. (2013) *Economisch weiden* [Economics of grazing], Report 679, Wageningen UR Livestock Research, Lelystad, the Netherlands, 126 pp.

Vermeij I. (2013) *KWIN Kwantitatieve Informatie Veehouderij 2013-2014*, Wageningen UR Livestock Research, Lelystad, the Netherlands, 407 pp.

Different harvesting strategies and cultivar mixtures for grass silage production in Finland

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Abstract

Scandinavian milk and beef production is based on high-quality grass silage. Harvesting time of grass, especially in the first cut, is the major factor that determines the optimization of dry matter yield and forage digestibility, and the subsequent improved feeding efficiency and productivity of the animals. The aim of this study was to explore how the number of harvests, three different cultivar mixtures and timing of the last harvest affect the amount and nutritive value of total yield and overwintering of the sward. The experiment was conducted at Maaninka and Sotkamo, Finland, during the 2013-2014 growing seasons. Experimental design of the study was split-split-plot with four replicates. Plots were sown with a mixture of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.). Three different mixtures of varieties of these species were used. The three-cut harvesting strategy produced higher dry matter and energy yield and higher digestibility than the two-cut harvesting strategy. Delaying the second cut increased the total dry matter yield and decreased D-value more than delaying the third cut. Differences between cultivar mixtures were observed but the interaction with number of harvests was minor.

Keywords: cultivar mixture, dry matter yield, D-value, grass, harvesting strategy

Introduction

Harvesting time of grass is the major factor for optimization of dry matter yield and forage digestibility, especially in the first cut. The daily change of digestibility (Kuoppala, 2010) and the accumulation of yield (Virkajärvi *et al.*, 2012) is faster in the first cut than in the regrowth. The three-cut strategy, which provides better utilization of the entire growing season than the two-cut strategy, is becoming more common in northern Finland, but there are few data available of growth rate and changes in nutritive value for this strategy. Typical forage grass leys are based on mixtures of timothy and meadow fescue. There are two different types of timothy in the Nordic regions: early varieties with good regrowth ability and lower digestibility, and late ones with moderate regrowth and high digestibility. Differences of digestibility with Nordic meadow fescue varieties are minor. Good winter hardiness is essential for both species. The aim of this study was to explore how the number of harvests, in combination with different cultivar mixtures and timing of the last harvest, affect the amount and nutritive value of total yield and the overwintering of the sward.

Materials and methods

The study was conducted as a field experiment at Maaninka (63°08' N, 27°19' E; loam soil type) and Sotkamo (64°11' N, 28°33' E; sandy clay loam), Finland, during the growing seasons of 2013-2014. Experimental design of the study was split-split-plot with four replicates. Plots were sown with a mixture of timothy (*Phleum pratense* L., 14 kg ha^{-1}) and meadow fescue (*Festuca pratensis* Huds., 6 kg ha^{-1}). The main plot was two (2H) or three (3H) harvests per growing season, the subplot was the cultivar mixture, and the sub-subplot was the early (EC) or the late (LC) last harvest. Three different cultivar mixtures were used: Tuure-Ilmari (T+I), Rubinia-Valtteri (R+V) and Grindstad-Inkeri (G+I). T+I represented the mixture of moderate development rate and high digestibility, which was hypothesized to be well suited for 2H. R+V and G+I represented the mixtures of good ability of regrowth and therefore more suitable for 3H. The EC of 2H plots were done at 5 weeks and LC of 2H plots at 7 weeks after the first

cut. LC of 3H plot was done at the end of growing season and the EC, on average, at 24 d before. 2H plots were fertilized with 100 kg N ha^{-1} for both cuts and 3H plots were fertilized with 90 kg N ha^{-1} for 1st and 2nd cuts and 50 kg N ha^{-1} for third cuts.

Dry matter yield (DM yield, kg DM ha^{-1}) and D-value (g kg^{-1} DM; near-infrared spectrometry, Valio Ltd.) were determined for each cut. Weighted means of D-value for annual DM yields were calculated. Energy yield (ME yield, GJ ha^{-1}) was calculated as DM yield × 0.016 × D-value × 1000^{-1}.

Statistical analyses were performed using ANOVA (Mixed procedure of the SAS 9.3). The LC plots only were used for these analyses.

Results and discussion

Both experimental years were favourable for the growth of the third cut. The three-cut strategy produced approximately 1,500 kg DM ha^{-1} higher DM yield and 23 g kg^{-1} DM higher D-value than the two-cut strategy (Table 1) with 30 kg ha^{-1} year^{-1} higher N fertilization. The success of the three-cut strategy was better than had been obtained previously (Hyrkäs *et al.*, 2012), and is explained by the favourable weather conditions in this study. The division of DM yield between cuts was approximately 50:50 in 2H and 35:35:30 in 3H.

G+I produced higher DM yield and lower D-value than T+I. The success of R+V varied between experimental sites (Table 1). Differences between ME yields were similar than between DM yields. Unexpectedly, only minor or no interaction between number of harvests and cultivar mixtures were found in this study. At Sotkamo there was tendency that the yield of T+I was lower than R+V and G+I in 3H but quite similar in 2H (*P*=0.057).

Table 1. Dry matter (DM) yields and digestibility values (D-value) in the total yield of growing season in the both experimental sites.[1]

Harvests (H)	Cultivar mixture (M)	Year (Y)	Maaninka			Sotkamo		
			DM yield kg DM ha^{-1}	D-value g kg^{-1} DM	ME yield GJ ha^{-1}	DM yield kg DM ha^{-1}	D-value g kg^{-1} DM	ME yield GJ ha^{-1}
	T+I		9,310 a	685 c	102.2 a	9,180 a	695 b	102.2 a
	R+V		9,650 a	678 b	104.8 a	9,650 b	694 b	107.1 b
	G+I		10,490 b	668 a	112.3 b	9,800 b	682 a	107.1 b
SEM			199	1.6	2.02	305	2.1	3.47
2H		2013	8,670	679	94.2	8,650	693	95.8
2H		2014	9,260	641	94.9	9,120	675	98.5
3H		2013	10,910	697	121.5	10,180	703	114.5
3H		2014	10,430	691	115.1	10,230	690	113.0
SEM			214	1.9	2.16	331	2.7	3.80
P value	H		0.002	<0.001	0.001	0.012	0.006	0.010
	M		<0.001	<0.001	<0.001	<0.001	<0.001	0.010
	Y		NS	0.001	NS	NS	0.017	NS
	H×M		NS	NS	NS	0.057	NS	0.083
	H×Y		0.002	<0.001	0.030	0.085	NS	NS
	M×Y		NS	NS	NS	NS	NS	NS
	H×M×Y		NS	NS	NS	NS	NS	NS

[1] ME = metabolisable energy; T+I = Tuure-Ilmari; R+V = Rubinia-Valtteri; G+I = Grindstad-Inkeri; SEM = standard error of the mean, NS = not significant, *P*>0.10. Values marked with the same letter do not differ (Tukey's test).

The proportion of timothy in the mixture varied between sites despite the same amounts of seed sown: it was approximately 70% at Maaninka, but only 20% at Sotkamo.

The average daily growth rate between EC and LC was +130 kg DM d^{-1} in the second cut and +20 kg DM d^{-1} in the third cut. The daily change of D-value was -2.5 g d^{-1} and only -0.2 g d^{-1}, respectively. These rates of change were clearly lower than published earlier for the first cut, 190 kg DM d^{-1} and -5-(-5.3) g d^{-1} (Kuoppala, 2010; Rinne *et al.*, 2010) as expected. The observed change in D-value in the second cut was somewhat faster than reported previously (-1.4 g d^{-1}; Kuoppala, 2010). Changes at the end of the growing season are slow and the importance of timing of harvests therefore decreases. There was no evidence of winter damage observed during the winter of 2013-2014.

Conclusions

The three-cut strategy is a good alternative to optimize both the high yield and digestibility of silage, although it requires slightly higher N inputs and favourable weather conditions. There are differences between the yield and digestibility of different cultivar mixtures but the interaction with number of harvests was only minor in this study. Timing of the second cut has a notable impact on the amount and nutritive value of the total yield, but the influence of date of third harvest is small.

References

Hyrkäs M., Sairanen A., Juutinen E., Virkajärvi P. and Suomela R. (2012) The effect of harvest timing on the amount and the quality of total yield of grass silage per growing season. In: Kuoppala K., Rinne M. and Vanhatalo A. (eds) *Proceedings of the XVI International Silage Conference Hämeenlinna*, Finland, 2-4 July 2012. MTT Agrifood Research Finland and University of Helsinki, pp. 178-179.

Kuoppala K. (2010) *Influence of harvesting strategy on nutrient supply and production of dairy cows consuming diets based on grass and red clover silage.* PhD thesis. MTT Science 11. MTT Agrifood Research Finland, Jokioinen, Finland, 99 pp.

Rinne M., Pitkänen T., Nyholm L., Nousiainen J. and Huhtanen P. (2010) Nurmiheinien ensimmäisen sadon sulavuuden ja sadon määrän mallit nurmirehuntuotannon hallintaan. In: Hopponen A. (eds.) *Maataloustieteen päivät 2010,* 12.-13.1.2010 Viikki, Helsinki: esitelmät, posterit. Suomen maataloustieteellisen seuran tiedote 26. 9 p.

Virkajärvi P., Pakarinen K., Hyrkäs M., Seppänen M. and Bélanger G. (2012) Tiller characteristics of timothy and tall fescue in relation to herbage mass accumulation. *Crop Science* 52(2), 970-980.

Performance and quality of legume monocultures and grass-legume mixtures during two dry years

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Abstract

The paper presents the effect of weather variables on performance and herbage quality of legume monocultures and grass-legume mixtures. In a field experiment, the total dry matter yield and its distribution during the growing period, content of crude protein and fibre of monocultures of *Trifolium pratense* and *Medicago sativa* and grass-legume mixtures under the climatic conditions of hilly region in Central Slovakia during two dry years was investigated. *Medicago sativa* cv. Kamila and Tereza grown as monocultures or as mixtures with *Festulolium braunii* (cv. Achilles) outperformed *Trifolium pratense* cv. Fresko and Veles and provided a well-balanced total and seasonal dry matter yield during both years. Across all experimental years, crude protein content was significantly higher at *Medicago sativa* monocultures and mixtures when compared to *Trifolium pratense* monocultures (*P*<0.05). Responses of nutritive parameters of both legume species to weather variables were different. The crude protein content in *Trifolium pratense* was independent of rainfall and temperature. In contrast, the fibre content correlated with temperature; correlations were stronger for *Medicago sativa* monocultures (*P*<0.05) than *Trifolium pratense* monocultures.

Keywords: dry matter yield, *Trifolium pratense*, *Medicago sativa*, grass-legume mixture

Introduction

Forage legumes are considered to be the backbone of ley farming in southern regions of Slovakia (Jančovič *et al.*, 2005) and in upland and mountain areas with high proportions of natural habitats, where it is necessary to produce high-quality conserved forage for winter. Whereas *Medicago sativa* has the greatest productive potential in southern regions with a lower total rainfall, *Trifolium pratense* is cultivated mainly in upland and mountain areas with total annual rainfall of more than 700 mm. Increasing variability in the seasonal temperature and precipitation patterns influences not only productivity (Chaplin-Kramer and George 2013), but affects the nutritive value and digestibility of forage grasses and legumes. The objective of this study was to assess the impact of drought on the yield stability and quality of *Trifolium pratense*, *Medicago sativa* and their mixtures with *Festulolium braunii* during two consecutive extremely dry years.

Materials and methods

In 2010, the trial was established in Banská Bystrica (48°74′N, 19°85′E; altitude 369 m.a.s.l.). The site is located in a moderately warm region and on soil classified as Leptic Cambisol Skeletic. The climate variables (rainfall – R, maximum temperatures – Tmax) were recorded daily. The trial was arranged in a randomized complete block design with two replications. The trial comprised the following 6 treatments: Treatment 1 – *T. pratense* (TP) cv. Fresko; Treatment 2 – TP cv. Veles; Treatment 3 – mixture of TP cv. Fresko with *Festulolium braunii* cv. Achilles; Treatment 4 – *M. sativa* (MS) cv. Kamila, Treatment 5 – MS cv. Tereza; Treatment 6 – mixture of MS cv. Tereza with *Festulolium braunii* cv. Achilles. The seeding rates of the monoculture were 20 kg ha⁻¹ for TP and 15 kg ha⁻¹ for MS and the seeding rates of

the mixtures were 26 kg ha^{-1}, of which 16 kg ha^{-1} was for *Festulolium braunii* and 10 kg ha^{-1} for TP or MS, respectively. The fertiliser application included 30 kg N ha^{-1}, 30 kg P ha^{-1} and 60 kg K ha^{-1} applied before seeding in spring 2010; 30 kg P ha^{-1} and 60 kg K ha^{-1} were applied in spring 2011 and 2012. The stands were cut three times a year. The dry matter (DM) yield was determined by drying to a constant weight at 60 °C in an electric drier. The crude protein (CP) was determined by the Kjeldahl method (N × 6.25). Fibre was determined by the Hennenberg-Stohmann method. DM yield, CP and fibre were subjected to a multi-factor analysis of variance (ANOVA). Statistical analyses were performed using Statgraphics software version 5.0.

Results and discussion

The DM yield of TP was below the range typically reported for this crop (Tucak *et al.*, 2013) and varied from 3.87 Mg ha^{-1} (cv. Veles) to 5.13 Mg ha^{-1} (cv. Fresko) (Table 1). The mixture of TP with *Festulolium braunii* overyielded TP cv. Fresko and TP cv. Veles by 25 and 45%, respectively.

In 2012, the largest decrease (67%) in DM production was observed in TP cv. Veles (Treatment 2). In contrast to TP, treatments with MS showed a significant increase in DM yield in 2012 (Table 1) when compared to 2011. In 2011, in all treatments the highest DM yields were obtained in the 2nd cut. In 2012, TP demonstrated the same pattern with the highest DM yields in the 2nd cut. The low values for the correlation coefficients indicated that neither rainfall amount nor T_{max} during the regrowth period directly affected the DM yield of TP (Table 2). In contrast to the TP monocultures, the mixture of TP with *Festulolium braunii* was positively correlated with rainfall (r=0.67, *P*<0.05). The higher correlation with rainfall may be related to higher sensitivity of *Festulolium braunii* to water availability during growing season, compared with that of legumes. Similarly, Gutmane and Adamovich (2008) reported that the DM yield of *Festulolium* hybrids was strongly dependent on the weather conditions in the year of assessment, and particularly the period of regrowth. Similar to TP, no relation between DM yield and rainfall was found for MS (Table 1). On average, TP and MS exhibited significantly higher CP values (*P*<0.05) than their mixtures with *Festulolium braunii* (Table 2). MS and TP monocultures had the highest CP content in the 2nd cut.

Table 1. Dry matter yield (Mg ha^{-1}) of the monocultures of *Trifolium pratense* (TP), *Medicago sativa* (MS) and of their mixtures with *Festulolium braunii* (FB) in the 1st, 2nd and 3rd cut, and Pearson correlation coefficients between the dry matter yield and sum of rainfall per cut (mm; r_R) and mean of maximum temperature (°C; r_{Tmax}).

Year	Cut number	T_{max}	R	Treatment[1]					
				1	2	3	4	5	6
2011	1st	19.1	59.0	1.22	0.73	2.38	1.09	1.41	1.00
	2nd	23.4	51.4	3.65	3.71	4.12	3.58	3.13	3.18
	3rd	25.1	48.2	1.61	1.18	2.53	3.02	3.31	1.45
Total DM yield				6.48	5.62	9.03	7.63	7.85	5.83
2012	1st	18.4	69.4	1.34	0.82	2.32	4.51	4.89	4.43
	2nd	25.5	33.6	1.74	1.00	1.68	4.14	3.29	3.37
	3rd	26.4	0.0	0.70	0.30	0.59	3.38	3.09	3.51
Total DM yield				3.78	2.12	4.58	12.02	11.27	11.31
r_{Tmax}				0.05	0.05	-0.32	0.23	0.04	0.03
r_R[2]				0.33	0.29	0.67*	-0.09	0.14	-0.15

[1] Treatment 1: TP cv. Fresko; Treatment 2: TP cv. Veles; Treatment 3: TP cv. Fresko with *Festulolium braunii* cv. Achilles; Treatment 4: MS cv. Kamila, Treatment 5: MS cv. Tereza; Treatment 6: MS cv. Tereza with *Festulolium braunii* cv. Achilles.

[2] * Positive correlation with rainfall (*P*<0.05).

Table 2. Mean content of crude protein (g kg^{-1}), fibre (g kg^{-1}) and Pearson correlation coefficients between the content of crude protein (g kg^{-1}), fibre (g kg^{-1}), sum of rainfall per cut (mm; r_R) and mean of maximum temperature (°C; r_{Tmax})

Cut	Crude protein Treatment[1]						Fibre Treatment[1]					
	1	2	3	4	5	6	1	2	3	4	5	6
1st	123	121	94	192	118	107	198.4	222.2	251.3	186.3	248.0	249.2
2nd	170	150	132	170	164	118	256.2	254.5	267.9	295.4	284.9	305.9
3rd	144	139	148	144	142	147	268.7	255.2	325.4	328.5	365.9	290.8
Mean [2]	143^b	137^b	124^s	169^c	141^b	124^a	241.1^a	243.1^a	281.6^b	270.0^a	299.6^c	281.9^b
r_{Tmax} [3]	0.07	0.08	-0.59*	0.55	-0.31	-0.49	-0.41	-0.35	-0.43	-0.53	-0.56	-0.38
r_R [3]	0.29	0.31	0.81	0.72*	0.52	0.51	0.56	0.33	0.61*	0.70*	0.67*	0.57

[1] Treatment 1: TP cv. Fresko; Treatment 2: TP cv. Veles; Treatment 3: TP cv. Fresko with *Festulolium braunii* cv. Achilles; Treatment 4: MS cv. Kamila, Treatment 5: MS cv. Tereza; Treatment 6: MS cv. Tereza with *Festulolium braunii* cv. Achilles.

[2] The values in the same row with different superscript letters are significantly different at *P*<0.05.

[3] * Significantly different at the 95% level.

For grass-legume mixtures, there was a positive relationship between CP content and T_{max}, and a negative correlation between CP content and total rainfall. The TP monocultures had a lower concentration of fibre than both MS monocultures and legume mixtures (Table 2). In our study, there was a non-significant negative correlation between fibre concentration and T_{max}. The fibre content was positively correlated with sum of rainfall available for the cut.

Conclusions

The results showed significant impact of water stress on DM production of *Trifolium pratense* and seasonal pattern of DM yield. In contrast, *Medicago sativa* displayed high yield potential and stability during two consecutive dry years. As would be expected, legume monocultures exhibited significantly higher CP content than mixtures with *Festulolium braunii*. Ambient temperature was the weather variable that predominantly affected the concentration of CP and fibre, especially of *Medicago sativa* monocultures.

Acknowledgements

References

Chaplin-Kramer R. and George M.R. (2013) Effects of climate change on range forage production in the San Francisco Bay Area. *PLoS ONE* 8, e57723.

Gutmane I. and Adamovich A. (2008) Analysis of sward management factors influencing *Festulolium* and *Lolium × boucheanum* yield formation. *Agonomijas Vēstis* (*Latvian Journal of Agronomy*), 117-122.

Jančovič J., Ďurková E. and Vozár Ľ. (2005) *Forage crops I. Field forage crop production*. ÚVTIP, Nitra, Slovakia, 100 pp.

Tucak M., Popović S., Čupić T., Španić V. and Meglič V. (2013) Variation in yield, forage quality and morphological traits of red clover (*Trifolium pratense* L.) breeding populations and cultivars. *Zemdirbyste-Agriculture* 100, 63-70.

The effect of potassium on dry matter production and nutritive value of grass on three different soil types

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Abstract

In Finland, grass yield response to potassium (K) fertilization varies with soil acid-extractable potassium (K_{HCl}) availability, rather than the traditionally used measure of soil acid ammonium acetate-extractable potassium (K_{AAc}). However, in previous experiments, no animal manure was used and grass nutritive value was only partially taken into account. The objective of this experiment was to measure the effects of cattle slurry, mineral K-fertilization (0, 50, 100, 150, 200 kg ha^{-1} year^{-1}) and their interaction on grass (*Phleum pratense – Festuca pratensis*) dry matter (DM) production and nutritional value (organic matter digestibility, K concentration, Diet Cation Anion Difference = DCAD, grass tetany index) under three different levels of soil K_{HCl}. Three-year field experiments were established at three locations: site 1, 2 and 3. The study was carried out as a split plot experiment. K_{HCl} concentration of soil did not entirely explain the utilization of potassium by grass. Mineral K fertilization, given as KCl, decreased nutritional value of forage except for DCAD, on which Cl has a strong positive effect. K uptake was more effective without slurry application especially on soils with low and medium levels of K_{HCl}.

Keywords: grass, potassium fertilization, extractable potassium, non-extractable potassium, cattle slurry, nutritive value of grass

Introduction

In Finland, the recommendation of K fertilization for cultivated short-term grasslands has been based on concentration of easily extractable potassium (mg K_{AAc} l^{-1} soil; Vuorinen and Mäkitie, 1955). However, in many Nordic studies the concentration of K_{HCl} (often referred to as 'potentially' or 'reserve K', 'mineral K', or 'acid-extractable K') seems to explain availability and utilization of potassium better than K_{AAc} (e.g. Virkajärvi *et al.*, 2014).

High concentrations of K, high diet cation anion difference (DCAD) and grass tetany index (GT, ratio of K × (Ca+Mg)$^{-1}$) in forage can increase the risk of milk fever and grass tetany (e.g. Pelletier *et al.*, 2008). Previous studies have concentrated mostly on DM production responses to mineral K-fertilization. Effects of mineral fertilization, and especially slurry application, in terms of their effects on K-related nutritional values of grass remain poorly understood.

In this study our main aims were to clarify how soil type and different K_{HCl} concentrations of soil affect the grass yield response to K fertilization, how cattle slurry application affects the grass yield production and how K fertilization (mineral or slurry) affects the nutritive value of the grass.

Materials and methods

The study was carried out as a split plot experiment at site 1 (63°08' N, 27°19' E, silt loam), site 2 (61°40' N, 27°13' E, sandy loam) and site 3 (64°41' N, 25°9' E, sandy loam), Finland, during the growing seasons of 2011-2014. The average concentrations of K_{HCl} in topsoil and subsoil were high/high (2,700/2,600 mg l^{-1}) medium/high (1,200/2,000 mg l^{-1}) and low/medium (4,50/8,00 mg l^{-1}), respectively. Sown

plots of a mixture of timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) were established in 2011 in four replicates using barley (*Hordeum vulgare*) as a cover crop. The plots were harvested two or three times per year. The effect of cattle slurry, compared with mineral N and P, was investigated as a main plot. Slurry at 30 Mg ha^{-1} was injected for the second cut and complemented with mineral N to correspond to the amount of soluble N on the main plot without slurry application. Mineral K-fertilization (0, 25, 50, 75 and 100 kg ha^{-1} for both the first and the second cut) was the subplot.

Dry matter yields (DM yield, kg DM ha^{-1}) were measured from each cut. Mineral concentrations of grass were determined by standard methods in the laboratory of the MTT Agrifood Research Finland. DCAD and GT were calculated using equations $[(Na^+ + K^+) - (Cl^- + S^{2-})] \times 1000$ and $K^+ \times (Ca^{2-} + Mg^{2-})^{-1}$, respectively (Ender *et al.*, 1962; Kemp and Hart, 1957). DCAD value 250 mmol$_c$ kg^{-1} DM and GT value 2.2 are used as maximum recommended values (Host *et al.*, 1997; Kemp and Hart, 1957). The digestibility values (D value; g kg^{-1} DM) were determined by near-infrared spectrometry (Valio Ltd). Statistical analyses were performed using ANOVA (Mixed procedure of SAS 9.3). Experimental sites were analysed separately.

Results and discussion

K-fertilization increased significantly the total DM yield only twice: site 1 in 2013 and site 2 in 2014, even though concentrations of soil K_{HCl} on these sites were high or medium, both in subsoil and topsoil. At low level of soil K_{HCl} concentration (site 3) no responses to K-fertilization were observed. Over the experimental years the fertilization effect was not significant at any site (Table 1). These results were not as expected. Potassium deficiency in grass (K concentration of <17 g kg^{-1} DM) was observed only at site 2 in 2014, treatment without K-fertilization (slurry or mineral-K). Previous findings have indicated that environmental factors, like exceptional dryness and moisture, can affect the exchangeable-K uptake from soil (Kuchenbuch *et al.*,1986; Saarela *et al.*, 1998). In these circumstances 50 kg K ha^{-1} was enough

Table 1. Slurry (MP) and K-fertilization (SP) effect on total DM yield (kg ha^{-1} y^{-1}) and K concentrations (g kg^{-1} DM), DCAD value, GT value and D-value (digestibility organic matter, g kg^{-1} DM) in the second cut over the experimental years 2012-2014 (Y).[1]

| | Site | Slurry (Mg ha^{-1} y^{-1}) | | SEM | K-fertilization (kg ha^{-1} y^{-1}) | | | | | SEM | Significance[2] | | | |
		0	30		0	50	100	150	200		MP	SP	MP*SP	Y
Total yield	1	10.7	10.6	1.26	10.5	10.7	10.7	10.6	10.6	1.40	ns	ns	ns	***
	2	10.0	9.9	1.43	9.9	9.9	10.0	10.0	10.0	1.42	ns	ns	ns	***
	3	13.3	12.8	2.27	12.9	13.2	13.0	13.0	13.1	1.80	ns	ns	ns	**
K	1	30.0	30.1	0.38	27.3	29.0	30.4	31.4	32.1	0.33	ns	***	***	***
	2	23.5	28.8	0.61	20.5	24.5	26.6	29.4	29.8	0.59	**	***	***	***
	3	31.7	34.3	0.62	27.4	30.7	33.5	36.0	37.4	0.62	**	***	***	ns
DCAD	1	355	303	10.6	478	384	318	239	228	9.5	**	***	**	***
	2	160	248	15.6	249	204	184	189	192	14.2	**	***	**	***
	3	272	247	11.5	384	302	233	198	183	12.6	ns	***	ns	ns
GT	1	2.3	2.4	0.05	2.1	2.3	2.3	2.4	2.5	0.04	ns	***	ns	***
	2	2.1	3.0	0.10	1.8	2.3	2.6	3.0	3.2	0.10	**	***	***	**
	3	2.0	2.6	0.05	1.8	2.1	2.3	2.6	2.8	0.06	***	***	***	**
D-value	1	677	678	1.7	693	684	675	668	667	1.7	ns	***	ns	***
	2	663	667	2.5	677	668	663	657	659	2.6	ns	***	**	**
	3	679	675	3.0	692	681	674	669	671	2.9	ns	***	**	***

[1] Values are averaged over the experimental years.

[2] *, **, and *** indicate the treatment effect is significant at $P<0.05$, $P<0.01$ and $P<0.001$, respectively. Non-significant effect is denoted by ns ($P>0.05$). Y×MP, Y×SP and Y×MP×SP were included in the model but not presented.

to satisfy grass K-requirement in these soil types. According to the present recommendations (based on K_{AAc}), the fertilization rate in this case would have been 130-170 kg ha^{-1} year^{-1}.

Mineral K-fertilization (as KCl) significantly decreased ($P<0.001$) grass nutritional quality (more K and GT, lower D-value) except for a positive effect ($P<0.001$) of mineral Cl on DCAD. Cl-uptake of grass was relatively more effective than K-uptake, which decreased DCAD-value of the grass. Nutrient imbalances can be partly corrected by using fertilizers containing balancing nutrients. When the concentration of K_{HCl} in soil was high the K-related quality values of grass were also high despite the fertilization rate. K-fertilization decreased D-value ($P<0.001$). Cattle manure was equally effective as mineral K as a source of K-fertilizer. Slurry increased the K-concentration of grass significantly on soils that had low/medium concentrations of K_{HCl}. The interaction between slurry application and mineral K-fertilization was almost always significant in the second cut, when K uptake was more effective without slurry application especially on soils with low/medium level of K_{HCl}. The opposite effect occurred in the first and third cuts.

Conclusions

Soil K_{HCl} concentration does not entirely explain the plant availability and utilization of potassium. The results of this study support the theory that the concentration of soil K_{HCl} would be a better basis for grass K-fertilization recommendations in Finland. In addition to soil analysis it is advisable to analyse K-related nutritional values (K-concentration, DCAD, GT) of the herbage yields. As a source of K fertilizer, cattle slurry is as effective as mineral K.

References

Ender F., Dishington I.W. and Helgebostad A. (1962) Parturient paresis and related forms of hypocalcaemic disorders induced experimentally in dairy cows. *Acta Veterinaria Scandinavica* 3, 5-52.

Horst R.L., Goff J.P., Reinhardt T.A. and Buxton D.R. (1997) Strategies for preventing milk fever in dairy cattle *Journal of Dairy Science* 80, 1269-1280.

Kemp A. and Hart M.L. (1957) Grass tetany in grazing milking cows. *Netherlands Journal of Agricultural Sciences* 5, 4-17.

Kuchenbuch R., Claassen N. and Jungk A. (1986) Potassium availability in relation to soil moisture. *Plant and Soil* 95, 221-243.

Pelletier S., Bélanger G., Tremblay G.F., Virkajärvi P. and Allard G. (2008) Timothy mineral concentration and derived indices related to cattle metabolic disorders: A review. *Canadian Journal of Plant Science* 88, 1043-1055.

Saarela I., Huhta H., Salo Y., Sippola J. and Vuorinen M. (1998) Kaliumlannoituksen porraskokeet 1977-1994. *Maatalouden tutkimuskeskuksen julkaisuja*. Sarja A 42, pp.41.

Virkajärvi P., Kykkänen S., Räty M., Hyrkäs M., Järvenranta K., Isolahti M. and Kauppila R. (2014) Potassium fertilization of grass in Finland. Use of acid-soluble potassium as a basis for potassium fertilization. *MTT Report* 165.

Vuorinen J. and Mäkitie O. (1955) The method of soil testing in use in Finland. *Agrogeological Publications* 63, 1-44.

Productive longevity of different alfalfa varieties in the Central non-Chernozem region

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Abstract

Productive longevity of different alfalfa varieties depends on soil fertility, weather conditions, intensity of use and disease incidence. The pasture-type alfalfa (*Medicago varia* Martyn.) variety Pastbischnaya 88 was tested for long-term persistence on well cultivated soils. In the 5th and 6th years of use 36-72 plants were left per 1 m^2 and dry matter yields reached 5-7 Mg ha^{-1}. Thinning of the swards was recorded both after unfavourable winter conditions and due to the diseases in the summer period. By the 15-17th year of use the productivity of alfalfa-based swards declined to 2.8-3.12 Mg ha^{-1}. Being well provided with P and K on the sod-podzolic soil, alfalfa persisted in the mixtures with smooth brome even in its 18th year of use. Presence of 1-7 alfalfa plants per 1 m^2 provided significantly higher yields than pure grass stands. Smooth brome is a good companion grass in alfalfa-grass mixtures for long-term twice-a-season use. This species considerably resisted dandelion invasions and did not suppress alfalfa. The key condition of smooth brome persistence in mixtures with other gramineous grasses is annual application of N_{90}. Without mineral nitrogen fertilization the swards were invaded by wild grasses and dandelion, and the share of smooth brome decreased to 10-18%. On moderately rich soils serious thinning of alfalfa-timothy swards was already recorded in the 4th year after sowing. Their productivity declined to a level of 1.58-2.92 Mg ha^{-1}. Productivity of alfalfa-grass mixtures exceeded that of the single-species timothy crop by 1.8-2.0 times.

Keywords: *Medicago sativa*, yield, productive longevity, variety

Introduction

Alfalfa crops are known to last up to 7-9 years. Planning the approximate period of use for them needs to consider the basic productivity, weed infestation and number of alfalfa plants per square unit. In the first year of use of alfalfa swards, counts of 130-300 plants per 1 m^2 have been recorded, but later this number is reduced dramatically (Berg *et al.*, 2007; Coruh and Tan, 2008). However, decreased productivity is noticed only when alfalfa presence becomes less than 43 plants per 1 m^2. Fewer plants per square unit result in more shoots per plant thus balancing the productivity (Berg *et al.*, 2007). Finding the interrelation between crop productivity, plant density and botanical composition of the swards in long- and short-term field trials helps in assessing the productive longevity of alfalfa, in single-species crops or combined with grasses.

Materials and methods

The field trial was established in 1996 at the experimental station RSAU-MAA n. a. K. A. Timiryazev, located in the Moscow region. The aim was to study persistence of alfalfa in single-species and mixed crops harvested two and three times a year. DM yield was calculated from the green mass harvested from the 25 m^2 plots. The proportions of legumes, grasses and forbs in the yield were found by calculating their percentages by weight. The following variants of swards were studied: grasses (smooth brome and timothy), grasses fertilized with N_{90}, alfalfa cv. Pastbischnaya 88 as a pure stand and in mixture with the grasses, alfalfa cv. Vega 87 and its mixed sward with the grasses. Alfalfa seeding rate was 18 kg for pure stands and 10 kg for the mixtures with smooth brome (*Bromopsis inermis* (Leyss.) Holub) and timothy (*Phleum pratense* L.) (5 kg each). The swards were fertilized with K_{180} till 2007, only because of economic considerations. ANOVA was used to evaluate the differences.

Results and discussion

On sod-podzolic soils alfalfa swards were already thin by the 4-6th years of use, despite these swards rarely suffering from any specific diseases or pests in the Moscow region due to the climatic conditions being untypical for them. In our trial Vega 87 receded to the level of 43 plants per 1 m^2 by the 6th year of management with three harvests per season (Table 1). Thrice-cut Pastbischnaya 88 retained 53 plants per 1 m^2; 2-cuts usage left 51 plants of Vega 87 and 72 plants of Pastbischnaya 88 per m^2 unit. The latter had only 2-17 plants left per 1 m^2 in the 14th year of use and still less in the 17th year (1-7 plants). However, alfalfa made up to 16.3-35.5% of the aboveground herbage mass, and the grasses were moderately competitive.

In their 15-17th years, smooth brome and timothy fertilized with nitrogen provided sustainably high DM yields of 4.58 Mg ha^{-1} on average (Table 2). The unfertilized sward was twice less efficient and invaded with *Dactylis glomerata* L. and forbs. Alfalfa variety Pastbischnaya 88 was more competitive than the older Vega 87, and maintained its high productivity in grass mixtures up to the 17th year of use.

Table 1. Alfalfa plant density per 1 m^2 in single-species crops.

Variety	Year of use				
	1st	2nd	6th	14th	17th
Twice cut					
Vega 87	299	256	51	6	3
Pastbischnaya 88	296	240	72	17	7
Thrice cut					
Vega 87	328	272	43	2	1
Pastbischnaya 88	278	208	53	6	3
Significance *** (*P*<0.05)	***	***	***	***	***

Table 2. Productivity of twice-cut 15-, 16- and 17-year-old alfalfa swards and mixtures with grasses, Mg ha^{-1} DM

Variant	2011	2012	2013	Average
Grasses (smooth brome and timothy)	2.60	1.59	1.55	1.91
Grasses fertilized with N$_{90}$	4.80	4.27	4.67	4.58
Alfalfa Pastbischnaya 88	3.26	2.38	3.15	2.93
Alfalfa Vega 87 with grasses	3.32	2.32	2.80	2.81
Alfalfa Pastbischnaya 88 with grasses	3.34	2.88	3.13	3.12
Significance *** (*P*<0.05)	***	***	***	***

Conclusions

Alfalfa variety Pastbischnaya 88, which is suitable for cutting and grazing, retains sufficient DM productivity of 5-7 Mg ha^{-1} for 5-7 years even in mixed swards with grasses. On poorer soils or if severely diseased, alfalfa stands decline in 3-4 years. Three harvests per season also have a negative effect on the productive longevity of alfalfa, in comparison with twice-cut swards. Smooth brome as a companion species had no suppressing impact on alfalfa and did not affect its persistence.

References

Berg W.K., Cunningham S.M., Brouder S.M., Joern B.C., Johnson K.D., Santini J.B. and Volenec J.J. (2007) The long-term impact of phosphorus and potassium fertilization on alfalfa yield and yield components. *Crop Science* 47, 2198-2209.

Coruh I. and Tan M. (2008) Lucerne persistence, yield and quality as influenced by stand aging. *New Zealand Journal of Agricultural Research* 51, 39-43.

Potential of fodder trees in high-output dairy systems

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Abstract

The reform of the EU's Common Agricultural Policy (CAP) has created renewed interest in the implementation of agroforestry and silvopastoral systems. The multifunctional use of trees for energy and wood production, nutrient cycling, carbon storage, biodiversity, landscape quality and – last but not least – fodder makes trees a potential third crop next to grass and maize on farmland including high-output dairy farms. To decide which trees to use for planting, it is important to have insight into the feeding value of the different species. Therefore we created a database on the feeding values, using data from the literature. The database includes records of tree leaves, twigs, and twigs with leaves of 40 different temperate tree species (620 records in total) (www.voederbomen.nl/nutritionalvalues). Using this database, we compared the nutritive value of the leaves of a number of temperate fodder trees. The nutritive values for grass (*Lolium perenne* L.) are shown for comparison. These data show that, compared to grass, the *in vitro* organic matter digestibility of tree leaves is relatively low. However, for some species the concentrations of crude protein, and of macro- and micronutrients, are relatively high, which shows the potential value of tree leaves as an additional feed source on dairy farms.

Keywords: tree leaves, digestibility, crude protein, minerals, CAP, greening measures

Introduction

The reform of the EU's Common Agricultural Policy (CAP) has created renewed interest in agroforestry and silvopastoral systems. The CAP includes several 'greening measures' that aim to enhance biodiversity on farmland, such as creating Ecological Focus Areas (EFA) and requiring farmers to grow at least three crops on their farms. The multifunctional use of trees for energy and wood production, nutrient cycling, carbon storage, biodiversity and – last but not least – fodder, makes trees an interesting candidate to grow as a third crop on Dutch dairy farms, next to grass and maize. The introduction of fodder trees on dairy farms requires insight into the cultivation, harvest, production and feeding value of different species. The objective of this survey was to create a database for application in The Netherlands of feeding values (energy, protein, and macro- and micronutrients) of common tree species, and compare these data to the feeding value of grass (*Lolium perenne* L.).

Material and methods

Based on a literature review, records about the feeding value of leaves and twigs from temperate tree species were collected into a database (www.voederbomen.nl/nutritionalvalues). The database includes studies from Germany (Becker and Nehring, 1965; Rahmann, 2004), the UK (Smith *et al.,* 2012), the Netherlands (Van Eekeren, unpublished results), France (Trémolières, 1999), Finland (Saramäki and Hytönen, 2004), Greece (Papachristou and Papanastasis, 1994) and also studies from outside Europe (Burner *et al.*, 2005; Chen *et al.*, 2011; Roder, 1992; Singh *et al.*, 1997). The database includes records of tree leaves, twigs, and twigs with leaves of 40 different temperate tree species (620 records in total). Using this database we compared the nutritive value of the leaves of a number of temperate fodder trees: alder (*Alnus glutinosa* L. Gaertn.), hazel (*Corylus avellana* L.), beech (*Fagus sylvatica* L.), ash (*Fraxinus exelsior* L.), robinia (*Robinia pseudoacacia* L.), large-leaved lime (*Tilia platyphyllos* Scop.) and willow (*Salix alba* L.). The nutritive values for grass (*Lolium perenne* L.) are shown for comparison.

Results

The literature study showed that there are ample data available on feeding values of temperate fodder trees. Compared to grass, the *in vitro* organic matter digestibility (OMD) of the different tree leaves is generally low (average values ranging from 30.6 to 57.8% for tree leaves, compared to 79% for grass) (Table 1). This is probably related to the high lignin and fibre content of tree leaves and/or the presence of secondary plant compounds such as tannins. Crude protein levels of the different tree species range from 15.7 to 21.4% of DM (Table 2). Some species, particularly lime (*T. platyphyllos*) and robinia (*R. pseudoacacia*) have a higher average crude protein content than perennial ryegrass in the Netherlands (16.5%) which could replace other protein sources in the diet. Average copper levels in tree leaves range from 7.7 to 15.3 mg kg^{-1} for the different species, compared to 8.9 mg kg^{-1} in grass (Table 3). Leaves of hazel and beech, particularly, contain high levels of copper. This micronutrient is of interest because in the Netherlands it is often lacking in the roughage for lactating cows and goats, and especially growing young stock.

Discussion and conclusions

Our analysis shows that various tree species are of interest in terms of their feeding value for livestock. Tree leaves could serve as alternative source of proteins, and of macro- and micronutrients. However, the records in the database show a considerable range in feeding values for the same tree species. This range is probably due to seasonal differences (Smith *et al.*, 2012), local soil conditions (Saramäki and Hytönen, 2004) and the ability of tree species to adapt to local conditions (Robinson, 2005). Unfortunately, most

Table 1. *In vitro* organic matter digestibility (%) of tree leaves. Average, minimum, maximum values and number of records (n) found in the literature are provided.

Species	Common name	Average	Min	Max	n
Alnus glutinosa	alder	48.1	10.4	69.1	6
Corylus avellana	hazel	47.7	46.4	50.0	3
Fagus sylvatica	beech	30.7	7.4	59.0	5
Fraxinus excelsior	ash	34.1	12.8	55.3	2
Robinia pseudoacacia	robinia	56.7	37.3	77.4	7
Salix spp.	willow	57.8	4.5	70.5	5
Tilia platyphyllos	large-leaved lime	30.6	15.0	46.2	2
Lolium perenne	grass	79.0			

Table 2. Crude protein levels in tree leaves (% of dry matter). Average, minimum, maximum values and number of records (n) found in the literature are provided.

Species	Average	Min	Max	n
Alnus glutinosa	19.2	14.4	26.2	6
Corylus avellana	16.1	14.1	20.4	7
Fagus sylvatica	18.0	14.3	23.3	18
Fraxinus excelsior	15.7	5.9	26.8	8
Robinia pseudoacacia	20.4	11.6	27.0	16
Salix spp.	15.9	9.8	23.1	10
Tilia platyphyllos	21.4	15.3	28.0	13
Lolium perenne	16.5			

Table 3: Copper levels in tree leaves (mg kg^{-1} dry matter. Average, minimum, maximum values and number of records (n) found in the literature are provided.

Species	Average	Min	Max	n
Alnus glutinosa	12.3	6.0	20.0	4
Corylus avellana	13.1	8.5	18.0	4
Fagus sylvatica	15.3	6.5	24.0	2
Fraxinus excelsior	10.0	10.0	10.0	1
Robinia pseudoacacia	7.7	7.0	8.3	2
Salix spp.	8.3	5.5	12.9	5
Tilia platyphyllos	8.0	8.0	8.0	1
Lolium perenne	8.9			

studies did not record the soil conditions. Therefore, we are now conducting a follow-up field study to investigate the relation between feeding value of fodder trees and harvest date, soil type and soil fertility.

References

Becker M. and Nehring K. (1965) *Handbuch der Futtermittel 2. Band*. Verlag Paul Parey, Hamburg, Germany.

Burner D.M., Pote D.H. and Ares A. (2005) Management effects on biomass and foliar nutritive value of *Robinia pseudoacacia* and *Gleditsia triacanthos* f. *inermis* in Arkansas, USA. *Agroforestry Systems* 65, 207-214.

Chen Y., Zhao Y., Fu Z.Y., Ma Z.W., Qian F.C., Aibibuli A., Yang B., Abula R., Xu X.L. and Aniwaer A. (2011) Chemical composition and *in vitro* ruminal fermentation characteristics of tetraploid black locust (*Robinia pseaudoacacia* L.). *Asian Journal of Animal Veterinary Advances* 2011, 1-9.

Papachristou T.G. and Papanastasis V.P. (1994) Forage value of Mediterranean deciduous woody fodder species and its implication to management of silvo-pastoral systems for goats. *Agroforestry Systems* 27, 269-282.

Rahmann G. (2004) Gehölzfutter – eine neue quelle für die öcologische tiernährung. *Landbouforschung Völkenrode Sonderheft* 272, 29-42.

Robinson B., Mills T., Green S., Chancarel B., Clothier B., Fung L., Hurts S. and McIvor I. (2005) Trace element accumulation by poplar and willows. *New Zealand Journal of Agricultural Research* 48, 489-497.

Roder W. (1992) Experiences with tree fodders in temperate regions of Bhutan. *Agroforestry Systems* 17, 263-270.

Saramäki J. and Hytönen J. (2004) Plantations of silver birch (*Betula pendula* Roth) and downy birch (*Betula pubescens* Ehrh.) on former agricultural soils. *Baltic Forestry* 10 (1), 1-11.

Singh P., Chaudhary L.C., Verma A.K. and Pathak N.N. (1997) Nutritive value of Robinia (*Robinia pseudoacacia*) leaves in growing soviet chinchilla rabbits. *World Rabbit Science* 5, 135-137.

Smith J., Leach K., Rinne M., Kuoppala K. and Padel S. (2012) Integrating willow-based bioenergy and organic dairy production – the role of tree fodder for feed supplementation. In: Rahmann G. and Godinho D. (eds) *Tackling the future challenges of organic husbandry. Proceedings of the 2nd OAHC*, Hamburg/Trenthorst, Germany, pp. 394-397.

Trémolières M., Schnitzler A., Sanchez- Pérez J-M. and Schmitt D. (1999) Changes in foliar nutrient content and resorption in *Fraxinus excelsior* L., *Ulmus minor* Mill. and *Clematis vitalba* L. after prevention of floods. *Annals of Forest Science* 56, 641-650.

A comparison of two grazing regimes during lactation for improving the sustainability of Latxa dairy sheep system

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Abstract

Land use and grazing management practices have changed during the last decades as a result of the intensification of traditional pasture-based systems. These changes have potential adverse environmental consequences. Dairy sheep production in the Basque Country has been based traditionally on a pasture-based farming system with a local dairy breed. The objective of the study was to determine the effect of two grazing management regimes, differing in the number of grazing and rest days per paddock, on pasture and dairy sheep production variables. There was no difference in herbage mass or dairy production variables between the two regimes but the regime with the longer rest periods resulted in greater amounts of herbage being harvested for conservation. The longer rest periods could also reduce the carbon footprint and benefit carbon capture by the pastures.

Keywords: dairy sheep, grazing management regimes, milk yield and composition, pasture, sustainability

Introduction

Land use and grazing management practices have changed during the past few decades as a result of the intensification of traditional pasture-based systems. Some of the consequences of these changes are directly related to environmental impacts, such as on soil quality. Permanent pastures have a huge capacity for improving soil health and carbon fixation. However, little attention has been devoted to grazing practices of these pastures during the past decades.

Dairy sheep production from pasture in the Basque Country has been traditionally based on the Latxa breed (Marijuán *et al.*, 2004). The assessment of the effect of grazing management on this system is critical to improving its efficiency. The main objective of the work is to determine the effect of two different grazing management regimes: grazing and rest periods of 6-10 days and 15 days, respectively (FG) vs grazing and rest periods of 2-3 days and 24 days, respectively (RG), on pasture and on dairy sheep production variables during the spring lactation period. Herbage mass and its nutritive value, and daily milk yield (DMY), milk fat (CF) content and sheep live weight (LW), were monitored in order to determine the effectiveness and sustainability of these grazing management regimes.

Materials and methods

An experiment was conducted using the experimental flock of NEIKER-Tecnalia during the spring lactating period (early April – late June 2014). Sheep were blocked into two homogeneous groups of 60 ewes, according to their age, daily milk yield, live weight and body condition score as described by Russel (1984). Each group was randomly assigned to FG or RG grazing regimes under the same stocking rate. The RG group of ewes grazed 3 times per plot with 2-3 days of stay on each one, and 24±2 days of rest between grazing periods. The FG group of ewes grazed 4 times per plot with 6-10 days of stay on each one and the rest between grazing periods was 15±3 days. Each group had access to a botanically diverse pasture after morning milking.

Data were collected fortnightly. The following measurements were made: 'grazing herbage mass' was estimated by cutting herbage to ground level with scissors in a 0.5×0.5 m quadrat. Herbage samples were dried (60 °C for 48 h) and weighed. The crude protein (CP), acid-detergent fibre (ADF) and neutral-

detergent fibre (NDF) contents of herbage samples were measured. Grass was harvested once during the study period and 'harvested herbage mass' was estimated by weighing the bales of hay obtained in each grazing regime paddocks.

Grazing data were collected daily on grazing-cards to describe the number of sheep per paddock; time spent grazing the pasture and the grazing management regime. Daily milk yield per ewe was measured one day each fortnight and milk samples were taken for analyses of CF content. Daily milk yield was corrected to standard DMY as described by Boquier *et al.* (1993). Finally, at the same time individual LW was determined.

All data were analysed by a generalised linear model (SAS, 2010) considering the following fixed effects: grazing management regime (FG and RG), month (April-June) and their interactions.

Results and discussion

The mean 'grazing herbage mass' for grazing and its mean CP content were similar on both grazing managements (Table 1). The difference was that the RG regime had 14% more 'harvested herbage mass' than the FG regime (4,712 kg DM and 4,062 kg DM, respectively) (Mandaluniz *et al.*, 2015a). The increase in grass availability in the RG regime could save or reduce the purchase of conserved forage under this grazing regime. Moreover, this reduction of inputs could have environmental benefits by reducing the carbon footprint (Mandaluniz *et al.*, 2015b).

According to the information collected on the grazing-cards, grazing time was increasing in both grazing managements from 4-6 h per day in April, to 6-8 h per day in May, and to 15-18 h per day in June.

Daily milk yield, milk fat content and standardized daily milk yield were similar for FG and RG groups (Table 2). Ewes of both groups had similar LW. There was a significant reduction in DMY and DMYs, and a significant increase in milk CF content between April and June.

Since the RG regime paddocks rest 24±2 days between grazing periods, and the FG regime paddocks rested 15±3 days, according to Teage *et al.* (2011), the longer resting time could benefit soil restoration and soil health, increase carbon fixation and herbage production. These variables will be monitored during the next 3 years in the Life Regen Farming project.

Conclusions

In conclusion, both grazing regimes, as carried out in the study, maintained milk yield and milk composition of the Latxa dairy sheep during the spring milking period. The increase in harvested herbage

Table 1. Herbage mass (grass) and nutritive value of herbage by grazing regime (FG and RG) and month.[1]

Variable[2]	Grazing regime[3]			Month			
	FG	RG	*P*-value	April	May	June	*P*-value
Grass (kg DM ha^{-1})	1,290±234	1,291±207	0.99	1,194+220^a	1,487+188^b	1,239+85^{ab}	0.001
CP content (g kg^{-1} DM)	164±31	156±25	0.26	173±27^a	165±17^{ab}	136±25^b	0.001
ADF content (g kg^{-1} DM)	250±66	246±30	0.73	215±16^a	291±30^b	254±24^{ab}	0.001
NDF content (g kg^{-1} DM)	480±90	480±60	0.85	423±44^a	564±62^b	467±54^{ab}	0.001

[1] Values in a row with different superscript letters are significantly different.

[2] Dry matter (DM); crude protein (CP); acid-detergent fibre (ADF); neutral-detergent fibre (NDF).

[3] FG = grazing and rest periods of 6-10 days and 15 days, respectively; RG grazing and rest periods of 2-3 days and 24 days, respectively.

Table 2. Daily milk yield (DMY), standard daily milk yield (DMYs), milk fat content (CF) and live weight (LW) by grazing regime and month.[1]

Variable	Grazing regime[2]			Month			
	FG	RG	*P*-value	April	May	June	*P*-value
DMY (ml d^{-1})	1,346±420	1,343±453	0.99	1,544±466[a]	1,229±401[b]	1,110±323[b]	0.001
DMYs (ml d^{-1})	1,193±351	1,218±382	0.39	1,334±383[a]	1,132±328[b]	1,081±324[b]	0.001
CF content (%)	6.63±0.9	6.50±1.0	0.12	6.21±0.9[a]	6.57±0.8[a]	7.32±0.8[b]	0.001
LW (kg)	60.8±7.6	61.7±8.8	0.19	60.0±8.0[a]	61.6±7.8[b]	63.3±7.6[c]	0.001

[1] Values in a row with different superscript letters are significantly different.

[2] FG = grazing and rest periods of 6-10 days and 15 days, respectively; RG grazing and rest periods of 2-3 days and 24 days, respectively.

bales on the RG grazing regime could increase the forage autonomy of farms and could reduce the carbon footprint of farms managed under this regime.

Finally, the longer resting time on the RG regime could benefit soil restoration and health and increase carbon fixation on the pasture. All these environmental parameters are being monitored in the project Life Regen Farming (http://www.regenfaming.eu) to evaluate different grazing regimes as a way to improve the sustainability of these dairy sheep production systems.

References

Boquier F. and Caja G. (1993) Recent advances on nutrition and feeding on dairy sheep. In: Kukovics S. (ed.) *Proceedings 5th International Symposium on machine milking of small ruminants,* pp. 580-607.

Mandaluniz N., Arranz J. and Ruiz R. (2015a) Proposal of an alternative grazing management of sustainable agro-livestock management. In: *54ª Reunión Científica SEEP*. Palma de Mallorca, 14-17 April 2015.

Mandaluniz N., Arranz J. and Ruiz R. (2015b). Efecto de las prácticas de manejo del pastoreo sobre la huella de carbono en un sistema de ovino lechero. In: *Workshop de la Red Remedia*, 23-25 de Marzo de 2015 (Madrid).

Marijuán S., Mandaluniz N., Ruiz R. and Oregui L.M. (2004) Utilisation of mountain pastures by dairy ewes: eastern Basque Country situation. *Options Mediterranéennes* 61, 185-188.

Russel A.J.F. (1984) Body condition scoring of sheep. *In Practice* 6, 91-93.

Teage W.R., Dowohower S.L., Baker S.A., Haile N., DeLaune P.B. and Conover D.M. (2011) Grazing management impacts on vegetation, soil biota and soil chemical, physical and hydrological properties in tall grass prairie. *Agriculture, Ecosystems and Environment* 141, 310-322.

The effects of cultivation date and method on the establishment of lucerne in the UK

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Abstract

Dairy farmers are under increasing pressure to maximise their use of home-grown high-protein forages to achieve sustainable intensification. The use of shallow tillage, such as direct drilling, is one approach farmers could use to reduce the establishment costs when incorporating these forages into high-output pasture-based systems. Lucerne (*Medicago sativa*) is a high yielding forage with high crude protein concentration which is highly palatable to ruminants. An experiment investigated the effect of establishment date and method on lucerne establishment. Findings showed that competition from grass was the main factor affecting the lucerne establishment. The yield of lucerne, established after either a first or second silage cut, either by ploughing or direct drilling, did not differ among treatments where herbicide was used. If lucerne is to be successfully established without the use of herbicide, it should be sown after ploughing not by direct drilling, and after a first silage cut.

Keywords: *Medicago sativa*, establishment technique, shallow tillage, yield

Introduction

Dairy farmers are under increasing pressure to maximise their use of home-grown high-protein forages to achieve sustainable intensification. Lucerne (*Medicago sativa*) is a high-yielding forage with high crude protein concentration and is highly palatable to ruminants (Marley *et al.*, 2007). The use of shallow tillage, such as direct drilling, is one approach farmers could use to reduce the establishment costs when incorporating these forages into high-output pasture-based systems. Furthermore, many farmers aim to establish new forage crops after harvesting a second silage cut, with an aim to harvest a sufficient dry matter (DM) yield of forage as winter feed for livestock. However, this could alter the success of establishing a subsequent forage crop depending on the establishment technique employed. Here we present the findings of an experiment investigating the effect of establishment date and technique on the yield and quality of a lucerne stand when compared to the existing sward.

Materials and methods

The experimental plots (10×2.8 m) were established in 2013 in a randomized block design on an area of stony, well-drained loam of the Rheidol series at Gogerddan (52°26'24.64'N 4° 1'39.77'W). Prior to the experiment, on 12 December 2012, calcium lime was applied to the area, at 5 Mg ha^{-1}, to achieve a soil pH of 6.2. Previously, the experimental site was sown in autumn 2006 with a perennial ryegrass mix and managed for silage, followed by sheep grazing annually. This established ryegrass sward was used as a control and received a target N application of 270 kg N ha^{-1} annum^{-1} in 2013 and 2014. Lucerne (cv. Timbale) plots were established at a target sowing rate of 22 kg ha^{-1} either after a first or second silage harvest; the cut was removed and plots were sown either by conventional reseeding or by direct drilling and either with or without a pre-cultivation herbicide. The treatments comprised of a 2^3 factorial + control, giving a total of 27 plots in a randomised complete block with three replicate blocks (Table 1). P and K were applied to achieve soil indices above 2. Lucerne plots did not receive any N post-establishment but ammonium nitrate was applied to treatments 5-9 until after 2nd cut silage in 2013. The DM yield of all plots was determined for 1st silage cut on 4 June 2013 and then treatments 1-4 were established on 18 June. Plots requiring herbicide (1, 2, 5 and 6) received glyphosate (360 g l^{-1})

Table 1. Treatments used to compare the effects of different lucerne establishment methods.

Treatment no.	Sowing date	Herbicide treatment	Sowing method	Herbicide 2014
1	June	pre sowing herbicide	ploughed & broadcast	yes
2	June	pre sowing herbicide	direct drill	yes
3	June	no herbicide	ploughed & broadcast	no
4	June	no herbicide	direct drill	no
5	August	pre sowing herbicide	ploughed & broadcast	yes
6	August	pre sowing herbicide	direct drill	yes
7	August	no herbicide	ploughed & broadcast	no
8	August	no herbicide	direct drill	no
9	Control	no herbicide	no cultivation	no

(Clinic Ace, Nufarm UK Ltd., Bradford, UK) at a rate of 4 l ha^{-1} prior to establishment and carbetamex (600 g kg^{-1}) (Crawler, Makhteshim-Agan Ltd., Thatcham, UK) applied at 3.5 kg ha^{-1} on 10 March 2014. Ploughed treatment plots were ploughed to a depth of 150 mm, power harrowed and rolled prior to surface sowing using a Fiona D784 seed drill (Westmac Maskinfabrik A/S, Bogense, Denmark) before being lightly harrowed and rolled using a flat roller. Plots for direct drill were sown with a Duncan Eco Seeder direct drill (Willow Farm Machinery Ltd., Ludford, UK) into slots 15 mm deep. Lucerne seed was inoculated with *Rhizobium meliloti* (Legume Technol. Ltd., Eastbridgford, UK). All plots received metaldehyde (15 g kg^{-1}) slug pellets (Tempt, Chiltern Farm Chem Ltd., Bowes, UK.) at a rate of 2.5 kg ha^{-1} after each establishment date. After the 2nd grass harvest on 31 July, the above process was repeated for treatments 5-8. Plots were managed to simulate a silage system followed by light grazing pre-winter. Plots were harvested using a plot harvester (J. Haldrup a/s, Løgstør, Denmark) at a height of 8 cm for silage cuts and 6 cm pre-winter. In 2013, plots with forage material above 8 cm were harvested on 31 July, 21 August, 1 October and 15 November. During 2014, all plots were harvested on: 13 May, 23 June, 4 August and 18 September, with a pre-winter cut on 31 October. DM yield was determined by weighing the material cut from an area of 10×1.5 m within each plot. Sub-samples of harvested forage were taken to determine DM and botanical composition. Data were analysed by ANOVA using GenStat® Release 13 (Payne *et al.*, 2011).

Results and discussion

The average DM yield of Cut 1 taken as determined from all plots in the establishment year was 5,914 kg DM ha^{-1} (standard deviation 568.4). Perennial ryegrass yield data confirmed visual observations and research (Bishop and Gramshaw, 1977) that the establishment success of lucerne is mostly affected by competition from grass, with the yield of lucerne on plots established after either a first or second silage cut, either by ploughing or direct drill, not differing among treatments where herbicide was used. In the first harvest year, plots established by direct drilling after a second silage cut and without herbicide had a lower DM yield compared to all other treatments, resulting overall in this treatment having the lowest lucerne yield (Table 2).

Conclusions

Competition from grass was the main factor affecting the success of lucerne establishment. The yield of lucerne established after either a first or second silage cut, either by ploughing or direct drilling, did not differ among treatments where herbicide was used. If lucerne is to be established without the use of herbicides, it should be sown after ploughing not by direct drilling, and early in the season, after a first silage cut.

Table 2. Effect of establishment method and date on the total dry matter (DM) yield (kg DM ha^{-1}), lucerne yield and perennial ryegrass yield during the establishment and first harvest year of lucerne plots compared to an existing ryegrass control sward.

			2013 yield			2014 yield		
			DM	Lucerne	Perennial ryegrass	DM	Lucerne	Perennial ryegrass
Control								
Existing grass			5,576 [e]	-	5,318 [d]	13,808 [b]	-	12,210 [e]
Ploughed								
Post 1st cut	Herb		2,896 [a]	1,815 [b]	5 [a]	13,917 [b]	13,538 [d]	26 [a]
	No herb		3,124 [ab]	1,267 [b]	29 [a]	15,138 [b]	13,351 [d]	1,373 [b]
Post 2nd cut	Herb		3,940 [d]	0 [a]	3,915 [c]	14,030 [b]	13,842 [d]	21 [a]
	No herb		3,767 [bd]	0 [a]	3,710 [c]	14,360 [b]	11,123 [c]	2,671 [c]
Direct drill								
Post 1st cut	Herb		3,179 [abc]	1,601 [b]	117 [a]	13,961 [b]	12,825 [d]	647 [ab]
	No herb		2,487 [a]	255 [a]	2,065 [b]	13,969 [b]	8,981 [b]	3,842 [d]
Post 2nd cut	Herb		3,820 [bcd]	2 [a]	3,606 [c]	13,845 [b]	13,476 [d]	141 [a]
	No herb		4,426 [d]	16 [a]	3,915 [c]	7,628 [a]	2,711 [a]	3,946 [d]
sed[2]			251.1	300.3	205.4	669.1	596.7	419.3
Probability			***	***	***	***	***	***

[1] Within columns, treatment values with different lower case superscript differ significantly (P<0.05).

[2] sed = standard error of a difference.

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References

Bishop H.G. and Gramshaw D. (1977) Effect of sowing rate, grass competition and cutting frequency on persistence and productivity of two lucerne (*Medicago sativa*) cultivars at Biloela, Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* 17, 105-111.

Marley C.L., Fychan R., Fraser M.D., Sanderson R. and Jones R. (2007) Effects of feeding different ensiled forages on the productivity and nutrient-use efficiency of lambs. *Grass and Forage Science* 62, 1-12.

Payne R.W., Murray D.A., Harding S.A., Baird D.B. and Soutar D.M. (2011) *Genstat® for Windows™* (14th edition). VSN International, Hemel Hempstead, UK, 150 pp.

The effect of tetraploid and diploid perennial ryegrass swards sown with and without clover on milk and herbage production

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Abstract

An experiment to investigate the impact of tetraploid and diploid perennial ryegrass swards sown with and without white clover on the productivity of spring milk production systems was established in 2012 (75%) and 2013 (25%). Four separate grazing treatments/swards were sown for the experiment: tetraploid only, diploid only, tetraploid with clover and diploid with clover. Eight cultivars (four diploid: Tyrella, Aberchoice, Glenveagh and Drumbo; four tetraploid: Aston Energy, Kintyre, Twymax and Dunluce) were sown as monocultures with and without clover. Thirty cows were allocated to each treatment after calving in February 2014. All treatments were stocked at 2.75 cows ha^{-1} and received 250 kg of nitrogen fertiliser ha^{-1}. There was no difference in milk or milk solids yield between the tetraploid-only (4,895 and 414 kg cow^{-1}, respectively) and diploid-only (4,848 and 403 kg cow^{-1}, respectively) swards. However, incorporating clover resulted in 13.3% greater milk yield and 13.4% greater milk solids yield (5,532 and 464 kg cow^{-1}, respectively, and 5,506 and 462 kg cow^{-1}, respectively, for the tetraploid with clover and diploid with clover treatments, respectively). Pasture dry matter (DM) production was 16.8% greater on the grass-clover swards (17,400 kg DM ha^{-1}) compared to the grass-only swards (14,900 kg DM ha^{-1}).

Keywords: white clover, grazing, dairy cow, milk production

Introduction

Worldwide demand for dairy products is increasing and pasture-based systems have the potential to produce increased volumes of high quality dairy products post-European Union milk quota abolition in 2015 (Lips and Rieder, 2005). The utilisation of increased quantities of grazed pasture at farm level will provide the basis of these sustainable livestock systems. Research has indicated that grass cultivars can affect milk production: Wims *et al.* (2013) reported that cows grazing tetraploid perennial ryegrass monoculture swards produced more milk than cows grazing diploid swards. There is renewed interest in forage legumes, particularly white clover (*Trifolium repens* L.), as it offers important opportunities for sustainable pasture-based animal production systems by (1) increasing pasture yield, (2) increasing pasture nutritive value and raising the efficiency of conversion of herbage to animal protein, (3) substituting inorganic nitrogen (N) fertiliser with symbiotic N fixation, and (4) mitigating and facilitating adaption to climate change (Lüscher *et al.*, 2014). Research has also shown the benefit of grass-clover over pure perennial ryegrass (*Lolium perenne* L.) swards for milk production, particularly in the second half of lactation (Harris *et al.*, 1997; Riberio Filho *et al.*, 2003). Therefore, the objective of this study was to evaluate the effect of tetraploid and diploid cultivars of perennial ryegrass, with and without clover inclusion, on the productivity of spring-calving milk production systems.

Materials and methods

A grazing experiment was established at Clonakilty Agricultural College (51°6N; 8°85W) in 2012 and 2013. 75% of the experimental area was reseeded in 2012 and 25% reseeded in 2013. The experimental design was a randomized complete block with a factorial arrangement of treatments, i.e. two grass ploidies (tetraploid and diploid) × two clover treatments (clover and no-clover), resulting in four treatments (tetraploid only (T); diploid only (D); tetraploid + clover (TC); and diploid + clover (DC)). There

were 30 cows per treatment group and all treatments were stocked at 2.75 cows ha^{-1} and received 250 kg N ha^{-1}. Each treatment had a separate farmlet of twenty paddocks. To create the farmlets, twenty blocks of paddocks (each block contained four paddocks (80 paddocks in total)) were created and four diploid (Tyrella, Aberchoice, Glenveagh and Drumbo) and four tetraploid (Aston Energy, Kintyre, Twymax and Dunluce) cultivars were sown as monocultures with and without clover in five different blocks around the experimental area. In the clover paddocks a 50:50 mix of Chieftain and Crusader clover was sown at a rate of 5 kg ha^{-1}. There were 120 dairy cows, comprising three breeds (Holstein-Friesian (HF), HF × Jersey (J) and Norwegian Red × HF × J), which were randomly assigned to one of four herds based on breed, calving date, parity and pre-experimental milk yield. Each herd was then randomly assigned to one of the four treatments. The four treatments were rotationally grazed from mid-February until mid-November 2014. Each farmlet was walked weekly to monitor average farm cover (O'Donovan, 2000) and when surpluses were identified they were removed in the form of baled silage. If a feed deficit occurred across all treatments, then all treatments were supplemented with concentrate. If a deficit occurred in an individual treatment then cows were supplemented with conserved forage produced from within that treatment. Sward clover content was estimated pre-grazing by cutting herbage within a quadrat (0.5×0.5 m) to 4 cm and separating a 70 g sample into grass and clover fractions and drying at 90°C for 15 hours to get the sward clover dry matter (DM) content. Sward clover content was not measured in February and March. Individual milk yields (kg) were recorded at each milking. Milk composition was measured weekly from a consecutive AM and PM milking. Milk and pasture production data were analysed using General Linear Models (PROC GLM) in SAS (SAS, 2006). Terms included in the model were ploidy, clover content and their interactions. Parity and breed were also included in the milk analysis.

Results and discussion

Sward clover content was 39 and 40% for TC and DC, respectively. Ploidy approached significance (P=0.056) for daily herbage allowance (HA). There was a tendency for diploid treatments (D and DC) to have greater HA (16.3 kg DM cow[-1] compared with the tetraploid treatments (T and TC; 15.1 kg DM cow[-1]). Clover did not affect HA (16.1 kg DM cow[-1] for T and D vs 15.4 kg DM cow[-1] for TC and DC). Milk production results for 2014 are presented in Table 1. Ploidy did not affect any of the milk production variables. Clover inclusion had an effect (P<0.001) on both daily and cumulative milk and milk solids yield per cow. Cows grazing both the TC and DC had 13.3 and 13.4% greater cumulative milk and milk solids yield cow[-1], respectively, compared with T and D. Fat content was not affected by clover content; however, there was an effect (P<0.01) on lactose content, while protein content approached significance (P=0.052) for clover swards. Pasture DM production was 16.8% greater on the grass-clover swards (17,400 kg DM ha^{-1}) compared with the grass-only swards (14,900 kg DM ha^{-1}).

Table 1. Effect of grass ploidy (P) and white clover (C) inclusion on milk production in 2014.[1]

	Sward treatment				SE	*P*	C	P × C
	T	D	TC	DC				
Milk yield (kg cow[-1] day^{-1})	17.7	17.5	20.0	20.0	0.28	0.765	<0.0001	0.881
Milk solids (kg cow[-1] day^{-1})	1.50	1.46	1.68	1.67	0.025	0.418	<0.0001	0.495
Fat (g kg^{-1})	47.4	47.0	46.5	46.8	0.73	0.935	0.457	0.725
Protein (g kg^{-1})	37.3	36.5	37.5	37.5	0.30	0.158	0.052	0.117
Lactose (g kg^{-1})	47.6	47.4	47.9	48.2	0.14	0.582	0.002	0.178
Cumulative milk yield (kg cow[-1])	4,895	4,848	5,532	5,506	63.7	0.708	<0.0001	0.914
Cumulative milk solids (kg cow[-1])	414	403	464	463	5.5	0.407	<0.0001	0.520

[1] T = tetraploid grass; D = diploid grass; TC = tetraploid grass + clover; DC = diploid grass + clover; SE = standard error.

Ploidy did not affect pasture DM production or milk production, but there was a significant increase in these parameters when clover was included. Similar to Riberio Fihlo *et al.* (2003), increased daily milk yield was observed for cows that grazed grass-clover swards compared with grass-only swards. Harris *et al.* (1997) indicated that the proportion of clover in pasture needs to be greater than 20% in order to see an animal production effect. Therefore, the high clover content in the current study was the reason for the significant increase in pasture DM and milk production.

Conclusions

White clover incorporation appears to offer an opportunity to increase pasture DM production and increase animal performance. However, the results presented are from year one of the experiment and further research is required as to the long-term effectiveness, persistency and sustainability of clover in Irish grazing systems.

Acknowledgements

References

Harris S.L., Clark D.A., Auldist M.J., Waugh C.D. and Laboyrie P.G. (1997) Optimum white clover content for dairy pastures. *Proceedings of the New Zealand Grassland Association* 59, 29-33.

Lips M. and Rieder P. (2005) Abolition of raw milk quota in the European Union: a CGE analysis at the member country level. *Journal of Agricultural Economics* 56, 1-17.

Lüscher A., Mueller-Harvey I., Soussana J.F., Rees R.M. and Peyraud J.L. (2014) Potential of legume-based grassland-livestock systems in Europe: a review. *Grass and Forage Science* 69, 208-226.

O'Donovan M. (2000) *The relationship between the performance of dairy cows and grassland management on intensive dairy farms in Ireland*. PhD thesis, University College Dublin, Dublin, UK.

Riberio Filho H.M.N., Delagarde R. and Peyraud J.L. (2003) Inclusion of white clover in strip-grazed perennial ryegrass swards: herbage intake and milk yield of dairy cows at different ages of sward regrowth. *Animal Science* 77, 499-510.

Wims C.M., McEvoy M., Delaby L., Boland T.M. and O'Donovan M. (2012) Effect of perennial ryegrass (*Lolium perenne* L.) cultivars on the milk yield of grazing dairy cows. *Animal* 7, 410-421.

Alleviating soil compaction can increase grassland productivity: a demonstration project

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Abstract

An estimated 70% of grassland soils in England and Wales exhibit signs of surface compaction. Soil compaction can result in reductions in grassland productivity and utilisation, impact on soil trafficability and health, and cause an increase in nitrous oxide emissions. Mechanical aeration of soils has been identified as a potential method of remedying soil structure in compacted soils. However, conflicting evidence exists as to the impact of these techniques on grassland productivity in compacted soils. Two commercial farms in the UK were used to demonstrate the effectiveness of sward-lifting and slit aeration on the dry matter yield and quality of grazing pastures. One site was located on a sandy loam soil and one on a clay loam soil. Average precipitation on the two farms ranged from 710 to 800 mm per annum. Both sites are located on improved, lowland grassland. Aeration was undertaken in the autumn and grass growth and utilisation were measured in the following season. Across both farms, grass yield response to surface aeration varied from -18 to +11% when compared with a non-aerated area. Negative results obtained at one site probably reflect inappropriate soil conditions at the time of aeration. There was no identifiable impact on sward quality.

Keywords: soil compaction, sward lifting, slit aeration

Introduction

Sustainable livestock production systems are increasingly reliant on the efficient production and utilisation of 'home-grown' forages. Although an estimated 42 million Mg of forage dry matter are consumed by ruminants in the UK per annum (Wilkinson, 2011), an estimated 70% of grassland soils in England and Wales are exhibiting signs of surface soil compaction (Newell-Price *et al.*, 2013). Research has indicated that soil compaction in grassland can reduce water infiltration, restrict working days, increase nitrous oxide losses and reduce sward productivity (Hargreaves *et al.*, 2013). In addition, Hargreaves *et al.* (2013) observed reductions in first-cut dry matter yield of 14 and 22% from grassland soils compacted by animals and tractors, respectively. Little is known about the effectiveness of soil-loosening treatments on alleviating compaction in grassland soils. Although improvements have been observed in water infiltration rates and soil structure (Bhogal *et al.*, 2011) limited information is available about the impacts on sward productivity. To support on-going research trials examining the effectiveness of sward lifting and slit aeration on grassland soils, two demonstration sites were set up to evaluate the effectiveness of soil-loosening techniques on grass growth, sward quality and soil structure.

Materials and methods

Two 5-ha lowland grassland sites were identified on commercial farms in northern UK. Site A is a three-year-old perennial ryegrass (*Lolium perenne*) and white clover (*Trifolium repens*) ley and is located on a sandy-clay loam soil. Site B is a five-year-old perennial ryegrass, located on clay loam soil. Both sites receive c. 250 kg N ha^{-1} fertiliser per annum and are rotationally grazed by lactating dairy cows from March to October. Annual precipitation for site A and site B is 800 mm and 710 mm, respectively. Both sites exhibited signs of severe topsoil compaction at 10-30 cm depth (Figure 1).

Figure 1. Pre-loosening soil at site A and site B.

Site A was subdivided into four 1.25-ha plots, each of which received one of four treatments: (1) no aeration; (2) sward-lifting aeration; (3) slit aeration; and (4) sward-lifting + spike aeration. Sward lifting was undertaken in October 2012 and spike aeration was undertaken in February 2013. In Autumn 2013 the trial was repeated on an adjoining 5-ha plot of similar soil type and under the same management as previously. Site B was subdivided into three 1.6 ha plots and the following three treatments assigned to one plot: (1) no aeration; (2) sward-lifting aeration; and (3) slit aeration. Sward-lifting and slit aeration were completed in December 2013 and March 2014, respectively. Grass dry matter yield and offtake were measured at each site at each grazing event using a rising plate meter (Jenquip, New Zealand). Grass samples were also analysed for dry matter, crude protein and metabolisable energy.

Results and discussion

Throughout 2013 and 2014, the slit-aeration and sward-lifting treatments at site A increased grass growth by 3.8 and 13.0%, respectively, compared to an non-aerated control (Table 1). In-field assessment showed an improvement in soil structure under both treatments compared to the control. The combined sward-lifting and spike-aeration treatment also increased grass growth by 15.1% compared to the non-aerated control. Grass offtake throughout the season was 2.8, 11.0 and 12.1% higher from the slit aeration, sward-lifting and slit + sward-lifting treatments, respectively, compared to the non-aerated control. In both years, increased grass offtake was evident from the first grazing event following aeration.

In contrast, at Site B slit aeration and sward-lifting aeration reduced grass yield at the first grazing event by 8.2 and 6.4%, respectively, and grass offtake by 25.3 and 13.8%, respectively (Table 2). This reduction is most likely due to wetter soil conditions at the time of loosening, coupled with a heavier soil at site B compared to site A. Significant destruction of grass roots was also evident at site B and a narrower time-window between aeration and the first grazing event may have contributed to this reduction in grass yield.

Table 1. The effect of different soil loosening techniques on grass growth, grass offtake and utilisation at site A.[1]

		No aeration	Slit aeration	Sward lifting	Slit aeration + sward lifting
2013	Growth (kg DM ha^{-1})	9,790	10,209	11,146	11,470
	Offtake (kg DM ha^{-1})	6,722	6,890	7,323	7,422
	Utilisation (%)	68.7	67.5	65.7	64.7
2014	Growth (kg DM ha^{-1})	12,474	12,878	13,980	14,106
	Offtake (kg DM ha^{-1})	8,760	9,032	9,911	9,972
	Utilisation (%)	70.2	70.1	70.9	70.7

[1] DM = dry matter.

Table 2. The impact of soil loosening techniques on grass growth, grass offtake and grass quality at site B.[1]

		No aeration	Slit aeration	Sward lifting
Grazing 1	Grass growth (kg DM ha^{-1})	2,670	2,450	2,500
	Grass offtake (kg DM ha^{-1})	870	650	750
Grazing 3	Grass growth (kg DM ha^{-1})	2,815	2,840	2,840
	Grass offtake (kg DM ha^{-1})	1,240	1,246	1,232
DM content (g kg^{-1})		193	184	178
Metabolisable energy (MJ kg DM^{-1})		11.8	11.8	11.7
Crude protein (g kg^{-1} DM)		198	220	221

[1] DM = dry matter.

By the third grazing event however, grass growth on the loosened treatments was comparable to that on the non-aerated control (2,840 vs 2,815 kg DM ha^{-1}; Table 2). There was no clear difference between grass growth on the aerated and non-aerated treatments over the whole season.

There were no apparent differences in grass dry matter or metabolisable energy content between the different aeration methods at either site. However, a small increase in grass crude protein content from the loosened treatments relative to the non-aerated area at site B was evident (Table 2).

Conclusions

Results from demonstration-farm trials suggest that the use of mechanical soil loosening on compacted grassland soils can result in grass yield improvements on sandy loam soils; however, on heavier soils the effectiveness of these techniques will depend on soil moisture levels at the time of loosening.

Acknowledgements

References

Bhogal A., Bentley C., Newell-Price J. and Chambers B. (2011) *The alleviation of grassland compaction by mechanical soil loosening*. DEFRA, London, UK.

Hargreaves P., Ball B. and Roberts D.J. (2013) Grassland soil compaction: effects on yield and nitrous oxide emissions. In: *Profitable and sustainable grazing systems: moving forward with science*. BSAS-BGS, Malvern, UK.

Wilkinson J.M. (2011) Re-defining efficiency of feed use by livestock. *Animal* 5, 1014-1022.

Calibration of an automated grass height measurement tool equipped with global positioning system to enhance the precision of grass measurement in pasture-based farming systems

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Abstract

Irish and European pasture-based systems of farming rely upon precise grass measurement and allocation to (1) achieve optimal economic return, as grazed grass is the cheapest feed source, and (2) to maintain the regrowth of high quality grass in each subsequent grazing. On farms implementing an intensive grazing system, grass management is usually carried out by subjective visual measurement and intuitive decision-making. To add objectivity to this process an automated grass measurement tool has been developed which will increase the precision of grass measurement and allocation for pasture-based systems of farming. The aim of this study was to calibrate this tool, to provide a decision support tool (DST) for farmers capable of precise grass height measurement with global positioning system location information. The operation of the DST involves the use of a micro-sonic sensor that finds the distance from a module, placed on the shaft of a rising plate meter, to the plate, by recording the time difference between the transmission and its reflective return from the plate. The results of this study indicate that the absolute height measurement of the DST is similar to that of a 'gold-standard' rising plate meter.

Keywords: grass height measurement, decision support tool, rising plate meter

Introduction

Pasture-based systems of farming must rely on precise allocation of grass in order to maximize economic return. Grazed grass is the cheapest feed source available to ruminant farmers from temperate oceanic climates, a climate Ireland shares with much of North West Europe. Strict management is paramount to ensure high quality grass in future rotations. Dillon (2011) has shown that profit per hectare was increased by €160 for each additional Mg of grass utilized per hectare within Irish dairy systems. Thus the economic reward from a pasture-based system in dairy farming is heavily dependent upon accurate estimation of the herbage mass (HM) of each paddock on the farm and the subsequent correct allocation of herbage allowance (HA) to the herd. This means that the correct amount of grass is allocated to meet the energy demands of the dairy herd, and also ensures the correct grass residual after grazing, resulting in increased herbage quality in the paddock for subsequent grazing rotations (Lee *et al.*, 2008). However, grass management on farms is usually carried out by subjective visual assessment and intuitive decision-making. Tucker (1980) showed that visual estimation of HM is subjective and therefore may be prone to variation between observers. To add objectivity to this process an automated grass measurement tool has been developed, which will increase the precision of grass measurement and allocation for pasture based systems. The aim of this study was to calibrate this tool to ensure precise grass height measurement and allow it to represent a decision support tool (DST) which farmers could use on farm.

Materials and methods

Calibration of the automated grass measurement tool (namely the 'Grasshopper') for height measurement was conducted between September and November 2014. The Grasshopper may be described as a micro-sonic measurement device. It was manufactured by True North Mapping, Shannon, Co. Clare, Ireland. A tool called the Jenquip is a rising plate meter which has traditionally been used to measure grass height

(Figure1). This mechanical method measures grass height by measuring the displacement of the circular plate by the grass. The Grasshopper when placed on the shaft of the rising plate meter measures the height of the grass (or plate) by recording the time for the sonic transmission from the Grasshopper unit on the Jenquip shaft and its reflective return from the circular plate (Figure 1). The Jenquip has been considered the 'gold standard' for grass measurement (Sanderson *et al.,* 2001; Soder *et al.*, 2006). Thus, the Grasshopper was calibrated against the Jenquip. A PVC pipe was cut into 32 sections, each of exact lengths between 2.5 cm and 18 cm in increments of 0.5 cm. The height of each pipe section was measured on 150 occasions by both the Jenquip (plate displacement) and the Grasshopper (time for the micro-sonic transmission from the grasshopper on the Jenquip shaft to the plate of the Jenquip and its return). Each measure of pipe section by the Jenquip and Grasshopper was done simultaneously. Fifty (of the 150) measurements at each pipe section height was carried out by one of three operators (in order to investigate operator effect). The data was managed in Microsoft Excel. A Pearson's correlation coefficient was achieved using the PROC CORR procedure in SAS to assess the linear relationship between the height of the pipes with both the Grasshopper and Jenquip measured heights. To determine how close the Grasshopper and Jenquip measured heights fitted the regression line with the known pipe heights, the PROC REG procedure in SAS was used to achieve R^2 values.

Results and discussion

There is an economic incentive to achieving maximum grass utilisation in a spring grazing pasture-based system of farming, as grass is a low cost highly nutritious feed source to produce. Precise grass allocation and targeting a low post-grazing grass residual ensures the return of high quality herbage in subsequent grazing rotations (Lee *et al.*, 2008). The use of a rising plate meter to determine herbage mass is reliant upon the accurate measurement of grass height which is subsequently used in previously developed equations specific to country and season to estimate herbage mass in the paddock. This study compared the heights of 32 different solid PVC pipes, measuring each pipe height 50 times and this was done by three different operators to account operator variation. There was no significant difference between operators for the data analysed. When known pipe heights were compared to the Grasshopper and Jenquip measured heights the Pearson correlation coefficients (R) were 0.999 and 0.998, respectively. Therefore the precision of the Grasshopper in measuring the pipe heights was considered marginally better than that of the Jenquip. The coefficient of determination indicated a strong relationship between the Grasshopper and the pipe heights (R^2 of 0.9984) similar to the relationship between the Jenquip
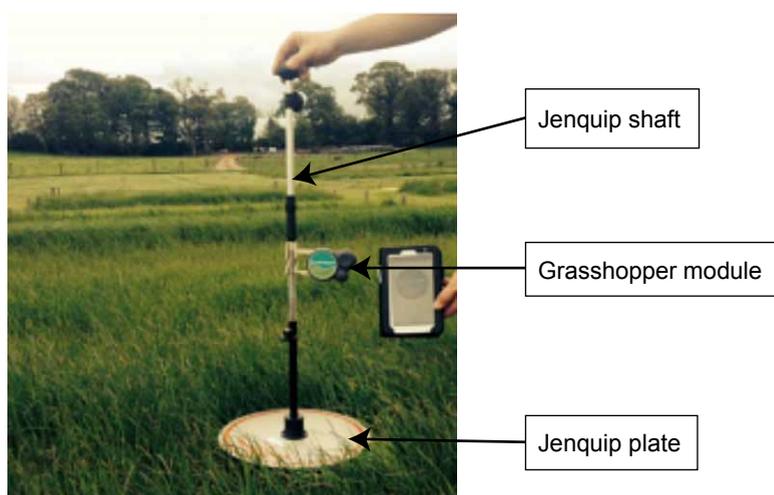
Figure 1. The Grasshopper module attached to the shaft of the Jenquip rising plate meter.

Table 1. Precision measures of pipe height recorded by the Grasshopper and Jenquip compared to actual pipe heights. Values represent the average of 32 different heights and 150 measures at each height.

Measurement tools	Measured pipe height standard deviation (cm)	Measured pipe height coefficient of variation	Measured pipe height difference from actual pipe height (cm)
Grasshopper	0.16	0.02	+0.37
Jenquip	0.18	0.03	-0.61

and the pipe heights (R^2 of 0.9979). The average standard deviation, coefficient of variation and height differences, across the 32 pipe heights, were lower for the Grasshopper compared to the Jenquip (Table 1).

Conclusions

The measurements of the pipe section heights recorded by the Grasshopper were marginally closer to the actual pipe heights than the measurements recorded by the Jenquip. As the Jenquip was considered to be the 'gold standard' in terms of height measurement, the Grasshopper could now be considered as calibrated successfully for height measurement. A future study will be conducted to calibrate the Grasshopper to measure compressed grass height at different herbage mass and dry matter contents.

Acknowledgements

References

Dillon P. (2011) The Irish dairy industry: planning for 2020. In: *Proceedings of the Teagasc National Dairy Conference 2011*. Athlone, Ireland, pp. 1-25.

Lee J.M., Donaghy D.J. and Roche J.R. (2008) Effect of defoliation severity on regrowth and nutritive value of Perennial Ryegrass dominant swards. *Agronomy Journal* 100, 308-314.

Tucker C.J. (1980) A critical review of remote sensing and other methods for non-destructive estimation of standing crop biomass. *Grass and Forage Science* 35, 177-182.

Sanderson M.A., Rotz C.A. and Rayburn E.B. (2001) Estimating forage mass with a commercial capacitance meter, rising plate meter and pasture ruler. *Agronomy Journal* 93, 1281-1286.

Soder K.J., Sanderson M.A., Stack J.L. and Muller L.D. (2006) Intake and performance of lactating cows grazing diverse forage mixtures. *Journal of Dairy Science* 89, 2158-2167.

The effect of different grass species and fertilization level in fodder galega mixtures

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Abstract

Fodder galega (*Galega orientalis* Lam.) is a forage legume that has been grown in Estonia for approximately 43 years. Pure galega is known to be a persistent and high-yielding crop rich in nutrients, in particular crude protein (CP). Galega is usually grown in a mixture with grass in order to optimize its nutrient concentration, increase dry matter (DM) yield and improve fermentation properties. There are certain grass species suitable for the mixture. In this study galega mixtures with reed canarygrass (*Phalaris arundinacea* L.) cv. Marathon, timothy (*Phleum pratense* L.) cv. Tika, red fescue (*Festuca rubra* L.) cv. Kauni and festulolium cv. Hykor were investigated in two successive years (2013-2014). Three cuts were carried out during in both years. Nitrogen (N) fertilization (rate of N50) was applied in spring before the first and second cuts. Early-season N applications to galega-grass swards can prevent N-deficiency in the spring. The total dry matter yield varied from 7.6 to 13.7 Mg ha^{-1}. The CP concentration in the DM varied from 123-188 g kg^{-1}. Both DM-yield and CP were dependent on the year, mixture and fertilization. High N fertilization favoured grass growth and reduced the role of galega in the sward.

Keywords: fodder galega, goat's rue, galega-grass mixtures, forage yield, fertilization

Introduction

Along with other legume fodder crops like lucerne and clovers, goat's rue (fodder galega) has been grown in Estonia for almost 43 years. Galega (*Galega orientalis* Lam.) is very persistent with a high-yielding ability. Results have shown that the yields can possibly be as high as 8.5 to 10.5 Mg of dry matter and 1.7 to 1.8 Mg of crude protein per hectare, with a crude protein (CP) concentration of 200-220 g kg^{-1} dry matter (DM) (Raig *et al.*, 2001). The nutritive value is highest when the 1st cut is taken at budding or at the beginning of flowering. In order to connect the need for nitrogen (N) fertilizer with biologically fixed N, it is favourable to grow galega in a mixture with grass. Of plant nutrients, nitrogen has the highest effect on yield and quality of forage crops. When choosing grasses for mixtures, the rate of species development, duration, and the effect on nutritive value should all be considered. Earlier results have shown that growing galega in mixtures with grasses improves the nutritive value and ensiling properties of forage crops (Lättemäe *et al.,* 2005; Meripõld *et al.*, 2014).

Materials and methods

The experimental field was established in 2012 in Saku Estonia (latitude 57° 25'). The study includes two years' data (2013-2014). The trial plots were established on a typical soddy-calcareous soil where the agrochemical indicators were as follows: pH$_{KCl}$ 6.3 (ISO 10390); humus concentration C$_{org}$ 3.3% and concentration of lactate soluble P and K being 114 and 161 mg kg^{-1}, respectively. Four galega-grass mixtures were used. The galega variety Gale was sown in binary mixtures with reed canarygrass (*Phalaris arundinacea* L.) cv. Marathon (7 kg ha^{-1}), red fescue (*Festuca rubra* L.) cv. Kauni (10 kg seed ha^{-1}), timothy (*Phleum pratense* L.) cv. Tika (8 kg ha^{-1}) and festulolium cv. Hykor (15 kg ha^{-1}), respectively. The sowing rate of the seed of Gale was 15 kg ha^{-1} in all mixtures. Pure fodder galega and festulolium plots were included in the trials as a control.

In order to increase competitiveness of grasses and DM yield at the first cut, two N fertilization levels were used: 0 and 50 kg ha^{-1} (April or May). The crop was cut with a scythe, then weighed, and samples

taken for analyses. The botanical composition of the crop was determined prior to sampling. A three-cut harvesting system was used and there were three replicated plots for each treatment. The data determined in this experiment were: DM yield, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF) and metabolisable energy (ME) contents. Accumulated effective temperatures over 5 °C for first cut in 2014 and 2013 were 241 and 291 °C, respectively. The trial results were processed statistically by the method of dispersion analysis (Excel for Windows 2003).

Results and discussion

The results indicate that galega-grass mixtures provided high DM yield in the two years after establishment. Over the two years, the yields from mixture-treatments varied from 7.6 to 13.7 Mg ha^{-1} year^{-1}, with significant differences between the average yields for the different N levels and mixtures (Table 1). The yields were higher in 2014 and ranged from 9.4 to 13.7 Mg ha^{-1}. Application of N fertilizer changed the botanical composition of the sward. N fertilizer increased the proportion of grasses and reduced the galega proportion in the galega-reed canarygrass and galega-timothy treatments.

In 2013 the average galega cv. Gale proportion in all mixture treatments was 27%, but in the second year it was 46%. At fertilization level N0 and N50 the red fescue cv. Kauni was less competitive (Figure 1).

Table 1. The dry matter yield (Mg ha^{-1}) of fodder galega-grass mixtures in 2013-2014 under 0 or 50 kh ha^{-1} N fertilization levels.[1]

Species	2013		2014	
	N0	N50	N0	N50
Galega	10.5	8.2	12.0	10.7
Galega/reed canarygrass	7.6	11.1	9.5	11.1
Galega/timothy	8.7	10.3	9.4	13.2
Galega/red fescue	7.9	10.3	11.4	11.4
Galega/festucolium	8.2	12.1	10.0	13.7
Festucolium	5.5	10.2	6.2	10.7

[1] Least significant difference (*P*<0.05) = 0.80.
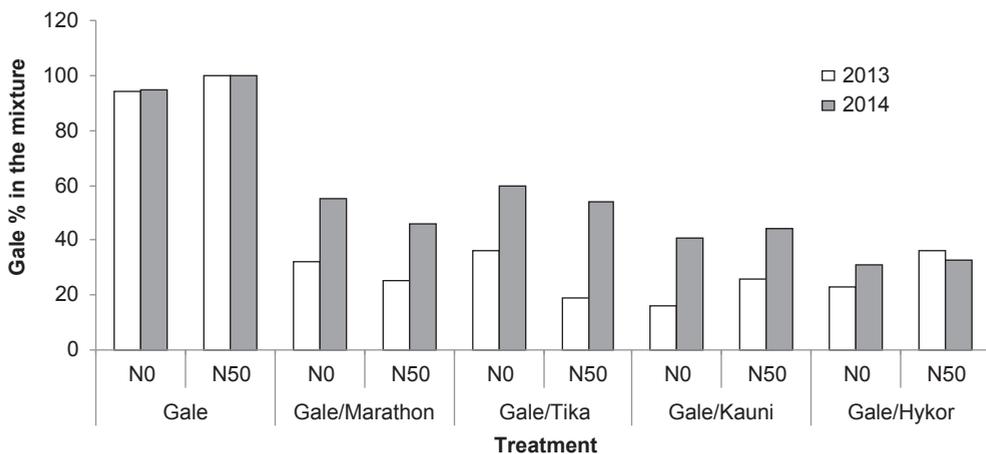
Figure 1. The botanical composition of galega-grass mixture of first cut in 2013-2014.

Table 2. The nutritive value of the fodder galega-grass mixtures of first cut in 2013-2014.[1]

Mixture	N-fertilizer	2013				2014			
		CP	NDF	ADF	ME	CP	NDF	ADF	ME
		g kg^{-1}	g kg^{-1}	g kg^{-1}	MJ kg^{-1}	g kg^{-1}	g kg^{-1}	g kg^{-1}	MJ kg^{-1}
Galega	N0	188	416	355	9.5	254	406	373	9.3
	N50	187	378	331	9.9	241	358	327	9.9
Galega/reed canarygrass	N0	142	581	387	9.1	197	479	365	9.3
	N50	142	547	375	9.3	204	404	298	10.2
Galega/timothy	N0	123	594	393	8.9	182	492	368	9.3
	N50	137	564	379	9.2	212	460	318	9.9
Galega/red fescue	N0	126	568	395	8.9	187	488	340	9.6
	N50	143	531	367	9.4	217	424	311	10
Galega/festulolium	N0	110	616	399	8.9	176	489	345	9.6
	N50	163	506	349	9.6	206	463	330	9.8
Festulolium	N0	82	613	375	9.3	86	536	308	9.7
	N50	146	560	369	9.3	155	506	320	9.9

[1] CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; ME = metabolisable energy.

The highest competitiveness was shown by the timothy cv. Tika and the reed canarygrass cv. Marathon at N50 fertilization in 2013.

The nutritive value of mixtures is presented in Table 2. In general, the nutritive value of mixtures was mainly dependent on the fertilization level. When fertilization level increased, CP concentration and ME increased but NDF and ADF decreased. Lower CP in mixtures (110-197 g kg^{-1} DM) and ME (8.9-9.6 MJ kg^{-1} DM) concentrations were found in the N0 treatments. At the N50 fertilization level, the CP (137-217 g kg^{-1} DM) concentration and ME (9.2-10.2 MJ kg^{-1} DM) both increased. The NDF and ADF concentrations in mixtures were lower in 2014 than in 2013, as plant development in 2014 was less advanced because of the weather (i.e. a lower accumulated effective temperatures for the first cut in 2014 compared to 2013).

Conclusions

The galega-grass mixtures maintained high yielding ability and nutritive value over two years. The nutritive value of mixtures was mainly dependent on fertilization. The N50 fertilization rate favoured grass growth, but reduced the role of galega in the sward. Similar high ME values were obtained in galega-festulolium and galega-reed canarygrass mixtures. The ME concentration was lower in galega-timothy mixture due to higher fibre concentration compared with other grasses. On the basis of these results, fertilization rate of N50 should be recommended in order to avoid grasses being lost from the sward and to prevent N deficiency in the spring.

References

Lättemäe P., Meripõld H., Lääts A. and Kaldmäe H. (2005) The improvement of fodder galega silage quality by using galega-grass mixtures and additive. In: *Integrating efficient grassland farming and biodivesity, Grassland Science in Europe*, Vol. 10. Tartu, Estonia, pp. 635-63.

Meripõld H., Lättemäe P., Tamm U. and Tamm S. (2014) The effect of different fodder galega-grass mixtures and nitrogen fertilization on forage yield and chemical composition. In: *The role of grasslands in a green future. Grassland Science in Europe,* Vol. 19 Aberystwyth, UK, pp. 780-782.

Raig H., Nõmmsalu H., Meripõld H. and Metlitskaja J. (2001) *Fodder galega,* monographia, ERIA, Saku, 141 pp.

Forage quality screening of *Lolium multiflorum* Lam. cultivars appropriate for high carbohydrate rations

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Abstract

High merit cows (>10.000 l cow^{-1} year^{-1}) are usually fed rations high in carbohydrates and low in fibre. In these diets the percentage of silage made from permanent grasslands is low, due to their limited energy contents. As a consequence, adding straw to high carbohydrate mixed rations is a common practice to ensure effective fibre for proper rumen function. However, low digestibility fibres negatively affect feed intake, especially when ruminal distention dominates control of feed intake around peak lactation. Therefore, an alternative diet, high in digestible fibre, seems an option to break the cycle of structural and energetic demands on the roughage. We examined a range of Italian ryegrass cultivars to obtain information about quality characteristics and variations which may be helpful for advisers asking for forages appropriate for high output systems. Samples from three cuts of a field trial with 22 *Lolium multiflorum* cultivars and candivars were analysed by near infrared reflectance spectroscopy for quality traits including acid detergent fibre (ADF), neutral detergent fibre (NDF), enzyme insolubility and water soluble carbohydrates. We considered NDF-ADF differences as most suited for assessing applicability in high carbohydrate rations. Based on these criteria we find significant varietal differences exist in *Lolium multiflorum*.

Keywords: Italian ryegrass, forage quality, hemicelluloses, high merit diets

Introduction

The abolition of the milk quota system in 2015 will further add to the economic pressure on European milk producers (Oudendag *et al.*, 2014). Degression of the unit costs of milk production by increasing the milk yield per cow is regarded as the main adaptive strategy of farmers to meet the challenges of fluctuating market prices. High-merit cows (>10.000 l cow^{-1} year^{-1}) are usually fed with rations high in carbohydrates and low in fibre. The percentages of silages made from permanent grasslands in these diets are low due to their limited energy contents. As a consequence, adding straw to high carbohydrate mixed rations is a common practice to ensure effective fibre for proper rumen function. However, low digestible fibre negatively affects feed intake, especially when ruminal distention dominates control of feed intake around peak lactation (Allen and Piantoni, 2014). Therefore, an alternative diet, high in digestible fibre, seems an option to break the cycle of structural and energetic demands on the roughage. We consider that Italian ryegrass (*Lolium multiflorum* Lam.) has the best potential among temperate forage grasses to provide sufficient fibre while also maintaining high energy contents. In this investigation, we analysed the extent and variability of forage quality traits, focussing on fibre characteristics among varieties of *L. multiflorum*.

Materials and methods

We established a field experiment with 22 cultivars of Italian ryegrass, in a randomised block design with four replicates on a sandy loam soil near Rostock (northeast Germany). Field plots (12 m^2) were sown in August 2008 and harvested five times in the following main harvesting years 2009 and 2010, using a Haldrup forage harvester at a cutting height of 6 cm. Fresh weights were measured and dry matter yields were calculated after drying a 500 g subsample in a draught oven at 60 °C to constant weight.

After grinding to 1mm particle size, samples of the first two growths were analysed by near infrared reflectance spectroscopy for quality traits including acid detergent fibre (ADF), neutral detergent fibre (NDF), enzyme insolubility (EULOS) and water soluble carbohydrates (WSC). We used the VDLUFA-freshgrass-calibration, which was adjusted for the effects of the harvest year on the base of reference analysis. Quality traits were analysed by analysis of variance (ANOVA) for varietal impacts.

Results and discussion

The influence of variety on quality traits characterising a good usability in high-merit rations is given in Table 1. Thus the crude fibre contents show considerable differences due to ryegrass variety at the first cut after establishment. This effect decreases with increasing sward development, indicating differences in sward and tiller structure due to variations in the rate of establishment and tiller development. Field observations support this interpretation. In contrast to strategies that focus on maximisation of energy content in high-merit rations, higher fibre contents can be tolerated as long as the fibre quality remains at a high level. High fibre quality is characterized by low lignin contents and high concentrations of hemicelluloses in the forage cell walls.

Table 1. Results of the analysis of variance (ANOVA, *P*-values), means and standard deviations of the means (in brackets) for some selected quality traits from different cuts.[1,2]

	CF (g kg^{-1} DM)	HC (g kg^{-1} DM)	HC/CF-ratio	WSC (g kg^{-1} DM)	EULOS (g kg^{-1} DM)
1st cut 2009	219.3 (14.5) ***	154.9 (23.1) n.s.	70.5 (8.53) n.s.	263.8 (15.7) n.s.	187.6 (24.45) *
1st cut 2010	275.6 (31.8) **	203.0 (18.6) *	74.1 (6.60) n.s.	113.2 (26.7) n.s.	265.3 (36.33) *
2nd cut 2010	283.6 (16.1) n.s.	181.0 (15.7) **	63.8 (4.43) *	170.1 (18.9) *	259.3 (23.62) n.s.

[1] CF = crude fibre; HC = hemicelluloses; WSC = water soluble carbohydrates; EULOS = enzyme insolubility; DM = dry matter.
[2] Effects of variety: ns = not significant; * $P<0.05$, ** $P<0.01$, *** $P<0.001$.
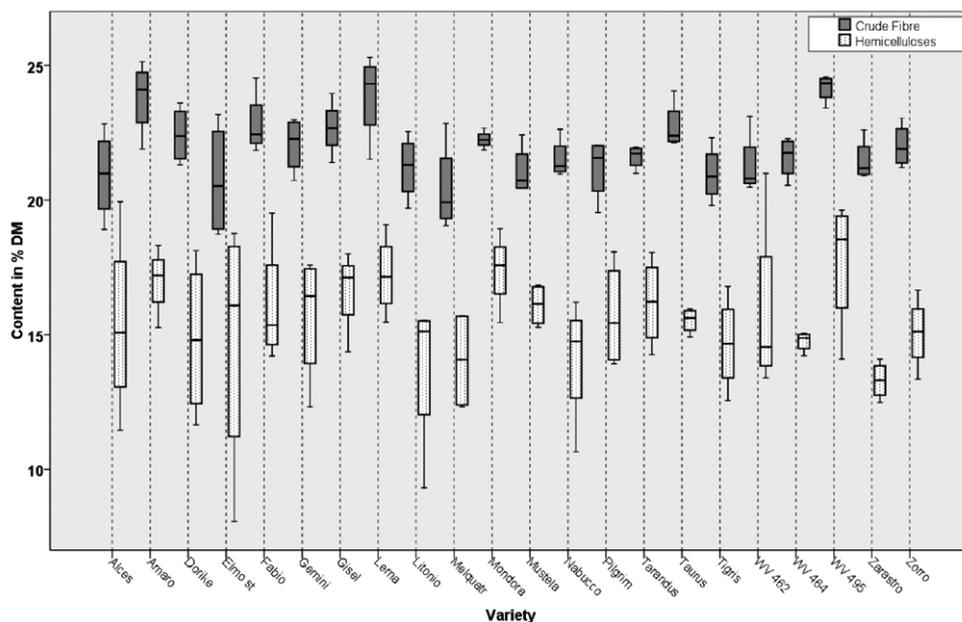
Figure 1. Crude fibre content and corresponding content of hemicelluloses of different varieties of *Lolium multiflorum* at the first cut of the first main harvest year. Boxplot: boundaries = Tukey's hinges, median = line inside the box, box length = interquartile range.

We found significant differences in the contents of hemicelluloses in two of three analysed cuts (Table 1). No single variety pattern could be seen, and even in the first cut no general effect of variety on this trait was detected (Figure 1). For example, cv. Zarastro showed lower hemicelluloses but higher sugar contents than did cv. Alces, with higher but more varying concentrations in the NDF-ADF difference at comparable levels of crude fibre.

Conclusions

Italian ryegrass cultivars could demonstrate their superior forage quality and suitability for feeding to high-merit cows. However, the forage quality pattern among the range of Italian ryegrass varieties may be quite different and can be modified further by cutting regime. For high-merit cow rations with an overload of highly degradable carbohydrates the fibre content and fibre quality become more important than the high energy contents arising from fructan accumulation in the stems. In the future, a different focus on quality breeding goals according to specific cropping and feeding strategies will be necessary.

References

Allen M.S. and Piantoni P. (2014) Carbohydrate nutrition – managing energy intake and partitioning through lactation. *Veterinary Clinics of North America: Food Animal Practice* 30, 577-597.

Oudendag D., Hoogendoorn M. and Jongeneel R. (2014) Agent-based modeling of farming behavior: a case study for milk quota abolishment. In: *Modern Advances in Applied Intelligence*. Springer International Publishing, Heidelberg, Germany, pp. 11-20.

Effect of chloride fertilisation on dietary cation-anion difference forage species

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Abstract

The dietary cation and anion difference (DCAD) is an important property when assessing feed for dry cows in order to avoid hypocalcaemia following calving. Low values of DCAD may reduce the risk of milk fever. DCAD is often calculated as the difference between the cations Na^+ and K^+ and the anions Cl^- and S^{2-}. Research has shown that chloride fertilization may reduce DCAD, and that there might be differences in DCAD between commonly used grass species. In a research project in Central Norway the effects on DCAD of different rates of chloride fertiliser application were investigated. Fertilization with 70, 140 or 210 kg Cl per hectare in calcium chloride did significantly reduce DCAD in forage from leys dominated by timothy and meadow fescue. Pure stands of seven grass species were fertilized with either 0 or 140 kg Cl per hectare in spring. The lowest values of DCAD were found in reed canary grass and perennial ryegrass.

Keywords: anions, cations, DCAD, DM yield, mineral difference

Introduction

Milk fever is the second most common production disease in Norwegian dairy production. In the sixties Norwegian scientists showed that anions in the feed could reduce the risk of milk fever (Ender *et al.* 1971). Rations with low values of DCAD activate the homeostatic regulation of calcium and increase intestinal absorption (Martín-Tereso and Martens, 2014). But anionic salts are not very palatable for cattle and it may thus be difficult to get the cows to eat the products. The most common formula of DCAD is: $([Na^+]+[K^+]) - ([Cl^-]+[S^{2-}])$ in mEq kg^{-1} DM. The contents of K and Cl are easier to manipulate than the contents of Na and S. To prevent hypocalcaemia, the DCAD in rations fed to non-lactating dairy cows 3-4 weeks before calving should be around -50 mEq kg^{-1} (Pelletier *et al.*, 2007). Research has shown that chloride fertilization may reduce DCAD, even to negative values, and that there might be differences in DCAD between commonly used grass species (Pelletier *et al.*, 2007). The results indicated an economically optimal rate in the spring between 78 to 123 kg Cl ha^{-1}. The DCAD decreased with advancing stages of development of the grasses. In a research project in Central Norway the effects of chloride fertiliser application on DCAD in different types of grassland were investigated.

Materials and methods

A fertiliser experiment was established in young leys dominated by timothy and meadow fescue at three sites in Central Norway in 2012. The experimental plots (2×7 m) were fertilised with either a 'normal' amount of potassium (according to soil analyses) or half the level of 'normal'. The application of nitrogen and phosphorus in spring was 120 kg and 17 kg per hectare, respectively. At each level of potassium application, the following amounts of Cl were given as calcium chloride in spring, in three replicates: 0, 70, 140 and 210 kg ha^{-1}. The experiments were harvested in 2012 and 2013 at the first cut about two weeks after start of heading of timothy. A similar field experiment was also established in Central Norway in 2013. Instead of four levels of chloride fertilization, the treatments were: 0 kg Cl, 140 kg Cl ha^{-1} in either calcium chloride or magnesium chloride and 210 kg in calcium chloride. This experiment was harvested in two years. In another type of experiment pure stands of seven grass species were established

at three sites in 2012, and fertilised and harvested in 2013 and 2014. The species were: timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* L.), cocksfoot (*Dactylis glomerata* L.), smooth bromegrass (*Bromus inermis* Leyss.), reed canary grass (*Phalaris arundinacea* L.), perennial ryegrass (*Lolium perenne* L.) and festulolium (*Festulolium*). The plots were fertilised with either zero or 140 kg Cl in calcium chloride. The first cut was harvested about two weeks after start of heading of timothy for all species, except smooth bromegrass and reed canary grass, which were cut one week later. Grass samples were analysed for content of minerals. Dietary cation-anion difference (DCAD), as mEq kg^{-1} DM, was calculated according the following equation:

$$((Na/22.9+K/39.1) - (Cl/35.5+S \times 2/32.07)) \times 1000.$$

Na, K, Cl and S are in g kg^{-1} DM.

Data from the fertiliser experiment (means for three replicates within year and site) were analysed according to an ANOVA with a split-plot design. The fixed factor potassium fertilization rate was on main plots and the fixed factor chloride application rate on sub-plots. Year (1 and 2) and site (1, 2 and 3) were included as random factors in the model. For the trials comparing different species, means for three replicates within each of three sites in one experimental year were subjected to ANOVA. These data were also analysed as a split-plot, with chloride application rate on main plots and grass species on sub plots. Site was included in the model as a random effect.

Results and discussion

Application of potassium and calcium chloride did not affect the dry matter yield in the fertilisation experiments (Table 1). The DCAD and the contents of K, Na and S were not significantly influenced by the level of potassium fertilisation. Application of chloride did lower the DCAD, and increased the content of K and Cl. The difference in DCAD between 140 and 210 kg Cl ha^{-1} was not significant. There was no effect of chloride type on DCAD. Fertilisation with 280 kg Cl ha^{-1} did not decrease DCAD compared to 140 kg Cl.

There were significant differences in DCAD between the species, but there were no effects of Cl fertilisation on DCAD in the different species on average of three field trials in the first year (Table 2).

Table 1. Dietary cation-anion difference (DCAD), content of minerals and dry matter (DM) yield at first cut. Effects of chloride and potassium fertilisation on leys dominated by timothy and meadow fescue. Average of three field trials in two years.

K fertilisation	Cl fertilisation	DM yield (Mg ha^{-1})	DCAD (mEq kg^{-1} DM)	K (g kg^{-1} DM)	Na (g kg^{-1} DM)	Cl (g kg^{-1} DM)	S (g kg^{-1} DM)
Low	0	7.3	151	16.7	0.51	7.5	1.4
	70 kg Cl ha^{-1}	7.3	83	18.2	0.74	11.6	1.4
	140 kg Cl ha^{-1}	7.1	52	18.9	0.72	13.4	1.3
	210 kg Cl ha^{-1}	7.2	43	18.4	0.78	13.3	1.4
Normal	0	7.2	134	19.3	0.48	10.5	1.4
	70 kg Cl ha^{-1}	7.1	110	21.6	0.64	13.5	1.4
	140 kg Cl ha^{-1}	7.3	81	21.2	0.46	14.1	1.4
	210 kg Cl ha^{-1}	6.9	64	21.7	0.48	15.0	1.4
P potassium fertilisation		ns[1]	ns	ns	ns	0.01	ns
P chloride fertilisation		ns	0.00	0.05	ns	0.00	ns
P Cl fertilisation × K fertilisation		ns	ns	ns	ns	ns	ns

[1] ns = not significant.

Table 2. Dietary cation-anion difference (DCAD), content of minerals and dry matter yield at first cut. Effects of chloride fertilisation on different species. Average of three field trials in one year.

Cl fertilisation		DM yield (Mg ha⁻¹)	DCAD (mEq kg⁻¹ DM)	K (g kg⁻¹ DM)	Na (g kg⁻¹ DM)	Cl (g kg⁻¹ DM)	S (g kg⁻¹ DM)
No Cl	timothy	7.2	235	19.3	0.15	6.8	1.2
	mead. fescue	6.5	229	23.1	0.27	9.9	1.6
	cocksfoot	5.9	347	23.9	0.88	7.8	1.5
	smooth bromegrass	7.4	213	16.8	0.27	5.8	1.1
	reed c. grass	6.4	180	19.4	0.20	8.1	1.4
	ryegrass	6.2	268	21.1	1.58	8.9	1.6
	festulolium	6.4	312	25.2	1.10	9.1	1.7
140 kg Cl ha⁻¹	timothy	7.0	110	19.9	0.17	12.3	1.1
	mead. fescue	6.7	154	24.6	0.22	14.4	1.6
	cocksfoot	5.4	156	28.0	1.15	18.3	1.5
	smooth bromegrass	7.0	154	18.7	0.20	10.1	1.1
	reed c. grass	6.9	36	20.4	0.28	13.9	1.5
	ryegrass	6.5	69	23.6	2.25	19.6	1.6
	festulolium	6.6	119	27.2	0.95	17.7	1.6
P chloride fertilisation		ns[1]	ns	ns	ns	ns	ns
P species		ns	0.00	0.00	0.00	0.00	0.00
P chloride fertilisation × species		ns	ns	ns	ns	0.00	ns

[1] ns = not significant.

Without Cl application the DCAD varied from 180 in reed canary grass to 347 in cocksfoot. When Cl was applied the DCAD was about 150 in meadow fescue, cocksfoot and smooth bromegrass. The lowest values were found in perennial ryegrass (69) and reed canary grass (36). In the second year the contents of minerals were analysed only for the treatment with 140 kg Cl ha⁻¹. The differences in DCAD between the species were similar to those of the first year. The grasses timothy, meadow fescue, cocksfoot and smooth brome grass had a DCAD of about 115. The values of perennial ryegrass, festulolium and reed canary grass were 83, 74 and 48, respectively. The differences in DCAD between species may partly be explained by differences in DM yield and time of heading in the first cut.

Conclusions

Chloride fertilisation decreased DCAD in forage significantly to a level suitable for feeding dry cows prior to calving. Although there were differences in DCAD between species, it may be difficult to achieve a sufficiently low DCAD by selecting only species with a low DCAD.

References

Ender F., Dishington I.W. and Helge-Bostad A. (1971) Calcium balance studies in dairy cows under experimental induction and prevention of hypo-calcaemic paresis puerperalis. The solution of the aetiology and the prevention of milk fever by dietary means. *Zeitung für Tierphysiologie. Tierernährung und Futtermittelkunde* 28(5), 233-256.

Martín-Tereso J. and Martens H. (2014) Calcium and magnesium physiology and nutrition in relation to the prevention of milk fever and tetany (dietary management of macrominerals in preventing disease). *Veterinary Clinics of North America: Food Animal Practice* 30(3), 643-670.

Pelletier S., Belanger G., Tremblay G.F., Seguin P., Drapeau R. and Allard G. (2007) Dietary cation-anion difference of Timothy (*Phleum pratense* L.) as influenced by application of chloride and nitrogen fertilizer. *Grass and Forage Science* 62, 66-77.

Establishing trampling-resistant mixed swards: a comparison of four seed mixtures

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Abstract

Increasing herd size often brings major challenges in maintaining dense swards, especially near cow houses. High-quality, trampling-resistant swards are crucial for grazing management, animal welfare and environmental protection. A field experiment initiated in July 2012 (triplicate plots) at Uppsala, Sweden, is comparing four seed mixtures with regard to establishment rate, resistance to trampling and grazing behaviour. The mixtures comprise forage and amenity cultivars of smooth meadow-grass (*Poa pratensis*) and red fescue (*Festuca rubra*), with/without inclusions of white clover (*Trifolium repens*), perennial ryegrass (*Lolium perenne*) and tall fescue (*Festuca arundinacea*). Degree of ground cover was evaluated by spatial analysis of Unmanned Aircraft System photographs (taken May, July, Sept. 2013, April 2014) and field measurements (plants m^{-2}) (August 2012, May 2013). Botanical composition was determined in May 2014. The seed mixture with tall fescue (35% cv. Borneo) established significantly more slowly than other mixtures ($P<0.05$), but by September 2013 had the highest ground cover (70%) due to a high proportion of white clover. In May 2014, all four mixtures had sufficient ground cover after winter (~86%). Next, the treatments will be intensively grazed and trampling resistance and grazing behaviour analysed.

Keywords: seed mixture, establishment, ground cover, spatial analysis, pasture

Introduction

Increasing herd size makes it difficult to maintain dense swards, especially near cow houses, where trampling-resistant swards are crucial for grazing management, animal welfare and environmental protection. In this project, the establishment rate, resistance to trampling and grazing behaviour of four seed mixtures are being compared. Sward establishment is described here. Resistance to grazing/trampling will be reported in early 2016 when two grazing seasons have been completed.

Materials and methods

Four seed mixtures were composed with the objective to find a mixture that would give a persistent sward resistant to trampling. The mixtures were sown randomly in 12 field plots (each 12×36 m^2), with three replicate blocks. Diploid perennial ryegrasses were chosen to give denser swards than tetraploids (Orr *et al.*, 2003). Two mixtures contained white clover, smooth meadow-grass and red fescue, one with perennial ryegrass (A) and the other tall fescue (B) (Table 1). Mixture C was similar to A, but without white clover. Mixture D contained similar proportions of species to C, but used amenity-type (sports turf) varieties, whereas C had forage-type varieties (Table 1). Sowing took place on 6 July 2012 in fertilised (50 kg N ha^{-1}) plots (A-D), adjoining a new ley sown in late May. Total seed rate was 30 kg ha^{-1}.

Sward establishment in each plot was assessed by two methods: (1) Counting the number of plants (grasses and clover) within a quadrat (0.5×0.5 m^2) thrown randomly 3 times per plot on two occasions (August 2012 and May 2013); and (2) determining degree of ground cover by aerial photography. Sward botanical composition was assessed in May 2014 by taking small plant samples from the corners and

Table 1. Seed mixtures used in treatments.

Species	Variety (type)	Seed mixture, %			
		A	B	C	D
Trifolium repens (L.)	White clover	Undrom (small leaves)	20	20		
Poa pratensis (L.)	Smooth meadow-grass	Kupol (forage)	35	35	44	
		Julius (amenity)				44
Festuca rubra (L.)	Red fescue	Gondolin (forage)	10	10	12	
		Cezanne (amenity)				12
Lolium perenne (L.)	Perennial ryegrass	Foxtrot (late, diploid, forage)	35		44	
		Bizet 1 (late, diploid, amenity)				44
Festuca arundinacea (Schreb.)	Tall fescue	Borneo (amenity)		35		

centre of a quadrat (0.3×0.3 m^2) thrown randomly 10 times per plot and determining dry weight (DW) of different species plot-wise. Degree of ground cover/bare soil in photographs taken by an Unmanned Aircraft System in May, July, September 2013 and April 2014 was evaluated by spatial analysis using the programme ArcGIS 10.0 (2013). The results were expressed as a percentage. All data were processed by analysis of variance in a model handling treatment and block as independent variables.

Results and discussion

Despite favourable weather conditions, with regular rain in summer 2012, sward establishment was slow. In August, there were large amounts of annual weeds, mainly common chickweed (*Stellaria media* L.) in the plots. Since the aerial photography could only evaluate ground cover, without distinguishing sown species from weeds, it was not carried out in autumn 2012. However, a count of established plants was made on 25 August (Table 2). The number of plants present had decreased by spring 2013 owing to extensive flooding of the entire study area in early spring, which killed many plants. Since the experiment comprised triplicate blocks with all treatments randomised within blocks, the effects of flooding were probably similar for all plots within blocks. However, significantly fewer plants had germinated in treatment B compared with treatments A-C in August 2012 and fewer plants were recorded in C compared with D plots in May 2013 (Table 2). Tall fescue is known to have slow establishment and an open growth pattern, while perennial ryegrass establishes rapidly and quickly provides ground cover (DairyNZ Farmfact, 2010). Statistical analysis revealed that the number of large, well-developed plants was significantly higher ($P<0.01$) in D plots (10) than in A-C plots.

In 2013 the plots were mowed regularly and dry weather meant that weeds were not a problem for aerial photography. The vegetation analysis based on photographs taken in May 2013 showed that the degree of ground cover was very low, on average 41% (Table 3). This was due to spring flooding. On average, 65% of the surface was covered with vegetation in July 2013, 62% in September 2013 and 86% in April 2014.

Table 2. Number of plants established (m^{-2}) for seed mixtures A-D.[1,2]

Recording occasion	Seed mixture[3]			
	A	B[1]	C	D
25 August 2012	31[a] (2.3)	20[b] (2.9)	29[a] (2.3)	35[a] (2.3)
6 May 2013	17[ab] (2.3)	16[ab] (2.9)	12[b] (2.3)	20[a] (2.3)

[1] One plot (out of three) of treatment B was deleted from the data set due to recording error.

[2] Least squares means (standard error in parenthesis), calculated separately for the two recording occasions. Values within rows with different superscript letters are significantly different ($P<0.05$).

[3] Seed mixtures A-D are described in Table 1.

Table 3. Degree of ground cover (%) in 2013 and spring 2014 for seed mixtures A-D.[1]

	Seed mixture[2]				SE
	A	B	C	D	
17 May 2013	41[ab]	32[b]	37[ab]	47[a]	3.1
17 July 2013	63[b]	71[a]	62[b]	66[ab]	2.2
14 September 2013	58[b]	70[a]	58[b]	63[b]	2.1
30 April 2014	83[a]	89[a]	87[a]	86[a]	2.0

[1] Least squares means and standard errors (SE), calculated separately for each assessment occasion. Values within rows with different letters are significantly different ($P<0.05$).

[2] Seed mixtures A-D are described in Table 1.

In May 2013, seed mixture B gave a significantly lower degree of ground cover than mixture D. At the next assessment, ground cover in B plots had strongly increased and was significantly higher than in A and C plots. In autumn 2013, mixture B covered significantly more of the surface than the other mixtures, but these differences evened out and by spring 2014 there were no significant differences between plots. The botanical analysis in spring 2014 revealed a tendency for a higher proportion of white clover in B plots than in A plots (33% vs 19%, $P<0.059$), most likely as a result of the late start and open sward by tall fescue giving less competition for clover at an early stage of establishment and consequently the observed higher proportion of clover in sward B compared with A. There was no difference in the proportion of ryegrass compared with tall fescue in A and B plots at the time of the botanical analysis in spring 2014. However, the proportion of wilted grasses was significantly higher in A and C plots than in B and D plots (26 and 21% vs 8 and 10%, respectively; $P<0.05$), probably an effect of more wilted grasses in cv. Foxtrot.

Conclusions

The seed mixture with tall fescue (35% cv. Borneo) established significantly more slowly than other mixtures ($P<0.05$), but by September 2013 had the highest ground cover (70%) due to a high proportion of white clover. In May 2014, all four mixtures had sufficient ground coverage after winter (~86%) which provides a basis for trampling-resistant swards.

Acknowledgements

References

ArcGIS (2013) How maximum likelihood works. Available at: http://tinyurl.com/36ukgab.

DairyNZ Farmfact (2010) Tall fescue establishment and management. Available at: http://tinyurl.com/mnja5cj.

Orr R.J., Cook J.E., Champion R.A., Penning P.D. and Rook A.J. (2003) Intake characteristics of perennial ryegrass varieties when grazed by sheep under continuous stocking management. *Euphytica* 134, 247-260.

Controlling docks (*Rumex obtusifolius* L.) using herbicides applied to seedling or established grassland

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Abstract

Docks are a widespread problem associated with intensively managed grassland. The experimental site was reseeded with perennial ryegrass in October 2009. A plot experiment (plots of 5m × 10m) was laid down in a randomised complete block design with nine treatments and eight replicates. Four treatments were each of four herbicides: (1) Linuron + 2,4-DB + MCPA; (2) MCPA + 2,4-DB; (3) CMPP; (4) Fluroxypyr + Triclopyr) applied at the seedling stage (SSH) in April 2010 and another four treatments (5) Amidosulfuron; (6) thifensulfuron; (7) Fluroxypyr + Triclopyr, and (8) Aminopyralid + Fluroxypyr) applied to established grassland (EGH) in April 2012. The ninth was an untreated control. Dock numbers and herbage production were measured over five years (2010-2014). SSH gave more ($P<0.001$) effective, enduring and eco-efficient control than EGH. EGH varied ($P<0.001$) in their effectiveness. In 2014 dock herbage dry matter (DM) production (Mg ha^{-1}) was 3.41 in the control compared with 1.38 for EGH and 0.55 for SSH. Across treatments in 2014 dock herbage suppressed grass herbage DM production (Mg ha^{-1}): grass = 11.17 − 1.047 × dock (R^2=0.73; $P<0.001$). Cost-effective long-term control was achieved by herbicide application during sward establishment.

Keywords: *Rumex obtusifolius*, docks, herbicides, grassland

Introduction

Broad-leaved dock (*Rumex obtusifolius* L.) hereafter described as 'dock' or 'docks' is a very common weed of intensively managed temperate grassland (Hopkins, 1986; Humphreys *et al.*, 1999). At low populations docks are of little consequence to grass production but at higher densities docks reduce the both the productivity of the sward and the intake of grazing animals (Derrick *et al.*, 1993; Hopkins and Johnson, 2003). In intensively managed temperate grassland, the control of docks is almost exclusively by selective herbicides. Control can often be poor and generally short-term with further applications required after a year or so (Hopkins and Johnson, 2003). The Sustainable Use of Pesticides Directive (SUD), Directive 2009/128/EC (Anonymous, 2009), places a legal framework on the general principles of reducing pesticides in agricultural production and the promotion of Integrated Pest Management (IPM). One of the principles of IPM is that herbicides should be targeted at weeds at their most susceptible developmental stage. Most of the published work on herbicide control was carried out on mature docks with very little conducted on seedling docks and the authors are not aware of any experiment comparing the effectiveness of seedling dock and mature dock herbicide treatments. The objectives of this study were to investigate the effectiveness of herbicides applied to seedling docks following grassland renovation or to mature docks in established grassland.

Materials and methods

The experimental site (52°35N, 7°31W and 20 m.a.s.l.) was reseeded with perennial ryegrass in October 2009. A plot experiment (plots 5×10 m) was laid down in a randomised complete block design with nine treatments and eight replicates. Four treatments were each of four herbicides applied at the seedling stage (SSH) in April 2010 and another four treatments applied to established grassland (EGH) in April 2012 (Table 1). The ninth was an untreated control. The herbicide treatments were selected based on approved

Table 1. Herbicide treatments in grassland over five years.

Seedling stage herbicides

1. 3.5 l ha^{-1} Alistell (Linuron 30 g l^{-1} + 2, 4-DB 220 g l^{-1} + MCPA 30 g l^{-1}; United Phosphorus Ltd.)
2. 5.0 l ha^{-1} Legumex DB (MCPA 40 g l^{-1} + 2,4-DB 240 g l^{-1}; Hygeia Chemicals Ltd.) + 10 g ha^{-1} Triad (Tribenuron-methyl 50% w/w; Headland Agrochemicals Ltd.)
3. 2.5 l ha^{-1} Duplosan KV (Mecoprop-P 600 g l^{-1}; Nufarm UK Ltd.)
4. 1.5 l ha^{-1} Doxstar (Fluroxypyr 100 g l^{-1} + Triclopyr 100 g l^{-1}; Dow AgroSciences)

Established grassland herbicides

5. 60 g ha^{-1} Eagle (Amidosulfuron 75% w/w; Bayer Crop Science Ltd.)
6. 22.5 g ha^{-1} Prospect SX (thifensulfuron-methyl 500 g kg^{-1}; Du Pont (UK) Ltd.)
7. 3.0 l ha^{-1} Doxstar (Fluroxypyr 100 g l^{-1} + Triclopyr 100 g l^{-1}; Dow AgroSciences)
8. 2.0 l ha^{-1} Forefront (Aminopyralid 30 g l^{-1} + Fluroxypyr 100 g l^{-1}; Dow AgroSciences)

product registration and all products were applied according to manufacturers' recommendations. In November 2009, dock seedling numbers were assessed in 0.25 m^2 quadrats at 10 m intervals along ten 100 m transects, placed at random positions across the experimental site. On average there were 8.1 seedling docks per m^2, standard deviation = 4.03. Plots were rotationally grazed by dairy cows each spring in February and March and then closed for silage. Silage was harvested in late May and in July. Subsequently, the plots were grazed rotationally by dairy cows for the remainder of the growing season; typically mid-November.

Dock population densities were assessed on two occasions (spring and autumn) each year over the course of five years (2010-2014). The total number of visible dock ramets was counted in each plot. A dock ramet was defined as having at least 4 leaves for the purposes of these assessments. Herbage was harvested for both silage cuts each year using a Haldrup plot harvester (J. Haldrup, Logstor, Denmark). Dry matter (DM) yield of harvested herbage was determined. Herbage from each plot was separated by hand into dock and other herbage before drying at 105 °C for 16 hours to determine the relative proportions of docks and other herbage on a dry-weight basis.

Dock numbers per plot in all nine treatments were subjected to a two-factor (herbicide treatment × sampling date) ANOVA with ramet numbers in April 2010 (prior to herbicide application) as a covariate. The main effects of each factor and interactions between factors were examined. Grass and dock herbage yields were each summed for each year over three years (2012, 2013 and 2014) and subjected to a two-factor (herbicide treatment × year) ANOVA. Relationships were examined using linear regression.

Results and discussion

In the untreated treatments dock numbers decreased initially with the lowest ramet densities recorded in autumn 2011 and during 2012 (Table 2). Subsequently, ramet numbers increased ($P<0.001$) substantially during 2013 and 2014. Following herbicide application SSH gave more ($P<0.001$) effective and enduring control than EGH (Table 2). The substantial increase in ramet numbers during 2013 and 2014 was evident across all treatments and was almost exclusively by clonal propagation. The rate of increase across all plots was proportional to the number of ramets present in each plot in spring 2013: dock numbers in autumn 2014 = 1.78 + 2.87 × dock numbers in spring 2013 (R^2=0.81; $P<0.001$). This substantial increase in ramet numbers, which commenced three and a half years after seedling establishment, has clear implications for the economic consequences of the herbicide treatments. Dock herbage yields increased ($P<0.001$) with dock numbers in 2013 and 2014 ($R^2 = 0.51$). Furthermore in 2014 dock herbage DM production (Mg ha^{-1}) was 3.41 in the untreated control compared with 1.38 for EGH and 0.55 for SSH.

Table 2. Dock ramet densities m^{-2} in grassland over five years.

Sampling dates	Dock ramets m^{-2}								
	Autumn 2010	Spring 2011	Autumn 2011	Spring 2012	Autumn 2012	Spring 2013	Autumn 2013	Spring 2014	Autumn 2014
Untreated	4.53	3.92	3.39	3.59	3.81	3.78	7.84	11.24	11.83
Seedling stage herbicides	Post-application								
1.	1.94	1.59	1.49	1.52	1.69	1.59	3.35	5.25	5.39
2.	1.53	1.30	1.30	1.28	1.49	1.33	2.20	3.08	3.58
3.	1.39	1.99	1.36	1.34	1.55	1.40	2.50	3.59	3.91
4.	0.90	0.37	0.43	0.43	0.43	0.46	0.62	0.85	1.03
Established grassland herbicides	Pre-application				Post-application				
5.	5.08	3.57	3.44	3.45	3.13	3.03	6.57	9.73	11.78
6.	4.47	3.98	3.31	3.38	2.36	2.27	5.31	8.86	9.82
7.	4.60	3.50	3.20	2.91	2.00	1.61	3.51	6.36	7.96
8.	5.38	5.18	3.79	3.84	1.15	0.69	2.86	5.46	5.84
	Herbicide			Sampling date			Herbicide × sampling date		
P-value	<0.001			<0.001			<0.001		
SEM[1]	0.201			0.438			0.604		

[1] SEM = standard error of the means.

Across treatments in 2014 dock herbage suppressed grass herbage DM production (Mg ha^{-1}): grass = 11.17 − 1.047 × dock (R^2=0.73; P<0.001). This relationship was not as strong in each of the earlier years. Impact of docks on grass herbage production increased as the dock became more prominent in swards during the course of the study.

SSH also gave more eco-efficient control than EGH. For example, treatment 4 involved 50% of the application rate of the same active ingredient as treatment 7, whereas the level of control of dock numbers achieved by treatment 4 in 2012, 2013 and 2014 was between 3.5 and 7.7 times better than treatment 7 (Table 2). The SSH targeted at the more vulnerable dock seedlings gave more cost-effective and eco-efficient control, in line with the SUD. It should be recommended to farmers to prioritise the application of post-emergence herbicides during grassland renovation even though the extent of dock problem might not become fully apparent until four years later.

Conclusions

Cost-effective, long-term and eco-efficient control of docks in intensively managed grassland was achieved by herbicide application during sward establishment.

References

Anonymous (2009) Directive 2009/128/EC of the European Parliament and Council of 21 October 2009. Establishing a framework for community action to achieve the sustainable use of pesticides. Available at: http://tinyurl.com/qcn6dff.

Derrick R.W., Moseley G. and Wilman D. (1993) Intake, by sheep, and digestibility of chickweed, dandelion, dock, ribwort and spurrey, compared with perennial ryegrass. *Journal of Agriculture Science* 120, 51-61.

Hopkins A. (1986) Botanical composition of permanent grassland in England and Wales in relation to soil, environment and management factors. *Grass and Forage Science* 41, 237-246.

Hopkins A. and Johnson R.H. (2003) Impact of control of dock (*Rumex obtusifolius*) on potential production from N-fertilised swards. *Grassland Science in Europe* 8, 200-203.

Humphreys J., Jansen T., Culleton N., MacNaeidhe F.S. and Storey T. (1999) Soil potassium supply and *Rumex obtusifolius* and *Rumex crispus* abundance in silage and grazed grassland. *Weed Research* 39, 1-13.

Benchmarking European permanent grassland production and utilization at national and regional levels

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Abstract

Grassland benchmarking was defined within the EIP-Agri Focus Group 'Permanent grassland' as an important subject because within Europe there are differences in grass production between countries and within countries. As yet there has not been clear benchmarking of national grass dry matter production within EU member states. For the grassland community to advance forward with knowledge of how to increase and improve grass dry matter (DM) production, benchmarking and understanding national levels of grass DM production and their differences will be an important first step. The objective of this work is to benchmark real grassland data based on local and regional site conditions, to establish the reasons for differences in grass output, differences in botanical composition, grazing season length, ratio of grazing to cutting and finally to establish a clear view of the level of grazing intensity in different member states. The secondary objective is to establish which grassland tools will work at farm level, to ensure grassland technology are available to improve farmers grassland knowledge and efficiency.

Keywords: grassland performances, benchmarks, pasture based diet, EIP

Introduction

Approximately half of the European Union's land is farmed, highlighting the importance of agriculture on the continent. Utilised agricultural area (UAA) in the EU is defined as the area taken mainly by arable land, permanent grassland and permanent crops (e.g. vineyards). Permanent grassland covers 32% of the UAA with important differences between the member states and differences in economics of grassland use (Huyghe *et al.*, 2014). France, UK and Spain have each over 7 million of hectares of permanent grassland. In 2007, over half of UAA was covered by permanent grassland in Ireland (76%), the UK (63%), Slovenia (59%), Austria (54%), Luxembourg (52%) and Portugal (51%). But not only does the area differ widely, grass utilisation is very variable among member states, as is the expression of ecological, structural, historical and cultural differences. Grazing systems are typically well developed for example in the North-West of Europe (Ireland, UK, France, Belgium, the Netherlands, North of Germany), some parts of the Centre of Europe (Austria), and in many parts of the Southern European countries (Portugal, Spain, South of Italy, Greece). Harvesting grassland for silage and hay is proportionally more important in central Europe (South of Germany, Switzerland, North of Italy) since indoor systems are more widespread in this region, although it is a common practice in other areas where forage conservation is needed.

Grazing systems became more environmentally sustainable as necessitated by the EU Nitrates Directive (1991), Water Framework Directive (2000), Kyoto Protocol (1997), the Soil Thematic strategy (2006), and CAP (2013-2020). Emissions of greenhouse gases (GHG) are a consequence of burning fossil fuel, converting forests and grasslands into arable land, and several other natural processes. Grass-based livestock systems are decreasing in importance in Europe despite the fact that grasslands maintain biodiversity and deliver many ecosystem services like carbon sequestration. Within Europe there are differences between grass production in quantity and quality terms within and between countries. As yet there has never been a clear benchmarking strategy of national grass dry matter production within EU member states. For the grassland community to advance forward with knowledge of how to increase and improve grass dry matter

(DM) production, benchmarking and understanding national levels of grass DM production and their differences will be an important first step. Indeed some countries may not be able to increase grass DM production due to climatic conditions and other major variables (water access, climate, etc.). The reasons why there is variation in DM production due to climate, soil types, types of vegetation and grass quality need to be established, benchmarked and well understood. Grasslands can be quite different in different countries as was shown in the European grassland classification that was recently published (Peeters *et al.*, 2014). This classification was the result of a combined work of the European Grassland Federation (EGF) and the EU-funded project MultiSward. In extensive livestock systems, abundant in European mountain areas and also in the Mediterranean region, permanent grasslands dominate, and it is common to have different grasslands in terms of botanical composition and structure (i.e. gradient from totally herbaceous to plant communities dominated by woody species) in the same rangeland. Factors like variations in geology, topography, microclimate and defoliation (selectivity, intensity and frequency) influence pasture diversity. In these systems, especially in communal areas, different livestock species and breeds graze at the same time with variable overlap in the use of resources depending on flock composition. Grassland overviews of Europe are given in papers of Helgadottir *et al.* (2014) for the North of Europe, Huyghe *et al.* (2014) for Mid Europe and Cosentino *et al.* (2014) for the Mediterranean Region.

If European grassland production continues not to be quantified, how can European grassland regions be assessed and how can the possibilities for any increase of profitability of permanent grassland be evaluated? The establishment of benchmarks will allow differences between European grassland productivity to be established and will allow for a better understanding why they exist and how to overcome their challenges.

Performances and competitiveness of grass

Some of the differences in member state milk production are highlighted in Figure 1, which shows a strong relationship between the total costs of production and the proportion of grass in the dairy cow's diet in a number of countries (Dillon *et al.*, 2005). The relationship shows that the average cost of milk production is reduced by 1 cent l^{-1} for a 2.5% increase in grazed grass in the cow's diet. The data also demonstrate that a considerable proportion of the dairy cows diet (50% +) must comprise grazed grass before a significant impact on cost of production is realized. This objective can be achieved easily in many EU member states. One of the main reasons for stressing the importance of grazing and better use of grass is that it is a home-grown resource and is a cost-effective feed. In Ireland, e.g. the ratio of the cost of grazed grass to that of grass silage and concentrate is 1:3:5; this can vary depending on the price fluctuations. These relationships may vary between all countries and are dependent on market prices for fertilizers, cereals, soybean and all other production inputs. The exact competitiveness of grass also needs to be documented for other member states.
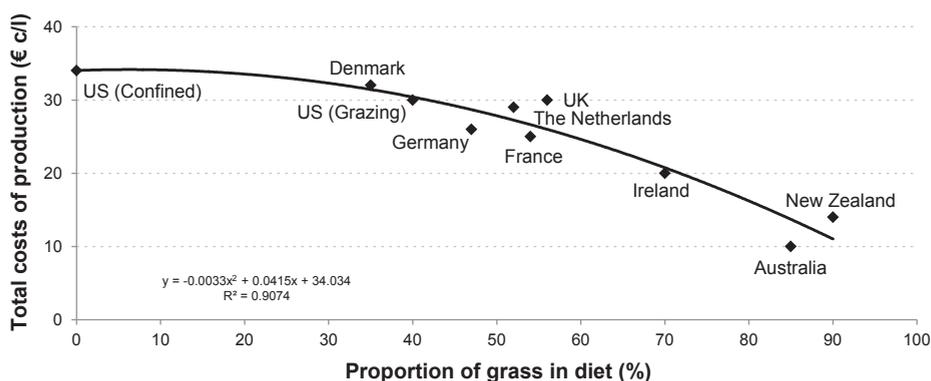

Figure 1. Relationship between total cost of production and proportion of grazed grass in the dairy cow's diet, ranging from total confinement (0% grass) to grass based feed systems (90% grass) (Dillon *et al.*, 2005).

In some countries high-cost milk production systems are based around indoor feeding. From a greenhouse gases viewpoint this is not favourable, as recent publications have stated that grazing systems have low GHG emissions (Del Prado *et al.*, 2014; O'Brien *et al.*, 2012; Soussana *et al.*, 2014). Full-time indoor systems are common in Switzerland, Germany, Denmark, the Netherlands, and Poland. Grazed grass cannot cover all feeding requirements of high yielding cows; they require a combination of grass, possibly other green forages, like e.g. silage maize and concentrates. There are, however, animals genetically suitable for grazing systems, and more grass-based countries are using such animals, i.e. crossbred dairy cows. Farm structure, land price and risk-reduction strategies explain that indoor feeding is most common in some regions. In countries where grazing is important, the management of the grazing season is broken down into the key seasons: spring, mid-summer and autumn. There are different approaches required at these different time periods due to differences in grass demand and supply, even in labour demand. For example, the grazing management required in the spring is focused on managing peak grass supply, whereas in mid-summer the focus is on managing the farm to grow sufficient grass to feed the herd with some pasture. Therefore, different levels of decision supports are required to ensure the produced grass is well utilised (Griffith *et al.*, 2014).

Conclusions

The above analysis highlights the need to benchmark member states for grass DM production and quality and to establish the reasons for differences in grass output, by member state and by region. The second objective is to establish which tools will work at farm level, in which farmers can use within their region or comparable areas to learn from each other and to have proper grassland technology available to improve the grassland knowledge. This work will have to be undertaken both at research and farm levels, which will require a participatory research. This work is a research proposal from the EIP-Agri-Permanent Grassland Focus Group, and it would require EU funding if it were to be undertaken.

Acknowledgements

References

Cosentino S.L., Porqueddu C., Copani V., Patanè C., Testa G., Scordia D. and Melis R. (2014) European grasslands overview: Mediterranean region. *Grassland Science in Europe* 19, 41-56.

Del Prado A., Van den Pol-van Dasselaer A., Chadwick D., Misselbrook T., Sandars D., Audsley E. and Mosquera-Losada M.R. (2014) *Synergies between mitigation and adaptation to climate change in grassland-based farming systems. Grassland Science in Europe 19, 61-74.*

Dillon P., Roche J. R., Shalloo L. and Horan B. (2005) Optimising financial return from grazing in temperate pastures. In: *Proceedings of a satellite workshop of the XX*[th] *International Grassland Congress*, Cork, Ireland, pp. 131-148.

Griffith V., O'Donovan M., Geoghegan A. and Shalloo L. (2014) Pasturebase Ireland – the measurement of grass dry matter production on grassland farms. *Grassland Science in Europe* 19, 279-282.

Helgadottir A., Frankow-Lindberg B.E., Seppaenen M.M., Soegaard K. and Ostrem L. (2014) European grasslands overview: Nordic region. *Grassland Science in Europe* 19, 15-28.

Huyghe C., De Vliegher A., Van Gils B. and Peeters A. (2014) *Grasslands and herbivore production in Europe and effects of common policies*. Quae Editor, Versailles, France, 320 pp.

Huyghe C., De Vliegher A. and Goliński P. (2014) European grasslands overview: temperate region. *Grassland Science in Europe* 19, 29-40.

O'Brien D., Shalloo L., Patton J., Buckley F., Grainger C. and Wallace M. (2012) Evaluation of the effect of accounting method, IPCCv LCA, on grass based and confinement dairy systemson greenhouse gas emissions. *Animal* 6, 1517-1527.

Peeters A., Beaufoy G., Canals R.M., De Vliegher A., Huyghe C., Isselstein J., Jones G., Kessler W., Kirilov A., Mosquera-Losada M., Nilsdottir-Linde N., Parente G., Peyraud J.L., Pickert J., Plantureux S., Porqueddu C., Rataj D., Stypinski P., Tonn B., Van den Poel-van Dasselaer A., Vintu V. and Wilkins R.J. (2014) Grassland term definitions and classifications adapted to the diversity of European grassland-based systems. *Grassland Science in Europe* 19, 743-750.

Soussana J.F., Klumpp K. and Ehrhardt F. (2014) The role of grassland in mitigating climate change. *Grassland Science in Europe* 19, 75-87.

Developing a predictive model for grass growth in grass-based milk production systems

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Abstract

In temperate regions grazed grass is the most economical means of feeding dairy cows. Grass growth is highly variable within and between years. A model capable of simulating daily grass growth depending not only on weather conditions but also on N fertiliser application and farm management would provide valuable information allowing farmers to make better management decisions around supplementation, silage making, fertilisation and grazing. The Moorepark Grass Growth Model (MGGM) is a mechanistic grass growth model developed to take into account weather, soil water and soil N dynamics. The response of the model to weather conditions, frequency of harvesting, initial soil N content and N fertiliser application was evaluated. The responses from the model were comparable with published studies. The MGGM responded coherently to grass harvesting and N fertiliser application and can predict the grass growth rate taking into account management and weather.

Keywords: grass growth model, soil N, fertiliser N, cutting frequency

Introduction

There is increased interest in grass growth prediction due to the low cost of grazed grass as a feed for ruminants in temperate regions (Finneran *et al.*, 2012). In a context of increasing food demand due to global population growth and the need for economic sustainability of grass-based farms, predictive grass growth models can improve the decision-making process at farm level. In temperate climates grass provides the cheapest feed for dairy cows (O'Donovan *et al.*, 2011). Grass growth is highly variable both within and between years (Hurtado-Uria *et al.*, 2013). Existing grass growth models were developed around specific questions, location or to answer key management based decisions. The objective of this study was to develop and evaluate a mechanistic model capable of simulating grass growth in a pasture-based system through the linkage of grass growth model (Jouven *et al.* 2006; Hurtado-Uria, 2013) and a soil N model (Paillette *et al.*, 2014). An internal validation of the model was undertaken to evaluate the capacity of the model to respond to changes in N fertiliser application, different initial quantities of soil mineral N and number of annual herbage harvests.

Materials and methods

This study involved the creation of a dynamic and mechanistic grass growth model (the Moorepark Grass Growth Model; hereafter referred to as MGGM) by adapting an existing grass growth model (Jouven *et al.*, 2006 as adapted by Hurtado-Uria, 2013) and combining it with a soil N and water model (Paillette *et al.*, 2014) (Figure 1). The model described by Jouven *et al.* (2006) was adapted and validated for use in Irish cut grass pastures (Adapted Jouven Model; Hurtado-Uria, 2013). Briefly, the Adapted Jouven Model describes the sward as a homogeneous community characterised by its density, temperature thresholds (minimum, optimum and maximum temperature for growth, and cumulative temperature range for reproductive growth) and leaf composition (specific leaf area, percentage of laminae and leaf lifespan). The sward is divided into green and dead plant material for both vegetative and reproductive parts. The soil N and water model (Paillette *et al.*, 2014) describes the soil water stock (l ha^{-1}; in top 1 m of soil) depending on soil type, precipitation and evapotranspiration, and soil mineral and organic
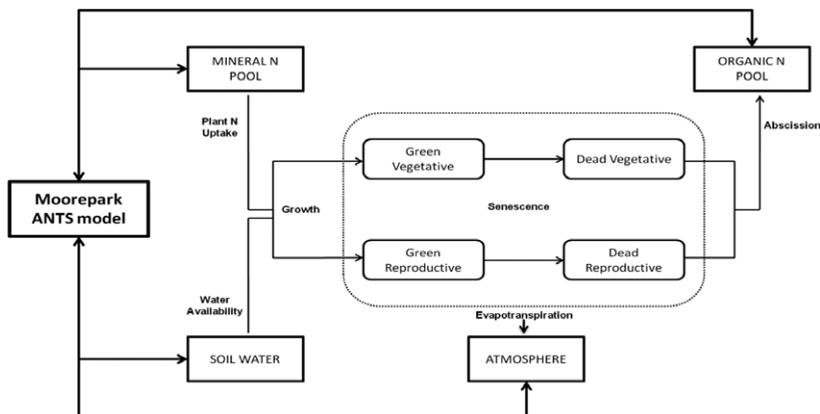
Figure 1. Schematic representation of the Moorepark Grass Growth Model.

N stocks, taking into account N fertiliser application, N recycled during grazing, N exchanges with the atmosphere (volatilization and organic N deposition), N lost through leaching, N mineralization and immobilization, plant N uptake and abscission. Model inputs are soil properties, sward details, farm management (e.g. N fertiliser application, grazing management), and weather data (e.g. temperature, rainfall, solar radiation). Outputs from the MGGM include growth rate (kg dry matter (DM) ha^{-1} day^{-1}), plant N uptake (kg N ha^{-1}) and biomass (kg DM ha^{-1}), as well as the N and water stocks and N losses.

The model was evaluated with six annual N fertiliser levels (0, 100, 200, 300, 400, 500 kg N ha^{-1} year^{-1}) applied in six or eleven applications, and cutting (>4 cm) 6 and 11 times per year. Fertiliser N was applied on 16 February and the day after each cut (for all but the last cut of the year) as 1/6 or 1/11 of total annual N fertiliser at each event. For each management, two initial soil mineral N contents (150 and 250 kg N ha^{-1}) and two years (2010 and 2013) of weather data were tested (the weather data was collected at Teagasc Moorepark, Co. Cork, Ireland, latitude 50°07' North, 8°16' West). Results were compared with published data.

Results and discussion

Frequency of cutting resulted in differences in biomass harvested and average daily growth rate (Table 1). Over all simulations predicted quantity of biomass harvested was 3 Mg DM ha^{-1} greater on paddocks harvested six times compared to paddocks harvested eleven times (11,533 and 9,587 kg DM ha^{-1} year^{-1}, respectively). Average growth rate was 5.4 kg DM ha^{-1} day^{-1} (17%) lower with eleven compared to six harvest events. The decrease in grass growth rate and DM yield described by the MGGM with increasing frequency of defoliation agrees with Pontes *et al.* (2007) as well as the trend reported by Herrmann *et al.* (2005). Total biomass harvested increased with increasing N fertiliser application. Herbage production at 0 N kg N ha^{-1} was 6,416 kg DM ha^{-1}, similar to Hennessy (2005), and increased to 15,088 kg DM ha^{-1} at 500 kg N ha^{-1}. Reid (1970) reported productivity of around 14.5 Mg DM ha^{-1} year^{-1} from grass only pastures receiving 560 to 896 kg N ha^{-1} year^{-1}. Average grass N content was higher under an eleven cut system than under a six cut system, similar to Pontes *et al.* (2007).

Conclusions

The MGGM responded coherently to harvesting and N fertiliser application. To be useful as a management tool, a grass growth model must at least be able to predict the trend of grass growth. The MGGM allows the exploration of the effect of different N fertiliser application or harvesting patterns on grass growth rate.

Table 1. Total biomass mass harvested, average daily grass growth rate, average herbage N content per kg dry matter (DM), average soil N content and end of year soil N content for simulations with different initial soil N contents, different frequencies of defoliation, different levels of N fertiliser application and different yearly weather conditions.

		Total biomass harvested (kg DM ha⁻¹)	Average daily growth rate (kg DM ha⁻¹ day⁻¹)	Average herbage N per kg growth (kg N kg DM⁻¹)	Average soil N content (kg N ha⁻¹)	Soil N content at the end of the year (kg N ha⁻¹)
Initial soil N content (kg N ha⁻¹)	250	10,046	31.7	0.045	202	140
	150	8,201	26.3	0.046	154	129
Number of cutting events	6	10,106	31.7	0.044	180	137
	11	8,142	26.3	0.047	176	131
N fertiliser application rate (kg N ha⁻¹ year⁻¹)	0	5,430	17.6	0.047	112	68
	100	6,472	21.4	0.047	140	97
	200	8,040	26.0	0.046	165	121
	300	9,796	31.1	0.045	189	145
	400	11,626	36.4	0.044	216	172
	500	13,378	41.5	0.043	245	204
Year	2010	9,266	29.1	0.045	175	135
	2013	8,982	29.0	0.045	180	134

Acknowledgements

References

Finneran E., Crosson P., O'Kiely P., Shalloo L., Forristal D. and Wallace M. (2012) Stochastic simulation of the cost of home-produced feeds for ruminant livestock systems. *Journal of Agricultural* Science 150, 123-139.

Hennessy D. (2005) *Manipulation of grass supply to meet feed demand of beef cattle and dairy cows*. PhD thesis. Queens University, Belfast, UK.

Herrmann A., Kelm M., Kornher A. and Taube F. (2005) Performance of grassland under different cutting regimes as affected by sward composition, nitrogen input, soil conditions and weather – a simulation study. *European Journal of Agronomy* 22, 141-158.

Hurtado-Uria C. (2013) *A quantitative analysis of temporal trends in grass growth in Ireland towards the development of predictive models*. Biological Sciences PhD thesis, Cork Institute of Technology, Cork, Ireland.

Hurtado-Uria C., Hennessy D., Shalloo L., O'Connor D. and Delaby L. (2013) Relationships between meteorological data and grass growth over time in the south of Ireland. *Irish Geography* 46, 175-201.

Jouven M., Carrère P. and Baumont R. (2006) Model predicting dynamics of biomass, structure and digestibility of herbage in managed permanent pastures. 1. Model description. *Grass and Forage Science* 61, 112-124.

O'Donovan M., Lewis E. and O'Kiely P. (2011) Requirements of future grass-based ruminant production systems in Ireland. *Irish Journal of Agricultural and Food Research* 50, 1-21.

Paillette C., Delaby L., Shalloo L., O'Connor D. and Hennessy D. (2014) Modelling soil nitrogen and water in a dairy cow grazed pasture. In: *Proceedings Agricultural Research Forum*, Tullamore Court Hotel, 10-11 March 2014, pp. 9.

Pontes LS., Carrère P., Andueza D., Louault F. and Soussana J.F. (2007) Seasonal productivity and nutritive value of temperate grasses found in semi-natural pastures in Europe: responses to cutting frequency and N supply. *Grass and Forage Science* 62, 485-496.

Reid D. (1970) The effects of a wide range of nitrogen application rates on the yields from a perennial ryegrass sward with and without white clover. *Journal of the British Grassland Society* 74, 227-240.

Organic fertilization on mountain grassland

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Abstract

Semi-natural grassland in the Central area of Apuseni Mountains, Romania is fertilized only with organic fertilizers. Manure from cows and horses is applied in quantities of 6 to 10 Mg ha^{-1}. There has been a recent tendency for intensification of grassland close to human settlements and a decline or even abandonment of that located further away. An experiment with four variants was established in order to follow the effect of enhanced inputs of manure on *Festuca rubra* L. grassland, in terms of productivity, quality and biodiversity, as well as to recommend the optimum quantity of fertilizer. Production increased with increasing amounts of manure, but the quality of fodder did not show the same trend. The cover of *Centaurea phrygia* C. A. Mey and *Pimpinella major* L. increased in the treatments with large amounts of manure and these species contributed to significant reductions in fodder quality.

Keywords: organic, mountains, biodiversity, fertilization

Introduction

Manures, as complex fertilizers, have an ameliorative effect on the physical, chemical and biological properties of soil, and their use causes significant increases in crop production (Rotar and Carlier, 2010). Increased production from permanent grasslands can be achieved by applying the most favourable dose of organic fertilizer (Vîntu *et al.*, 2010). Manure has been shown to improve the growth of a number of species, especially those from the forbs category, because of the pool of seeds contained by it (Samuil *et al.*, 2013). The aim of our study is to follow the effect of intensified treatments with organic fertilizer on *Festuca rubra* L. grassland on grassland productivity, quality and species richness and to recommend the optimum dose of organic fertilizer.

Materials and methods

Experimental variants were installed in 2001 and were designed to follow the effect of small and large inputs of manure on grassland productivity and floristic composition. The experimental design was a randomized block method with 4 treatments, in four replications: T1 – unfertilized, T2 – 10 Mg ha^{-1} manure, T3 – 20 Mg ha^{-1} manure, T4 – 30 Mg ha^{-1} manure. The manure contains 3.04 kg Mg^{-1} N, 2.90 kg Mg^{-1} P and 2.47 kg Mg^{-1} K, and was cut once a year. The harvesting period was chosen according to the particular site conditions, located on an altitude of 1,130 m.a.s.l. and characterized by an annual average temperature of 5.2 °C and annual precipitation of 1,123 mm. The floristic composition was determined by the Braun-Blanquet method as modified by Păcurar and Rotar (2014). Floristic data processing was performed with PC-ORD, version 6, which uses the multivariate analysis of the botanical data (McCune and Grace, 2011). For data processing and interpretation we used multidimensional scaling (NMS), which is well suited to data coordination that are not normal or discontinuous (Peck, 2010). Production and quality data, analysed with Boxplots, provides simple graphical representation of the central tendencies of spread in variables with Tukey HSD Test. Sward fodder value was calculated based on species quality score on a scale from 1 (poor) to 9 (excellent), after Dierschke and Briemle (2002), as modified by Păcurar and Rotar (2014). Sward fodder value was performed on a scale from 1 (poor sward, quality dominated by toxic species) to 9 (excellent) after Păcurar and Rotar (2014).

Results and discussion

The intensification of *Festuca rubra* L. grassland management by applying organic fertilizers resulted in an increased dry matter yield (DM, Figure 1). Yield increased asymptotically with fertilizer rate especially when 30 Mg ha^{-1} organic manure was applied (from 1.8 Mg ha^{-1} DM up to 3.5 Mg ha^{-1} DM). The treatment with 20 Mg ha^{-1} organic manure did not show significant differences relative to the unfertilized, while the treatment with 30 Mg ha^{-1} organic manure increased yield by 1 Mg ha^{-1} DM relative to treatment T2 and by 2.7 Mg ha^{-1} DM relative to the unfertilized (T1). The fodder sward value quality has an increasing trend in T2 and T3 compared to T1, but no statistical significance was detected. Treatment T4 caused a significant reduction of fodder sward value quality compared to all treatments. This phenomenon is related to treatment effects on floristic composition.

Under the influence of manure, *Festuca rubra* L. grassland evolved to a *Festuca rubra* L. –*Agrostis capillaris* L. grassland (T2) and further in *Trisetum flavescens* L. grassland (T3, T4, Figure 2). T1 and T2 in the first type of grassland provided a quite high harvest with high quality fodder sward value and a high phytodiversity. These treatments (T1 and T2) favoured Juncaceous species and more oligotrophic species (*Hieracium aurantiacum* L.; *Potentilla erecta* L.) as well as oligo-mesotrophic species (*Agrostis capillaris* L.; *Leucanthemum vulgare* Lam.). T3 and T4 favoured the occurrence of mesotrophic species (*Trifolium pratense* L.; *Trisetum flavescens* L.) as well as *Fabaceae* species. However, the presence of *Fabaceae* did not result in increased in fodder quality, as usually happens when *Fabaceae* species are present. This
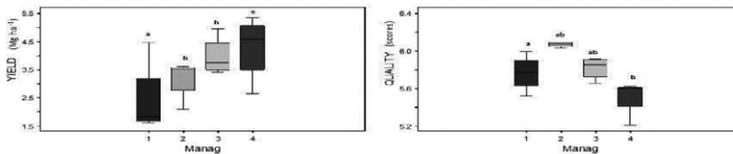
Figure 1. The effect of manuring on DM yield and herbage quality of *Festuca rubra* L. grassland. T1 = unfertilized; T2 = 10 Mg ha^{-1} manure; T3 = 20 Mg ha^{-1} manure; T4 = 30 Mg ha^{-1} manure.
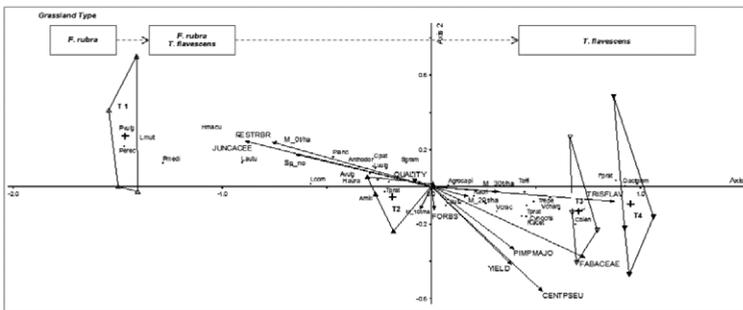
Figure 2. Botanical composition changes under the influence of manure.

Legend: M_oMg ha^{-1} = unfertilized; Sp_no = species number; Amill = *Achillea millefolium* L.; Agrocapi = *Agrostis capillaris* L.; Avulg = *Alchemilla vulgaris* L.; Anthodor = *Anthoxanthum odoratum* L.; Cpat = *Campanula patula* L.; Centpseu = *Centaurea pseudophrygia* C. A. Mey.; Cautu = *Colchicum autumnale* L.; Cbien = *Crepis biennis* L.; Cynocris = *Cynosurus cristatus* L.; Dactglom = *Dactylis glomerata* L.; Festprat = *Festuca pratensis* L.; Festrbr = *Festuca rubra* L.; Haura = *Hieracium aurantiacum* L.; Hmacu = *Hypericum maculatum* Crantz; Lautu = *Leontodon autumnalis* L.; Lvulg = *Leucanthemum vulgare* Lam.; Lcorn = *Lotus corniculatus* L.; Lmult = *Luzula multiflora* Ehrh.; Pimpmajo = *Pimpinella major* L.; Planc = *Plantago lanceolata* L.; Pmedi = *Plantago media* L.; Perec = *Potentilla erecta* L.; Pvulg = *Prunella vulgaris* L.; Racri = *Ranunculus acris* L.; Racet = *Rumex acetosa* L.; Sgram = *Stellaria graminea* L.; Taraoffi = *Taraxacum officinale* Weber ex F.H. Wigg.; Tprat = *Tragopogon pratensis* L.; Tprat = *Trifolium pratense* L.; Trepe = *Trifolium repens* L.; Trisflav= *Trisetum flavescens* L.; Vcham = *Veronica chamaedrys* L.; Vcrac = *Vicia cracca* L.); T1-T4 refers to treatments, Quality = refers to fodder sward value quality.

could be explained by the low proportion in the sward of red and white clover. The strong increase in the proportion of *Centaurea pseudophrygia* C. A. Mey and *Pimpinella major* L. had a negative effect on sward fodder value.

Conclusions

The intensification of *Festuca rubra* L. grassland management is justified in the Apuseni Mountains up to application levels of 10 Mg ha^{-1} manure. This treatment leads to an increase in sward quality and also to a wide phytodiversity of the grassland. The intensification with higher quantities of manure is not justified since they lead to higher yields of herbage of lower sward fodder value.

Acknowledgements

References

Dierschke H. and Briemle G. (2002) *Kulturgrasland. Wiesen, Weiden und verwandte Staudenfluren*. Ulmer, Stuttgart, Germany, 239 pp.

McCune B. and Grace J.B. (2011). *Analysis of ecological communities*. Mjm Software Design, Gleneden Beach, OR, USA, pp. 188-198.

Păcurar F. and Rotar I. (2014) *Metode de studiu și interpretare a vegetației pajiștilor*. Risoprint Publisher, Cluj-Napoca, Romania, 225 pp.

Peck J.E. (2010) *Multivariate analysis for community ecologists: step-by-step using PC-ORD*. MjM Software Design, Gleneden Beach, OR, USA, 162 pp.

Rotar I. and Carlier L. (2010) *Cultura pajiştilor*. Risoprint, Cluj-Napoca, Romania.

Samuil C, Vîntu V., Sirbu C. and Stavarache M. (2013) Influence of fertilizers on the biodiversity of semi-natural grassland in the Eastern Carpathians. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 41(1), 195-200.

Vîntu V., Talpan I., Ionel A. and Samuil C. (2010) Influence of mixture and fertilization on the behaviour of some grasses and perennial legume species on temporary pastures in the Moldavian forest steppe. *Romanian Journal of Grasslands and Forage Crops* 1, 81-91.

Effect of feeding system on cow milk fatty acids composition in a panel of Galician dairy farms

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Abstract

Sixty farms located in the Galicia region (NW Spain) were sampled four times during 2012 and samples of ration ingredients and bulk-tank milk were taken with the objective of studying the relationships between dairy cow ration and the fatty acid (FA) composition of the milk. Diets were grouped into five clusters based on ration ingredients and significant differences among clusters were observed for saturated, polyunsaturated, omega-3 and conjugated linoleic fatty acids, as well as for the omega6-omega3 ratio. In general, milk from grazing extensive systems and from intensive systems based on silage and concentrates supplemented with extruded linseed showed the highest contents of human-health FA. The ability of FA-based discriminant functions for assigning farm tank milk samples to a particular diet was deemed as not satisfactory.

Keywords: authentication, pasture, silage, linseed supplement, milk, fatty acids

Introduction

There is currently an increased consumer demand for information related to consumption of functional foods that may exhibit health benefits beyond their nutritional value. Actual studies focus their efforts on feeding strategies to obtain dairy milk low in saturated fatty acids (SFA), high in polyunsaturated FA (PUFA), low omega6/omega3 ratio and increased levels of certain functional molecules like conjugated linoleic acid (CLA) that matches the actual human-health requirements and which also has a higher market value. The objective of this work was to define 'typical diets' fed on Galician dairy farms and to explore the relationship between diet and fatty acid (FA) composition of the milk, as well as to evaluate the capacity of FA profile for tracing the feeding origin of milk.

Materials and methods

This work was performed on a panel of sixty dairy farms in Galicia (NW Spain) with different levels of intensification. The farms were visited four times (once every three months) during the year 2012. At each visit, an alimentary survey was made that recorded the composition of the diet being consumed by the lactating dairy cows and samples of feed ingredients and bulk tank milk were taken. Diet composition was expressed in terms of percentage of each component of the ration in the total dry matter intake (DMI) by the cows. In the case of grazing animals, pasture intake was estimated as the difference of the DMI and the total dry matter of the ration consumed indoors. DMI (kg d^{-1}) was estimated following the expression DMI = 5.5 + 0.33Y + 0.01LW, where Y is milk yield (l d^{-1}) and liveweight (LW) was fixed as 650 kg. FA composition of milk-tank samples was determined by gas chromatography.

Finally, a data set of 158 observations with diet composition and FA profile was obtained. A cluster analysis of diet data was performed (Proc Cluster of SAS) followed by stepwise discriminant analysis (Proc Stepdisc of SAS) to identify which individual FA showed a better discriminant power for the different clusters, after which discriminant functions for the diet types were constructed (Proc Discrim of SAS) using the selected FA as independent variables. The ability of these functions to correctly assign the diet origin of a given milk sample was checked and ANOVA analysis was performed on clusters diet

composition and representative FA profile, after the transformation of the percentage data by means of the arcsine function.

Results and discussion

Five typical diets were identified by cluster analysis based on the composition of dominant forage source in the ration (grazed pasture, grass silage, maize silage, dry forages, by-products, concentrate) and the use or not of linseed as a concentrate supplement (Table 1). Clusters were identified as: pasture (P) where approximately 50% of DMI was fresh pasture; maize and grass silage (MS+GS), where maize and grass silages accounted by 34 and 22% DMI, respectively; GS, where this forage represented 51% DMI; linseed supplemented maize and grass silages (MS+GS+L), where extruded linseed was almost 3% DMI, and grass silage with by-products (GS+B), where dominant forage was grass silage as in cluster 3 with 9% DMI as by-products (sugar beet pulp). Significant differences among clusters were detected ($P<0.0001$) for the main ingredients of the rations.

SFA percentage was significantly lower ($P<0.0001$) in linseed diets and the highest values were found in the GS+B diets. Linseed and pasture diets showed the highest percentage values for PUFA, omega-3 FA and CLA, whilst unsupplemented maize silage-dominant diets (MS+GS) showed the highest omega-6/omega-3 ratio ($P<0.0001$). The better performance of pasture diets, compared with silage and dry forage diets has been observed by other authors, for example Rouillé and Montourcy (2010) in French dairy farms. In general, milk from extensive systems which include fresh pasture in the diet and from intensive systems based on silage and concentrates supplemented with extruded linseed showed the least-saturated and highest-unsaturated FA profile, which is in accordance with the observations of other authors (Dhiman *et al.,* 1999; Palmquist *et al.*, 1993).

Alpha-linolenic acid ($P<0.0001$), palmitic acid ($P<0.0001$), conjugated linolenic acid ($P<0.0001$), SFA ($P=0.0021$) and myristic acid ($P=0.0068$) were the FA showing the highest discriminant capacity for the five types of diet. Discriminant functions for assigning milk samples to one of the diet types are shown in Table 2. The cross-validation process showed that the percentage of success obtained in the

Table 1. Diet composition and milk fatty acids (FA) composition by cluster.

	Cluster of diet[1,2]					*P*-value
	P (n=48)	MS+GS (n=38)	GS (n=22)	MS+GS+L (n=38)	GS+B (n=12)	
Diet composition (% of each ingredient in total dry matter intake)						
Pasture	45.7[a]	0.94[c]	13.6[b]	2.2[c]	11.4[b]	<0.0001
Grass silage	8.0[d]	21.9[c]	50.5[a]	23.2[c]	35.0[b]	<0.0001
Maize silage	13.9[b]	33.7[a]	1.4[c]	33.0[a]	8.5[b]	<0.0001
Dry forages	9.6[a]	3.6[b]	6.3[ab]	4.7[ab]	8.9[a]	0.0117
By-products	0.3[b]	0.0[b]	0.2[b]	0.0[b]	9.3[a]	<0.0001
Concentrate	22.1[c]	39.6[a]	27.5[b]	33.8[a]	26.9[b]	<0.0001
Extruded linseed	0.1[b]	0.0[b]	0.1[b]	2.9[a]	0.0[b]	<0.0001
Milk fatty acids composition (% total FA unless stated otherwise)[2,3]						
Saturated FA	67.4[bc]	68.0[b]	68.3[ab]	65.8[c]	69.9[a]	<0.0001
PUFA	4.55[a]	4.07[b]	4.03[b]	4.69[a]	4.07[b]	<0.0001
Omega-3 FA	0.88[b]	0.61[d]	0.79[bc]	0.97[a]	0.75[c]	<0.0001
CLA	0.87[a]	0.55[c]	0.68[bc]	0.78[ab]	0.62[c]	<0.0001
Omega-6/-3 ratio	3.3[b]	5.0[a]	3.4[b]	3.0[b]	3.6[b]	<0.0001

[1] P = pasture, MS = Maize silage; GS = Grass silage; L = Linseed supplement; B = by-products.

[2] Means within the same row which are followed by the same letter are not significantly different by Duncan's multiple-range test.

[3] PUFA = polyunsaturated fatty acids; CLA = conjugated linoleic acid.

Table 2. Discriminant functions for each type of diet (top) and percentage of observations assigned to the correct diet (bottom) based on their fatty acid (FA) composition.

Discriminant functions	Cluster of diet[1]				
	P	MS+GS	GS	MS+GS+L	GS+B
Intercept	-820.5	-798.2	-835.0	-786.0	-832.7
α-linolenic acid	4.7	-2.3	3.4	8.1	3.5
Palmitic acid	-17.9	-18.1	-18.3	-18.1	-17.8
Conjugated linolenic acid	126.6	122.6	125.6	120.1	125.1
Total saturated fatty acids	-59.6	-59.5	-61.7	-57.7	-60.4
Myristic acid	42.0	41.8	42.8	41.3	42.3

Initial group	Assigned group				
	P	MS+GS	GS	MS+GS+L	GS+B
P	58	7	19	6	10
MS+GS	5	63	11	8	13
GS	10	10	65	0	15
MS+GS+L	5	0	5	84	5
GS+B	16	0	29	0	55

[1] P = pasture, MS = Maize silage; GS = Grass silage; L = Linseed supplement; B = by-products.

assignation of a given milk sample to the correct diet, when applying the discriminant equations, was low. As can be seen, only 58% of milk samples from the pasture group were correctly assigned to that group. Similarly, only 63, 65, 84 and 55% of the samples initially in MS+GS, GS, MS+GS+L and GS+B groups, respectively, was correctly assigned. This shows that using milk FA composition as the only tool for tracing the dietary origin of tank milk samples from dairy farms is not good enough to be used in practice, which is in concordance with the findings of Capuano *et al.* (2014).

Conclusions

It was possible to define five 'typical diets' in Galician dairy farms based mainly on the predominant forage in the ration. A clear relationship between diet and FA profile of dairy milk was observed. 'Pasture' and 'linseed supplemented' diets type showed a more healthy FA profile. The potential of FA for tracing the dietary origin of tank milk samples from dairy farms seems to be not sufficiently reliable.

References

Capuano E., Van der Veer G., Boerrigter-Eenling R., Elgersma A., Rademaker J., Sterian A. and Van Ruth S.M. (2014) Verification of fresh grass feeding, pasture grazing and organic farming by cows farm milk fatty acid profile. *Food Chemistry* 164, 234-241.

Dhiman T.R., Anand G.R., Satter L.D. and Pariza, M.W. (1999) Conjugated linoleic acid content of milk from cows fed different diets. *Journal Dairy Science* 82, 2146-2156.

Palmquist D.L., Beaulieu A.D. and Barbano D.M. (1993) Feed and animal factors influencing milk fat composition. *Journal Dairy Science* 76, 1753-1771.

Rouillé B. and Montourcy M. (2010) Influence of French dairy feeding systems on cow milk fatty acid composition. *Grassland Science in Europe* 15, 619-621.

Botanical composition of clover-grass silages affects milk yield in dairy cows

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Abstract

The botanical composition of clover-grass silage is said to affect nutritive value and nutrient degradation kinetics. But does the production response of the cow reflect the standard chemical analysis which underlies the determination of feed value, and the morphological differences between grasses and clover? This study aims to investigate the effect of clover-grass silages differing in botanical composition on feed intake and milk yield. A 4×4 Latin square was carried out with first-cut 2013 silages under controlled conditions. Silage based on perennial ryegrass with white clover gave the highest intake and energy-corrected milk (ECM) yield together with a tall fescue-based silage. The latter was surprising, given the general lower organic matter digestibility of tall fescue. Silage based on perennial and hybrid ryegrass with red and white clover produced the lowest intake and ECM. Unexpectedly, the measured variable which correlated best with the results was the content of red clover in the silages: intake and ECM decreased linearly with increasing content of red clover. This may, however, be confounded with effects of grass varieties among treatments. Results indicate that intake and production response may not be described solely by a standard chemical analysis of the silage, and that botanical effects have an effect on the cows.

Keywords: feed efficiency, forage, clover-grass mixtures, red clover

Introduction

High voluntary feed intake, which is of utmost importance for high milk yields, depends, among others, on the physical characteristics and the chemical composition of the forage. In broad terms the content of neutral detergent fibre (NDF) and NDF digestibility of the forage determines feed uptake and organic matter digestibility (OMD) of the formulated ration. It is well known that the digestion properties in the cow of the NDF fraction from forage grasses and legumes are different, and high intake and production potential of clover silages compared with grass silages are reported (Dewhurst *et al.,* 2003; Moorby *et al.,* 2009). However, in previous studies, silages from pure stands of grass and clover have often been prepared and then a graded proportion made on a dry matter (DM) basis. This does not directly apply to farming situations in normal practice, where clover-grass mixtures for silage often consist of many different grass and clover varieties. More knowledge on the botanical effects of clover-grass mixtures on feed intake, milk production, and biology of the cow is needed. The purpose of this investigation was to study the effect of clover grass silages based on 4 different grass mixtures on milk yield and milk composition, as well as feed intake, and seek to elucidate if there are differences between different clover-grass mixtures which cannot be determined by a standard chemical analysis.

Materials and methods

The investigation was based on a feeding trial which was carried out at the Danish Cattle Research Centre (DKC), Aarhus University. To include the variation normally found in clover-grass silage within a grass mixture, sixteen different lots of clover-grass silage based on 4 grass mixtures bought from Danish milk producers were transported to DKC and wrapped. All silages were of the 1st cut of 2013, and all were harvested within a time span of 1 week. The silage from each farmer was typically a mix of up to 3-year leys, but was dependent on a grass mixture. The silages were selected mainly on basis of OMD and DM, and needed to be generally well-fermented. The experimental design was an incomplete replicated 4×4 Latin square with 4 experimental periods of 21 days. 49 Danish Holstein cows in 4 groups according

to lactation number and lactation stage were randomly allocated to treatments. The treatments were clover-grass silage based on the 4 grass mixtures, all of which consisted of perennial ryegrass (PR) and white clover (WC) (Trt 35) but differed with the addition of hybrid ryegrass and red clover (RC) (Trt 42), Festulolium and RC (Trt 45), and tall fescue (Trt 36). These mixtures allows for some comparison to be made between different grass varieties and between red and white clover. Within each treatment, the 4 respective silages were fed to the cows in separate periods. The cows were fed a partial mixed ration (PMR) consisting of clover-grass silage, corn silage, rapeseed cake, soybean meal, barley (rolled), mineral and vitamin premix, and $CaCO_3$. The PMR fed to the cows alone differed in the type of clover-grass silage, which constituted 30% of the PMR on DM basis and was formulated to a crude protein minimum of 16.5% of DM. The forage-to-concentrate ratio was 70:30. The cows were offered 3 kg of concentrate per day in the milking robot. The MIXED procedure in SAS (version 9.3; SAS Institute Inc., Cary, NC, USA) was used for statistical analyses. Treatment, period, and square were described as fixed effects and cow within square and cow within period as random effects. DM intake and milk yield were analysed using the average from the last 7 days of the periods. Data are presented as LSMEANS ± residual errors of the means. Significance was declared at $P \leq 0.05$, and tendencies were considered at $0.05 < P \leq 0.10$. Differences between treatment means were examined using the PDIFF option of the LSMEANS statement. Correlations between relevant variables were made using the PROC CORR statement.

Results and discussion

The cows on Trt 35 and 36 tended to have increased PMR intake compared with cows on Trt 42 and 45 (Table 1). There was no difference in concentrate intake between treatments. The total DM intake turned out significantly lower with Trt 42 compared with Trt 35 and 36.

Similarly, Trt 42 and 45 produced lower milk yield compared with Trt 35 and 36 (Table 2) and Trt 42 alone produced lower energy-corrected milk (ECM) yield than Trt 35 and 36. Nevertheless, the differences in milk yield among treatments were modest. The response on milk yield could not be explained by differences in OMD between clover-grass mixtures as Trt 35 and 36 had the same milk yield but differed in OMD. Indeed, Trt 36 based on tall fescue (75% of grass seed mixture) had on average the lowest OMD (76.8±0.58) while Trt 35 had the highest OMD (79.6±0.78). The lower OMD with Trt 36 was no surprise as tall fescue generally has lower OMD than PR. The rather surprisingly higher milk yield with the tall fescue-based clover-grass silage may be partly related to the fact that the PMR was mixed well in a Cormall horizontal feed mixer for 45 minutes to ensure a homogenous ration and minimize feed sorting at the feeding table. One might speculate that this helped to increase the accessibility and surface area of cell walls for microbial attachment and enzyme activity. Trt 42 produced lower milk fat yield compared with the other treatments, while a tendency for a reduction in milk fat percentage was observed especially with Trt 35, but also with 42. The numerically lower milk fat percentage with Trt 35 may be a result of dilution by increased milk yield. Lower milk fat content with RC silage compared to grass

Table 1. Feed intake with 4 different clover grass mixtures in dairy cows.[1]

	Clover-grass mixture[2]				SEM	*P*-value
	Trt 35	Trt 36	Trt 42	Trt 45		
PMR, kg DM d^{-1}	21.2	21.3	20.8	20.8	0.25	0.08
Concentrate, kg DM d^{-1}	2.4	2.4	2.3	2.3	0.04	0.37
Total feed intake[3], kg DM d^{-1}	23.6^{ac}	23.7^{a}	23.1^{b}	23.2^{bc}	0.25	0.04

[1] PMR = partial mixed ration; DM = dry matter; SEM = standard error of the mean.

[2] Treatments: Trt 35 = perennial ryegrass (PR)-white clover (WC); Trt 36 = tall fescue-PR-WC; Trt 42 = PR-hybrid ryegrass-WC-red clover (RC); Trt 45 = Festulolium-PR-RC-WC.

[3] Values with different superscripts in the same row differ significantly ($P \leq 0.05$).

Table 2. Milk yield and composition, and feed efficiency with 4 different clover-grass mixtures in dairy cows.[1]

	Clover-grass mixture[2]				SEM	P-value
	Trt 35	Trt 36	Trt 42	Trt 45		
Yield[3]						
Milk, kg d^{-1}	38.5[a]	38.3[a]	37.6[b]	37.8[b]	0.7	0.05
ECM, kg d^{-1}	38.6[a]	38.7[a]	37.7[b]	38.2[ba]	0.6	<0.01
Fat, kg d^{-1}	1.53[a]	1.54[a]	1.49[b]	1.53[a]	0.03	<0.01
Protein, kg d^{-1}	1.32[a]	1.31[ab]	1.29[b]	1.29[b]	0.02	0.05
Composition						
Fat, %	3.99	4.07	4.01	4.08	0.06	0.07
Protein, %	3.45	3.44	3.47	3.44	0.03	0.20
Feed efficiency (kg ECM kg^{-1} DM)	1.65	1.64	1.64	1.66	0.02	0.83

[1] ECM = energy-corrected milk yield; DM = dry matter; SEM = standard error of the mean.

[2] Treatments: Trt 35 = perennial ryegrass (PR)-white clover (WC); Trt 36 = tall fescue-PR-WC; Trt 42 = PR-hybrid ryegrass-WC-red clover (RC); Trt 45 = Festulolium-PR-RC-WC.

[3] Values with different superscripts in the same row differ significantly ($P \leq 0.05$).

silage has been observed previously (Steinshamn, 2010) and this red clover effect may help to explain the reduced milk fat concentration with Trt 42. Surprisingly, it was found that the measured variable with best correlation to the milk yield response was the content of red clover in the clover-grass silages (determined by NIRS based on a red clover calibration under development at the authors' own lab). Hence, milk yield decreased linearly with increasing content of red clover. This may be confounded with effects of grass varieties among treatments. Nevertheless, milk fat concentration was not decreased with Trt 45. Milk protein yield was lower with Trt 42 and 45; however, not different from Trt 36. Differences however between treatments were small. Interestingly, feed efficiency (kg ECM kg^{-1} DM) did not differ between treatments.

Conclusions

The investigation showed that feed intake and production response of the cows could not be described solely by a standard chemical analysis of the clover-grass silage. The study indicates that botanical effects may be of importance for the cows, and points to the content of red clover relative to white clover and grasses in silage under farming conditions in practice, as a possible negative factor on feed intake and milk production. The results warrant further investigation.

References

Dewhurst R.J., Fisher W.J, Tweed J.K.S. and Wilkins R.J. (2003) Comparison of grass and legume silages for milk production. 1. Production responses with different levels of concentrate. *Journal of Dairy Science* 86, 2598-2611.

Moorby J.M., Lee M.R.F., Davies D.R., Kim E.J., Nute G.R., Ellis N.M. and Scollan N.D. (2009) Assessment of dietary ratios of red clover and grass silages on milk production and milk quality in dairy cows. *Journal of Dairy Science* 92, 1148-1160.

Steinshamn H. (2010) Effect of forage legumes on feed intake, milk production and milk quality – a review. *Animal Science Papers and Reports* 28, 195-206.

A soil and weather dependent estimator of the soil's capacity to supply nitrogen

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Abstract

The ability of soils to meet nitrogen (N) requirements of grass via mineralization of organic matter is of economic and environmental importance to farmers and society. Soil N mineralization is controlled by soil organic matter dynamics and regulated by water availability and temperature. In the Netherlands, the soil N supply in grasslands is estimated by a statistical model relating N supply to the total amount of N present in soil. We showed that a single N index is insufficient to predict the contribution of N mineralization at field scale, limiting the farmer's possibilities to optimize yields and N-use efficiency. Based on experimental data, we integrated routine soil and climatic parameters in simple empirical models explaining more than 50% of the variation in annual N supply. Combining this information with recent organic manure applications, national fertilizer regulations and optimum N dose-response relationships we showed that the net N efficiency of farming systems can be improved, both on field and farm scale. The developed algorithms are implemented in Dutch advisory systems and will boost the efficiency of N fertilizers.

Keywords: soil N supply, growing season, weather dependency

Introduction

The protein content of grasslands in the Netherlands has decreased from 207 g protein kg^{-1} dry matter in 1996 to around 150 g kg^{-1} nowadays. This decrease has been attributed to the tightening of manure policies, fertilizer use and, consequently, a decrease in the capacity of soils to supply N. Simultaneously, sustainable livestock production systems are increasingly reliant on on-farm production of high quality forages. This requires accurate knowledge of soil N supply (SNS) in order to use the limited amounts of manure and fertilizer optimally. SNS is sensitive to factors controlling the mineralisation potential (e.g. soil properties, geohydrology and manure history) and to environmental conditions. Measuring SNS within the growing season, however, is very laborious, and a more holistic approach is required, which involves the use of combined N indices together with weather data (Dessureault-Rompre *et al.*, 2010; Luce *et al.*, 2011; Ros, 2011). This paper summarizes the results of a 4 year programme entitled 'A novel method in agricultural N management: Unravelling the mystery of natural N release in soils to the benefit of farming and environment' focusing on the integration of routine soil and climatic parameters in the forecast of SNS during the growing season. Currently this approach is implemented in agricultural advisory systems of the main agricultural laboratory of the Netherlands.

Materials and methods

Using a meta-analysis approach, we evaluated the predictive value of most common soil tests (extracting a specific labile N fraction) developed over the last 100 years (using 2,068 observations from 218 papers). The mean correlation coefficient for each soil test was calculated using fixed-effect or random-effect models as implemented in METAWIN 2.0 (Rosenberg *et al.*, 2000). The current approach in the Netherlands (using total N in soil as an estimator of SNS during the season) has been assessed by evaluation of 470 field experiments (227 sand, 98 clay and 145 peat soils) that have been performed during 1960 to 2014.

Based on the collected data, we designed a holistic empirical model combining relevant soil properties with climatic data. The potential soil N supply (under controlled environmental conditions) was quantified using either a combination of soil properties indicative for the labile N pool in soil or a direct approach using Near-infrared reflectance spectroscopy (measuring anaerobic NH_4 production over 14 days at 40 °C). Daily rainfall, evaporation and temperature were derived from nearby weather stations. They were used to correct the potential N supply for the effect of environmental conditions. This correction was made using dimensionless scaling functions for soil water and temperature effects, and mineralization flushes due to rewetting, all derived from published laboratory experiments.

The integrated empirical model was subsequently evaluated on a set of incubation and field experiments, including most relevant soil types in the Netherlands. The mineralisation of N was determined in 100 soils using a classic aerobic incubation assay over a period of 20 weeks. Relevant soil properties were determined, including different kinds of extractable soil organic matter fractions. The mineralisation of N in 44 grassland experiments was determined by the N uptake of unfertilized plots (performed over different years and sites).

Results and discussion

The N uptake in unfertilised mineral grassland soils increased with soil organic matter and total N levels, indicating that these soil properties have some potential to estimate the capacity of soils to supply N. Nevertheless, the statistical power of these models was quite low (Figure 1) showing that uncertainty remains above the 50 kg N ha^{-1}. Variation among years was substantial but not related to changes in manure policies, suggesting that weather conditions are the main factor responsible for strong variability among years. A mean prediction error of 50 to 100 kg N ha^{-1} shows that a direct approach (using one soil test to estimate soil N supply) is not suitable for optimisation of fertiliser management in practice.

The meta-analysis showed that all soil tests were positively related to the potential of soils to supply N. Nevertheless, none of them explained more of the variation in N supply than total N, suggesting that the relationship between both is likely to depend on their mutual relationship with soil organic matter (SOM) (Ros, 2011). It seems evident that an increase in SOM levels increases the capacity of soils to supply N, because there is more substrate available for mineralisation. Similarly, an increase in
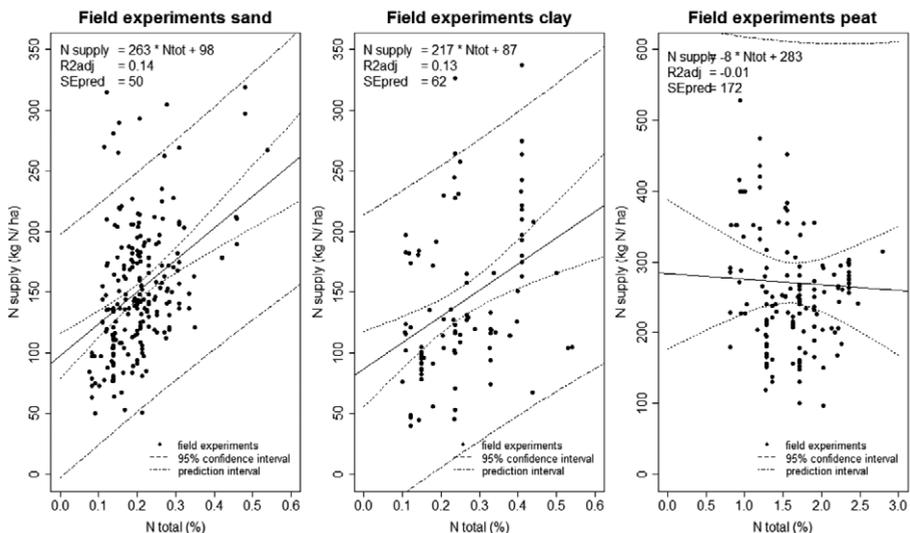

Figure 1. Observed N uptake (or soil N supply) in unfertilised grasslands from field experiments on sand, clay and peat soils (data from experiments performed in 1960 to 2014).

N mineralization rates may increase the levels of depolymerized and recalcitrant by-products; products that have been identified as the main constituents of soil test extractable N. Predictions of SNS were significantly lower for field experiments (R^2<20%) compared to measurements under controlled conditions (R^2>40%). Unfortunately, regression coefficients strongly suggest that the holy grail of an extractable and bioavailable organic matter fraction is likely to remain elusive (Andrén *et al.*, 2008). The variation in regression coefficients might be related to the idiosyncratic response of soil test N and SNS to, for example, a change in climatic conditions and manure history, but these aspects have not yet been investigated. Furthermore, the use of soil tests in sustainable fertiliser programmes requires a more holistic approach accounting for differences in soil organic matter levels (and quality), texture and weather.

Combining soil properties reflecting the soil organic matter content on the one hand, and soil texture on the other resulted in the best estimate of the SNS under controlled environmental conditions (R^2 >0.75). The uncertainty was in most cases smaller than 40 kg N ha^{-1}, giving a more robust and reliable estimate of the SNS than the current Dutch N recommendation system. Similar findings were shown for experiments performed under variable conditions for soil moisture (not shown). Accounting for the variable weather conditions in field experiments had a substantial effect on predicted N supply: annual differences could vary between -20 and +80 kg N ha^{-1} over the period 1960 to 2011. Use of this holistic approach reduced the prediction uncertainty in field experiments by about 10 to 30%: the mean standard error of prediction could be reduced from 30 kg N ha^{-1} down to 10 kg N ha^{-1}.

Conclusions

The meta-analysis and the assessment of the Dutch SNS concept show that the current black-box approach consisting of the evaluation of regression statistics is oversimplified, hampering the search for a reliable and robust estimate of soil N supply. As shown, great progress can be made using a more holistic approach integrating soil properties and weather conditions.

References

Andrén O., Kirchmann H., Kätterer T., Magid J., Paul E.A. and Coleman D.C. (2008) Visions of a more precise soil biology. *European Journal of Soil Science* 59, 380-390.

Dessureault-Rompre J., Zebarth B.J., Burton D.L., Sharifi M., Cooper J.M. and Grant C.A. (2010) Relationships among mineralizable soil nitrogen, soil properties, and climatic indices. *Soil Science Society of America Journal* 74, 1218-1227.

Ros G.H. (2011) *Predicting soil nitrogen supply. Relevance of extractable soil organic matter fractions*. PhD thesis Wageningen University, the Netherlands, 248 pp. Available at: http://edepot.wur.nl/168954.

Rosenberg M.S., Adams D.C. and Gurevitch J. (2000) *MetaWin. Statistical software for meta-analysis*. Version 2.0. Sinauer Associates, Inc., Sunderland, MA, USA.

St Luce M., Whalen J.K., Ziadi N. and Zebarth B.J. (2011) Nitrogen dynamics and indices to predict soil nitrogen supply in humid temperate soils. *Advances in Agronomy* 112, 55-102.

Mineral fertilization on mountain grassland

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Abstract

As seen in other studies conducted over time, mineral fertilization provides an opportunity to improve grassland productivity and fodder quality. The aim of our research is to follow the effect of large amounts of mineral fertilizers on mountain grassland systems (for conditions specific to Apuseni Mountains, Romania) as well as to evaluate if increasing the quantity and quality of sward fodder value is applicable for the highly diverse grassland specific to Apuseni Mountains. The findings come from an experiment with 4 treatments (T1 = control (unfertilized), T2 = $N_{50}P_{25}K_{25}$, T3 = $N_{100}P_{50}K_{50}$, and T4 = $N_{150}P_{75}K_{75}$). Mineral fertilization is directly proportional to dry matter (DM) harvested, which reaches up to 5.38 Mg ha^{-1} DM. As a result, radical floristic changes occurred, *Festuca rubra* L. grassland type evolved into a *Festuca rubra* L. – *Trisetum flavescens* L. grassland, then into *Agrostis capillaris* L. – *Trisetum flavescens* L. grassland and then into one of *Agrostis capillaris* L. grassland type. The high inputs did not result in significant yield increases, but led to the disappearance of *Festuca rubra* L. grassland type and hence its specific diversity. Some nitrophilic species were better installed compared to oligomesotrophic species or oligotrophic species.

Keywords: mineral fertilization, mountains, grasslands, diversity

Introduction

N-fertilization is decreasing in North-West Europe grassland farming, mainly due to legal restrictions (EU directive 91/676/EEC) (Cougnon *et al.*, 2014). Research has shown that applying fertilizers on grasslands is economically justified since, generally, 1 kg of active element results in an increase of 80-100 kg of green matter (Coman and Moisuc, 2011). This economic productivity is also strengthened by the fact that 1 Mg ha^{-1} of dry matter can extract 20-21 kg of N, 6-8 kg of P, 20-21 kg of K and 10-14 kg of Ca. The aim of our research is to follow the effect of an intensified management with large quantities of mineral fertilizer on mountain grasslands (Apuseni Mountains, Romania) and to evaluate if this method of increasing the quantity and quality of sward fodder value is suitable for grassland phytodiversity in the Apuseni Mountains.

Materials and methods

The experimental variants designed to follow the effect of small and large inputs of mineral fertilizer on grassland productivity and floristic composition were installed in 2001, in the Apuseni Mountains, Romania. The experimental design was made according to the randomized block method in four replications (blocks), with 4 treatments: T1=control (unfertilized), T2 = $N_{50}P_{25}K_{25}$, T3 = $N_{100}P_{50}K_{50}$, and T4 = $N_{150}P_{75}K_{75}$, which included 1 cut per year at the end of July. The experimental site is located on an altitude of 1130 m.a.s.l. and characterized by an annual average temperature of 5.2 °C and annual precipitation of 1123 mm. Floristic composition was determined after the Bran-Blanquet method modified by Păcurar and Rotar (2014). Floristic data processing was performed with PC-ORD, version 6, which uses multivariate analysis of the ecological data entered into the spreadsheet (McCune and Grace, 2011). For data interpretation we used Principal Coordinates Analysis. In PCoA one can use any square symmetrical distance matrix, including semi-metrics such as Sorensen distance, as well as metric distance measures such as Euclidean distance (Peck, 2010). Production and quality data were analysed with Boxplots which provide simple graphical representation of the central tendencies of spread

in variables with Tukey HSD Test. Sward fodder value was calculated based on species quality score on a scale from 1 (poor-) to 9 (excellent), after Dierschke and Briemle (2002), as modified by Păcurar and Rotar (2014). Sward fodder value was performed on a scale from 1 (poor sward quality dominated by toxic species) to 9 (excellent) after Păcurar and Rotar (2014).

Results and discussion

Treatments with mineral fertilizers caused linear increases in yields (statistically assured), from 2.2 Mg ha^{-1} DM (T1) to 5.3 Mg ha^{-1} DM (T4, Figure 1). The sward quality of T3 has a general tendency to increase which is proportional to the grassland intensification. On T2 we recorded 3.58 Mg ha^{-1} and on T3 4.49 Mg ha^{-1}. The highest quality was observed in T2, followed by T4 and then T3. Floristic composition of *Festuca rubra* L. grassland is modified under the influence of mineral fertilization (Figure 2). Under the influence of mineral fertilizer, *Festuca rubra* L. grassland evolved to a *Festuca rubra* L. – *Trisetum flavescens* L. grassland (T2) and further to an *Agrostis capillaris* L.-*Trisetum flavescens* L. grassland (T3) and an *Agrostis capillaris* L. grassland (T4, when N$_{150}$P$_{75}$K$_{75}$ were applied). T1 and T2 favoured a wide diversity with oligotrophic and oligo-mesotrophic species and with a large contribution of Fabaceae species. The other two treatments (T3 and T4) favour a stronger increased contribution of
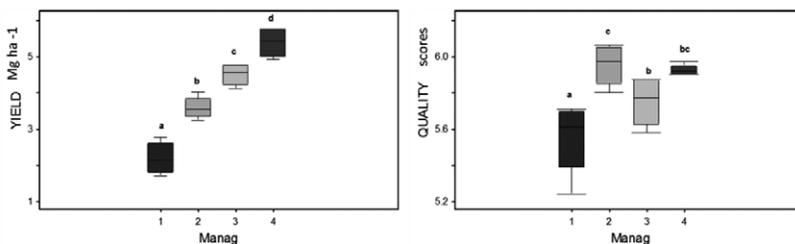

Figure 1. The effect of mineral intensification upon DM and quality on *Festuca rubra* L. grassland type.
Legend: Manag= management; Yield =Mg ha^{-1}; 1=control, T2= 50 kg ha^{-1} N; 25 kg ha^{-1} P; 25 kg ha^{-1} K, T3=100 kg ha^{-1} N; 50 kg ha^{-1} P; 50 kg ha^{-1} K; T4= 150 kg ha^{-1} N; 75 kg ha^{-1} P; 75 kg ha^{-1} K.
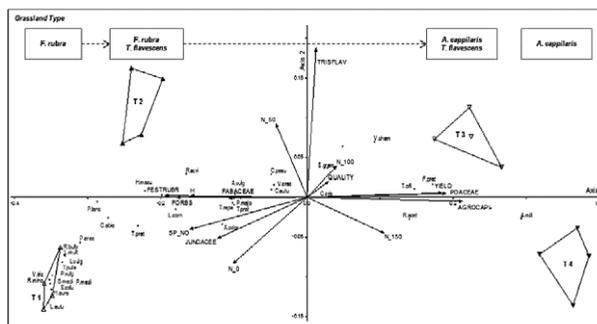

Figure 2 Botanical composition changes under the influence of mineral fertilization
Legend: T=treatments; Amill = *Achillea millefolium* L., Agrocapi= *Agrostis capillaris* L.; Avulg= *Alchemilla vulgaris* L.; Anthodor= *Anthoxanthum odoratum* L.; Bmedi = *Briza media* L.; Cabie= *Campanula abietina* Griseb.;Centpseu = *Centaurea pseudophrygia* C. A. Mey., Cautu = *Colchicum autumnale* L., Ceris = *Cirsium erisithales* Jacq.; Festprat = *Festuca pratensis* L., Festrbr= *Festuca rubra* L.; Haura = *Hieracium aurantiacum* L., Hmacu= *Hypericum maculatum* Crantz; Lautu =*Leontodon autumnalis* L., Lvulg =*Leucanthemum vulgare* Lam., Lcorn = *Lotus corniculatus* L., Lmult = *Luzula multiflora* Ehrh.; Pimpmajo = *Pimpinella major* L., Planc = *Plantago lanceolata* L., Pmedi = *Plantago media* L.; Pvulg = *Prunella vulgaris* L., Racri = *Ranunculus acris* L.; Rbulb = *Ranunculus bulbosus* L.; Rmino = *Rhinanthus minor* L.; Racet = *Rumex acetosa* L.; Sgram = *Stellaria graminea* L.; Scolu = *Scabiosa columbaria* L., Toffi = *Taraxacum officinale* Weber ex F.H.Wigg.; Tpule = *Thymus pulegiodes* L.; Tprat = *Tragopogon pratensis* L., Tprat = *Trifolium pratense* L., Trepe = *Trifolium repens* L., Trisflav= *Trisetum flavescens* L.; Vcham = *Veronica chamaedrys* L.; Vcrac= *Vicia cracca* L.; Vtric = *Viola tricolor*)

Poaceae and reduced Fabaceae species. Due to the decline of phyto-diversity, *Agrostis capillaris* L species became dominant. The presence of Fabaceae species and also the presence of *Trisetum flavescens* L. ensure a high quality on T2. In the T3 treatment, the presence of *Trisetum flavescens* L. and *Agrostis capillaris* L. determined the sward fodder value score, while in T4 the sward fodder value score is almost exclusively due to *Agrostis capillaris* L.

Conclusion

The results showed that increasing dry matter yield (DM) does not necessarily mean a corresponding increase in sward fodder value quality. Small amounts of fertilizers can sometimes cause a large increase in quality as a result of the installation of mesotrophic species and a favourable substrate for Fabaceae. For the specific conditions of the Apuseni Mountains, for the *Festuca rubra* L. grassland type we recommend treatments T2 or T3 or a solution found between their boundaries.

References

Coman M. and Moisuc A. (2011) Bibliographic study of the impact of fertilization on permanent grassland. *Research Journal of Agricultural Science* 43(4), 33-39.

Cougnon M., Baert J. and Reheul D. (2014) Dry matter yield and digestibility of five cool season forage grass species under contrasting N fertilizations. *Grassland Science in Europe* 19, 175-177.

Dierschke H. and Briemle G. (2002) *Kulturgrasland. Wiesen, Weiden und verwandte Staudenfluren*. Ulmer, Stuttgart, Germany, pp. 239-241.

McCune B and Grace J.B. (2011) *Analysis of ecological communities*. Mjm Software Design, Gleneden Beach, OR, USA, pp. 188-198.

Peck J.E. (2010) *Multivariate analysis for community ecologists: step-by-step using PC-ORD*. MjM Software Design, Gleneden Beach, OR, USA, pp. 162-165.

Păcurar F. and Rotar I. (2014) Metode de studiu şi interpretare a vegetaţiei pajiştilor. Risoprint Publisher, Cluj-Napoca, Romania, pp. 225-228.

The development of yield and digestibility of a grass mixture during primary growth and regrowth

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Abstract

Development of yield and digestibility of grass leys was studied in Maaninka, Finland during the 2014 growing season. A field plot of 8 ha was sown in 2013 using a mixture of timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.) and perennial ryegrass (*Lolium perenne* L.). The field was divided into two sectors according to the timing of the first harvest. The early first cut was taken on 10 June and the late first cut on 23 June. Four sampling points were used per sector. Samples were taken around the first cut and during the regrowth approximately every fifth day. Digestibility of grass (D-value) was determined by near-infrared spectrometry. The primary cut produced higher dry matter yield than the regrowth. A low grass growth rate during the regrowth was partly compensated for by using a long growing period. The D-value of grass decreased almost at the same rate in both the primary growth and the beginning of the regrowth period. The D-value of regrowth increased at the end of growing period. Thus the rate of decrease of the D-value of the regrowth depends on the observation period.

Keywords: grass, D-value, growth model, harvest timing, yield

Introduction

Comparisons between different harvesting strategies require information about changes in grass growth rate and digestibility. These changes depend on the timing of harvest and the period of the growing season, as well as forage species. Time-series studies are needed to explore parameters for grass growth models. The development of yield and digestibility of grass leys was studied in Maaninka (63°08' N, 27°19' E), Finland during the 2014 growing season. This paper reports on part of a larger milk production study, results of which will be reported elsewhere.

Materials and methods

An 8-ha field plot was sown in 2013 using a mixture of timothy (*Phleum pratense* L.), meadow fescue (*Festuca pratensis* Huds.) and perennial ryegrass (*Lolium perenne* L.). The field was divided into two sectors according to the timing of the first harvest. The early first cut was taken on 10 June and the late first cut on 23 June. There were four separate sampling points per sector. Two subsamples (2×0.25 m^2) were taken from each sampling point before and after the early (E) and late (L) harvest approximately every fifth day. The development of the regrowth of E (ER) and the regrowth of L (LR) were also studied by taking samples by a similar procedure to the primary growth sampling. Dates of first and last sampling and the number of sampling dates in each time series (E, L, ER, EL) are presented in Table 1.

The yield and dry matter content (DM) were measured from both subsamples and the average was used. Grass digestibility (D-value; g digestible organic matter in DM) was determined with near-infrared spectrometry (Valio Ltd, Seinäjoki, Finland). The growth-affected temperature sum (growing degree days, GDD, °C d, the base 5 °C) was measured by the Finnish Meteorological Institute weather station at Maaninka. The GDD for treatments E and L was calculated by starting from the beginning of the growing season and for the ER and LR from the day of the first harvests.

Table 1. The first and the last sampling dates, growth-affected temperature sums (GDD) and the number of sampling times of each time series.

	First sampling		Last sampling		Sampling times
	Date	GDD, °C d	Date	GDD, °C d	
E	9 June	286	18 June	343	3
L	13 June	323	4 July	447	5
ER	7 July	194	8 August	695	7
LR	21 July	315	12 September	943	11

Statistical analysis was performed by analysis of covariance using the Mixed procedure of SAS 9.3. The model contained continuous terms GDD and GDD^2, a categorical term time series and the interaction-term of GDD and time series.

Results and discussion

GDD and GDD^2 significantly explained the DM yield. The first DM yield measurement for E was missed, therefore E remained without reliable information about grass growth rate. However, the growth rate of E should be similar to that of L because of the same growing history. The primary yield increased until the last sampling date on 4 July (Figure 1) owing to the relatively low growth rate, 129 kg DM d^{-1} compared to 191 kg DM d^{-1} reported earlier for Finland (Rinne *et al.*, 2010). The lower accumulation of GDD (-90 °C d between 13 June and 4 July) compared to long-term average can explain the difference.

Typically, on commercial farms the regrowth yield is lower compared to the first cut. This is a consequence of low grass growth rate in the second cut, which was 80 kg DM d^{-1} in this study. The slope of L differed from the slopes of ER and LR (P=0.002) and the yield increase reached a plateau at 6,000 kg DM ha^{-1} in LR, whereas the increase in L did not have a break point. Thus L would produce maximal DM yield during the growing season. A low growth rate during the regrowth would be compensated by a long growing period so that the yield of the first and second cuts would be comparable, despite the timing of harvest in the first cut (Figure 1), if the timing of harvest stays within reasonable limits.

The D-value decreased on average by -2.6 g d^{-1} in treatments E and L, which is low compared with the value of -5 g d^{-1} reported by Rinne *et al.* (2010). This is a consistent result with the low growth rate of L. According to Rinne *et al.* (2010) the GDD gives a relatively good estimate for changes in D-value of the grass (R^2=0.82). Exceptionally cool weather in June and/or the presence of perennial ryegrass in the mixture could have slowed down the rate of decrease of D value in the first cut.
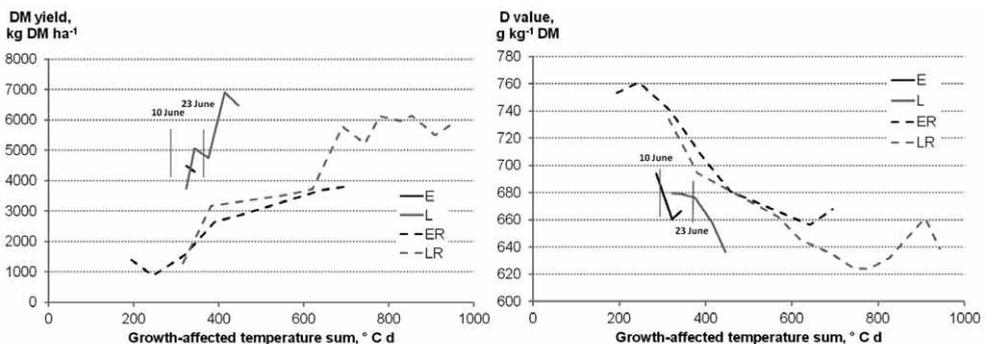

Figure 1. The effect of growth-affected temperature sum (°C d) on grass dry matter (DM) yield and D-value. The vertical lines represents harvesting dates of early (E) and late (L) first cut. R = regrowth yield.

At the beginning of the regrowth period the decrease in grass D-value, -3.4 g d^{-1}, was exceptionally high compared to the average of -1.2 g d^{-1} reported by Kuoppala (2010) for regrowth of timothy or timothy-meadow fescue swards. The slopes of series between primary and regrowth did not differ (not significant). The change in D-value was quadratic ($P<0.001$ for GDD^2) showing an increase at the end of season and the average decrease was -1.8 g d^{-1} during the regrowth sampling period. At the end of the growing season the changes in both yield and digestibility of the grass are moderate; at this period growing tillers and senescence counterbalance each other.

Conclusions

The primary cut produced higher DM yield compared with that of the regrowth. A low daily grass-growth rate during regrowth was partly compensated by a long growing period. The D-value of grass decreased almost at the same rate in both the primary growth and at the beginning of the regrowth period. The D-value of regrowth increased at the end of the growing period. Thus the rate of decrease of D-value of the regrowth depends on the observation period.

References

Rinne M., Pitkänen T., Nyholm L., Nousiainen J. and Huhtanen P. (2010) Nurmiheinien ensimmäisen sadon sulavuuden ja sadon määrän mallit nurmirehuntuotannon hallintaan. In: Hopponen A. (eds) *Maataloustieteen päivät 2010, 12.-13.1.2010 Viikki, Helsinki: esitelmät, posterit. Suomen maataloustieteellisen seuran tiedote 26.* 9 p.

Kuoppala K. (2010) *Influence of harvesting strategy on nutrient supply and production of dairy cows consuming diets based on grass and red clover silage.* PhD thesis. MTT Science 11. MTT Agrifood Research Finland, Jokioinen, Finland, 99 pp.

High productivity of perennial grasses with alfalfa mixtures in North-Eastern Romania

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Abstract

The current tendency is for intensification of livestock farming, pursuing continuous improvement of quantitative and qualitative performance of products. Intensification of meadows can be achieved through the use of valuable species, highly productive varieties of perennial grasses and legumes, by cultivating perennial grasses and legumes in mixtures and by proper management of meadows. Unlike pure cultures, mixing alfalfa with orchard grass provides a more balanced energy-protein feed, while providing the opportunity of ensiling alfalfa in good condition due to the contribution of soluble carbohydrates provided by the orchard grass. The purpose of this research was the capitalization of pure-crop alfalfa and mixed crop of alfalfa with orchard grass as succulent fodder packed in bales. Objectives and activities are represented by quantifying the quantitative elements which express the quantitative value, as well as the elements which express the qualitative value of fodder. The highest average yields achieved over three years, for all three mixtures tested, were obtained by fertilizing with $N_{100}P_{50}$ kg ha^{-1}. The quality of the fodder was influenced by the proportions of the two species in the mixture and by the level of fertilisation.

Keywords: ensiled fodder, fertilization, production, wilting, quality

Introduction

Intensification of meadows can be achieved through the use of valuable species, highly productive varieties of perennial grasses and legumes, by cultivating perennial grasses and legumes in mixtures, by agrotechnical measures and by proper management of meadows. Unlike pure cultures, alfalfa with orchard grass provides a more balanced energy-protein feed, while providing the opportunity of ensiling alfalfa in good condition due to the contribution of soluble carbohydrates from the grass. The idea of approaching the performance of temporary meadows established on the basis of mixtures of perennial grasses and legumes on various agricultural fields was imposed by the need to supplement the production of fodder obtained from permanent grasslands. Alfalfa is widely used in mixtures, because it yields high quality crops, even in less favourable climatic conditions (Nyfeler *et al.*, 2008; Smit *et al.*, 2008; Thumm 2008; Vrotniakiene and Jatkauskas, 2010). This paper presents the results for three alfalfa-orchard grass mixtures used for the production of ensiled forage, cropped under differentiated fertilization, in terms of dry matter production and fodder quality.

Materials and methods

The experiment was set up on the Ezareni farm in the spring of 2010. It was located on a field with a slope of 10°, an altitude of 107 m, on a cambic chernozem soil, with a pH value of 6.7-6.8, and 2.73 to 2.93% content of humus, 21-25 mg l^{-1} P_{AL}, 226-232 mg l^{-1} K_{AL} and 112-139 mg l^{-1} CaO. The weather conditions during the experiment were characterized by an average annual temperature of 9.5 °C and annual rainfall of 552.4 mm. In all experimental years, the distribution of rainfall during the vegetation period was extremely irregular, which presented problems concerning grass growth and recovery after harvest. The experiment was bifactorial, arranged in a split-plot design, in four replicates, plot size of 19 m × 5 m. The main experimental factor was represented by the type of species mixture, whereas the second factor was represented by fertilization. Were tested alfalfa-orchard grass mixtures, with varying degrees of participation: a_1 – alfalfa 100%, a_2 – alfalfa 75% + orchard grass 25%; a_3 – alfalfa 50% + orchard grass

50%. Fertilization treatments were as follows: b_1 – unfertilized control, b_2 – $N_{50}P_{50}$ kg ha^{-1}; b_3 – $N_{75}P_{50}$ kg ha^{-1}; b_4 – $N_{100}P_{50}$ kg ha^{-1}. The sampling depended on the mixture and rate of fertilizers. The mixtures were harvested during the flowering stage of the alfalfa. The yields obtained were weighed and biomass samples were harvested in order to determine the dry matter (DM) content and to perform chemical analyses of the forage. The data on yield and chemical composition were analysed by ANOVA and by comparison with the Least Significant Differences.

Results and discussion

Production and chemical composition of herbage before ensiling are presented in Table 1. Mixing alfalfa with orchard grass without fertilization decreased both the fresh fodder crude protein (CP) content and the yield of CP, but for fertilization treatments of $N_{75}P_{50}$ and $N_{100}P_{50}$ both mixtures of species showed significant increases compared to the control. Production mean values were between 8.2 and 9.2 Mg DM ha^{-1} for a_1, 8.0 and 8.4 Mg DM ha^{-1} for a_2, 7.3 and 8.2 Mg DM ha^{-1} for a_3. The quality of feed was influenced by the species components, their proportions in the mixture, and the type and level of fertilization (Table 1). The crude protein content of the fodder increased with increasing percentage contribution of alfalfa, especially when combined with fertilizer application. The mixture consisting of alfalfa 75% with 25% orchard grass showed an average total yield of CP ranging between 1,279 kg ha^{-1} and 1,372 kg ha^{-1} being close to that of the control (1,385 kg ha^{-1}). Total average CP yields recorded for the mixture consisting of 50% alfalfa with 50% orchard grass ranged between 1,186 kg ha^{-1} in the absence of fertilization and 1,225 kg ha^{-1}, when fertilized with $N_{100}P_{50}$. The Ca/P ratio was good for all the fodder mixtures, and all four types of fertilization, and did not drop below the minimum threshold of 2.8. The content of neutral detergent fibre and acid detergent fibre was influenced by the percentage contribution of alfalfa in the fodder mixture and by the rate of fertilization.

The quality of ensiled feed was influenced by the species components, their proportions in the mixture and the type and level of fertilization (Table 2). For the mineral content in fresh fodder, higher values of Ash, Ca and Mg were recorded in pure-crop alfalfa fertilized variants, followed by lower fertilized variants

Table 1. Production and chemical composition of the fodder before silaging.[1]

Mixture[2]	Fertilisation[3]	DM (Mg ha^{-1})	CP (kg ha^{-1})	CP (g kg^{-1})	NDF (g kg^{-1})	ADF (g kg^{-1})	Ca (g kg^{-1})	P (g kg^{-1})	Mg (g kg^{-1})	Ca/P
a_1	b_1	8.2	1,385	178.1	397.3	317.3	124.2	27.4	28.1	4.5
	b_2	8.5	1,434	181.5	424.3	339.2	127.1	29.1	28.7	4.4
	b_3	8.7	1,463	184.4	440.6	352.3	129.4	30.1	29.3	4.3
	b_4	9.2	1,486	187.8	458.7	366.3	131.3	30.8	29.5	4.3
a_2	b_1	8.0	1,279	169.1	128.7	327.1	113.4	28.4	27.7	4.0
	b_2	7.9	1,305	172.3	161.0	353.4	106.7	29.8	27.1	3.6
	b_3	8.3	1,324	175.8	485.7	372.2	100.1	30.6	26.2	3.3
	b_4	8.4	1,327	178.2	508.2	389.5	97.3	31.2	25.1	3.1
a_3	b_1	7.3	1,186	160.4	449.4	332.9	111.3	29.3	27.4	3.8
	b_2	7.7	1,201	163.3	488.0	362.3	102.9	30.7	26.2	3.4
	b_3	8.0	1,220	167.9	518.4	385.6	94.3	31.6	25.2	3.0
	b_4	8.2	1,225	171.4	545.1	405.5	89.4	32.1	24.4	2.8
LSD 0.1%		1.1	50	4.6	27.4	22.8	6.7	1.7	1.3	

[1] DM = dry matter; CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; LSD = least significant difference.

[2] Mixture: a_1 – alfalfa 100%, a_2 – alfalfa 75% + orchard grass 25%; a_3 – alfalfa 50% + orchard grass 50%.

[3] Fertilization treatments: b_1 – unfertilized control; b_2 – $N_{50}P_{50}$ kg ha^{-1}; b_3 – $N_{75}P_{50}$ kg ha^{-1}; b_4 – $N_{100}P_{50}$ kg ha^{-1}.

Table 2. Chemical composition and fermentation parameters of grass-legume silage.[1]

Mixture[2]	Fertilisation[3]	CP (g kg^{-1})	NDF (g kg^{-1})	ADF (g kg^{-1})	Ca (g kg^{-1})	P (g kg^{-1})	Mg (g kg^{-1})	pH	Acetic acid (g kg^{-1})	Lactic acid (g kg^{-1})	Butyric acid (g kg^{-1})	Total acids (g kg^{-1})
a_1	b_1	164.2	413.7	339.1	116.5	25.9	26.1	4.6	26.7	39.6	1.5	67.8
	b_2	167.6	441.6	361.3	118.8	27.4	26.3	4.7	27.1	36.7	2.2	66.0
	b_3	170.1	459.2	375.0	120.6	28.0	26.6	4.8	27.5	33.5	3.1	64.1
	b_4	172.4	478.5	389.4	121.8	28.4	26.3	4.8	28.2	30.6	3.8	62.6
a_2	b_1	157.4	444.2	348.8	105.9	26.8	25.9	4.5	26.3	44.8	0.8	71.9
	b_2	162.7	475.1	374.7	99.8	28.4	25.5	4.3	24.5	47.6	0.1	72.2
	b_3	167.9	498.9	393.3	93.4	29.6	25.0	4.3	21.2	51.8	0.1	73.1
	b_4	172.4	520.0	410.2	91.2	30.3	24.2	4.2	18.6	54.9	0.1	73.6
a_3	b_1	150.4	463.7	354.3	103.9	27.8	25.7	4.4	24.1	47.6	0.6	72.3
	b_2	155.0	501.0	383.4	96.6	29.4	24.9	4.2	21.3	51.8	0.0	73.1
	b_3	160.7	530.4	406.3	88.5	30.6	24.2	4.1	18.5	55.6	0.0	74.1
	b_4	165.7	555.3	425.5	84.2	31.5	23.8	3.9	16.7	59.7	0.0	76.4
LSD 0.1%		4.0	32.1	22.4	5.5	1.5	1.1	0.3	2.1	3.1	0.8	3.6

[1] CP = crude protein; NDF = neutral detergent fibre; ADF = acid detergent fibre; LSD = least significant difference.

[2] Mixture: a_1 – alfalfa 100%, a_2 – alfalfa 75% + orchard grass 25%; a_3 – alfalfa 50% + orchard grass 50%.

[3] Fertilization treatments: b_1 – unfertilized control; b_2 – $N_{50}P_{50}$ kg ha^{-1}; b_3 – $N_{75}P_{50}$ kg ha^{-1}; b_4 – $N_{100}P_{50}$ kg ha^{-1}.

of the mixture of alfalfa 75% with 25% orchard grass. For the content of P, higher values were recorded for the mixture 50% alfalfa + 50% orchard grass, in the fertilized variants, followed by fertilized variants of the mixture 75% alfalfa + 25% orchard grass. Therefore, the mixture type 75% alfalfa + 25% orchard grass was the most balanced in mineral components of the feed. Following the silaging process of the fodder, small losses were recorded for contents of Ca, P and Mg.

Conclusions

Regardless of the mixture type, the highest yields were obtained by the fodder mixture in which alfalfa was the dominant species (a_1). The highest average yields achieved in the three years were obtained by fertilizing with $N_{100}P_{50}$ kg ha^{-1} (b_4) for all three mixtures. The quality of the fodder was influenced by the proportions of the two species in the mixture and by the level of fertilisation. For fresh fodder production it is recommended to use the mixture with alfalfa 100% (a_1) and for silage production the best mixture is a_3. For a very good preservation of silage and good DM yields the recommendation is to use the type 50% alfalfa + orchard grass 50% fertilized with higher rates of mineral fertilizer.

References

Nyfeler D., Huguenin-Elie O., Suter M., Frossard E. and Lűscher A. (2008) Well-balanced grass-legume mixtures with low nitrogen fertilization can be as productive as highly fertilized grass monocultures. *Grassland Science in Europe* 13, 197-199.

Smit H. J., Nepal S., Van Vilsteren D., Witkowska I.M. and Elgersma A. (2008) Seasonality of productivity, botanical composition and N concentrations of four forage legume – grass mixtures under cutting. *Grassland Science in Europe* 13, 628-630.

Thumm U. (2008) Influence of site conditions on interspecific interactions and yield of grass-legume mixtures. *Grassland Science in Europe* 13, 332-334.

Vrotniakiene V. and Jatkauskas J. (2010) Fermentation quality and dry matter losses of grass-legumes treated with lactic acid bacteria mixture. *Grassland Science in Europe* 15, 575-577.

Sward surface height estimation with a rising plate meter and the C-Dax Pasturemeter

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Abstract

Pasture-based production systems are economically interesting, but only if grown herbage is efficiently used. The sward surface height (SSH) and the herbage mass (HM) are appropriate indicators to use in checking pasture management and thereby improving the output of milk and meat per hectare (ha). Because farms are becoming larger, the periodic measurement of SSH with a rising plate meter takes more and more time. Devices towed by small vehicles, such as the C-DAX Pasturemeter (PM), could reduce the workload significantly if the measurements are carried out correctly. To verify the estimation accuracy of the PM as compared to an electronic rising plate meter, the SSH of 252 strips (each approximately 8 m^2) and 187 paddock diagonals on multi-species pastures of two farms were measured. Subsequently, the strips were cut, and the harvested biomass was weighed. The dry matter (DM) of a subsample of the biomass was determined to calculate the HM in kg DM ha^{-1} over 49 mm. Because the measuring principles of the two devices are different, equations were created for the conversion of SSH. Furthermore, regressions were developed to estimate the HM based on the SSH. With the two devices, HM estimations of similar quality were obtained.

Keywords: pasture, sward surface height, herbage mass, rising plate meter, pasturemeter

Introduction

Pasture-based production systems are economically interesting (Dillon *et al.*, 2005), but only if grown herbage is efficiently used (Shalloo, 2009). The sward surface height (SSH) and the herbage mass (HM) are appropriate indicators to use in checking pasture management (O'Donovan, 2000) and thereby improving the output of milk and meat per ha. According to Hannson (2011), a variety of methods and devices are used to estimate SSH or HM: visual methods, pasture rulers, sward sticks, plate and disc meters, and devices mounted on vehicles or towed equipment. Because farms are becoming larger, the periodic measurement of SSH with a rising plate meter takes more and more time. Devices towed by small vehicles, such as the C-Dax Pasturemeter (PM), could reduce the workload significantly if the measurements are carried out correctly. Experience has shown that using the PM, the measuring time can be reduced to approximately 1/6 as compared to using the rising plate meter (RPM). On the other hand, the initial cost is about ten times higher. The aim of this study was to verify the estimation accuracy of the PM as compared to the RPM on multi-species pastures in Switzerland.

Materials and methods

The PM (C-DAX Ltd., Palmerston, North, NZ, unit: mm) is an electronic device mounted on a sled. It is trailed behind a small vehicle and operates at speeds of up to 20 km h^{-1}. With 18 light beams spaced at 20 mm, the PM takes 200 height-measures s^{-1} (C-DAX, 2014).

From 2011 to 2013, comparative measurements were made of the pasture of the organic farm 'Ferme École de Sorens' (820 m.a.s.l., Switzerland), and 2014 of the pastures at Agroscope ILS in Posieux (640 m.a.s.l., Switzerland), run according to the proof of ecological performances. In 2011, every week, the SSH of the diagonals of all used pasture paddocks, 187 in total during the vegetation period, were simultaneously measured with the RPM (Jenquip, Feilding, NZ, 1 unit corresponds to 0.5 cm) and the PM. In 2012 and 2014, four herbage strips averaging 8 m^2 large and covering the SSH range between 50

to 160 mm were cut weekly. During 2013, four herbage strips were cut every two weeks. Thus, there were a total of 92 strips in 2012, 52 strips in 2013 and 108 strips in 2014. Before and after cutting the strips, the SSH was measured with the RPM and the PM. The harvested biomass was weighed, and the DM of a subsample was determined to calculate the HM ha^{-1} over an average cut height of 49 mm. According to the technical notes of the Swiss Grassland Society (AGFF, 2007), three-quarters of the herbage strips were visually associated with specific types of plant communities. A regression analysis was performed with Systat 13 (Systat Software Inc., San Jose, CA, USA).

Results and discussion

Because the measurement principles of the devices used are different, compressed (RPM) versus non-compressed SSH (PM), contrasting results for the same swards were obtained. The average of the 439 SSH measures was lower ($P<0.001$) when measured with the RPM (12.4±4.3 units or 62±21 mm, respectively) as compared to the PM (94±35 mm). As the measurements of the two devices correlate well, a function based on a linear regression was created to convert the results. To increase validity, a merged data set with an arithmetic mean of SSH = 94 mm (38 to 216 mm) or 12.4 units (5 to 35), respectively, was used to calculate the following regression:

$$y = 7.2\,x + 5.3\ (n=439,\ R^2=0.79,\ SEE=15.9)$$

where y = SSH in mm measured with PM, x = SSH in units measured with RPM, and SEE = standard error of the estimate.

For Sorens and Posieux, site-specific regressions exhibited differences in relation to the y-intercept (0.7 vs 19, $P<0.001$) and the slope (7.45 vs 6.4, $P=0.003$), which may indicate the need for regionally adapted regressions. Because the measurements on both sites were not performed during the same year, the effects of year and site could not be separated.

The following regressions estimate the HM per ha over measured cut heights of 49±9 mm and 7.4±1.4 units, respectively:

$$\text{RPM:}\ y = 118\,x - 728\ (n=252,\ R^2=0.81,\ SEE=285)$$

$$\text{PM:}\ y = 15.2\,x - 742\ (n=252,\ R^2=0.77,\ SEE=311)$$

where y = HM kg ha^{-1}, x = SSH measured with PM (mm) or RPM (units), SEE = standard error of the estimate.

Hannson (2011), in Denmark, found similar coefficients of determination (0.63 to 0.89) for the HM estimated with the PM SSH. In the present study, the y-intercepts did not differ in relation to the measuring devices, but the slopes did due to the contrasting measuring principles and differences in relation to the units. For pre-grazing HM targets of 1,200 to 1,500 kg ha^{-1}, the SEEs are high, so prior sward density measures would probably improve the precision of the HM estimation per ha. The coefficients of correlation for HM estimation based on SSH measured with the RPM or the PM are equal ($r_{RPM}=0.90$, $r_{PM}=0.88$, $P=0.26$). Consequently, both regressions explain a similar percentage of the total variation of HM per ha – approximately 80%. Discrepancies exist regarding the HM estimation relative to the sites. Both slopes of the regressions for the HM estimation on the Posieux site are higher (RPM: 111 vs 131, $P=0.001$ and PM: 13.9 vs 17.8, $P<0.001$) than those for Sorens, which may be due to denser swards in Posieux or an effect of the year because the measurements were not performed the same year. Differences in the botanical composition of the swards may contribute to the contrasting regressions as

well. In Sorens, 55% of the visually determined strips were grass-rich (>70% grasses), 22% were balanced (50 to 70% grasses), and 17 were diverse (>50% forbs). Ryegrasses were not the dominant grasses (<50% of the grasses) in Sorens. In addition to ryegrass and *Poa* species, *Phleum pratense* and *Dactylis glomerata* were present, among others. Although mineral N-fertilizer was used in Posieux, 55% were balanced, 19% were grass-rich, 17% were balanced with ryegrass domination (>50% of the grasses) and 9% were grass-rich with ryegrass-dominated plant community types. To adjust the regressions to the types of plant communities, to the site or to other factors, a much larger dataset would be required.

Conclusions

The SSH measured with the RPM or the PM provided similar estimations of HM per ha and explained about 80% of the variation. The standard error of the estimate is too high to provide an accurate estimate of the HM, so prior sward density measures would probably improve the precision of the HM estimation per ha. To create individual regressions for specific plant communities or for specific sites, a much larger dataset must be analysed.

References

AGFF (2007) Bewertung von Wiesenfutter. *AGFF-Merkblatt* 3, 6 pp.

C-DAX (2014) *Pasturemeter: assembly and operation manual*. Available at: http://tinyurl.com/nrht6ua.

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005) Optimising financial returns from grazing in temperate pastures. In: Murphy J.J. (ed.) *Utilisation of grazed grass in temperate animal systems*. Satellite Workshop of 20th International Grassland Congress, Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 131-147.

Hannson L. (2011) *Herbage dry matter mass of pastures estimated through measures of sward height*. Master thesis, University of Copenhagen, Copenhagen, Denmark, 78 pp.

O'Donovan M. (2000) *The relationship between performance of dairy cows and grassland management practice on intensive dairy farms in Ireland*. PhD Thesis. National University of Ireland, 366 pp.

Shalloo L. (2009) Milk production costs – Can we compete? Teagasc National Dairy Conference 2009, pp. 19-38. Available at: http://tinyurl.com/odqrk4s.

Predicting the harvest date of silage maize based on whole crop or cob dry matter contents

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Abstract

In Germany, it is recommended to harvest silage maize at a whole-crop dry matter (DM) content (GTS) of 32 to 36% and a cob DM content (KTS) of about 55%. Predicting harvest date may be challenging for sites with a high risk of summer drought. Harvesting silage maize at the optimum stage of development is a prerequisite for maximising yield, forage quality and resource-use efficiency. This is especially challenging for sites that have frequent summer droughts, which cause fast maturation of the stover. The objectives of the current study were to evaluate the predicting ability of three modelling approaches: the semi-mechanistic MaisProg model, simulating GTS and KTS, and a temperature-sum driven tool (PAGF) predicting KTS. The study was based on an 8-year field experiment, conducted at Paulinenaue, north-eastern Germany, where maize hybrids were harvested weekly from August until silage maturity. The results revealed that, under conditions of frequent summer droughts, MaisProg-GTS seems less suitable, as indicated by an unsatisfactory correlation coefficient (0.68). Better model fit was achieved by the KTS-based approaches (MaisProg: 0.92, PAGF: 0.96). In particular, PAGF showed a higher correlation for early harvest date predictions (mid/late August), which is advantageous in terms of arranging the hiring of contractors.

Keywords: *Zea mays*, model, temperature sum, MaisProg

Introduction

In Germany, maize silage plays an increasingly important role in feeding systems for high-yielding dairy cows as well as in intensive beef production. According to recommendations (Lütke-Entrup *et al.*, 2013), silage maize should be harvested at the stage of physiological maturity BBCH 87 (Meier, 2001) when the kernel dry matter (DM) content is about 55-60%. This allows feeding value of maize for ruminants and forage yield to be maximised, conservation, and maize resource-use efficiency to be increased. Under the growth conditions and for maize hybrids grown in Germany, this developmental stage is characterised by a whole-crop DM content (GTS) of 32 to 36% and a cob DM content (KTS) of about 55%. The MaisProg harvest time prognosis tool, based on GTS, has been implemented nationwide in 2005 (www.maisprog.de; Herrmann *et al.,* 2006) to improve maize silage quality. While it has shown good agreement between observed and predicted GTS for most environments, a higher prediction error was found for a site (Paulinenaue, northeastern Germany) with sandy soil and rather low and unevenly distributed precipitation, where even limited drought periods can cause a fast maturation of the stover (Schuppenies and Pickert, 2000). For such conditions, KTS might be a more suitable indicator of silage maturity than GTS. The objectives of the current study, therefore, were to evaluate the predictive ability of three approaches, the semi-mechanistic MaisProg model, calculating (1) GTS and (2) KTS based on weather variables, plant-available soil water and hybrid characteristics, and (3) a temperature-sum driven tool (PAGF) predicting KTS.

Materials and methods

The study is based on a multi-year field experiment (2007-2014) conducted at Paulinenaue, north-eastern Germany (latitude 52 º 68′ N; longitude 12 º 72′ E) on a sandy soil, with a mean annual temperature of 9 °C, a mean annual precipitation of 520 mm, where three maize hybrids (Salgado, early; Lukas, mid-early; PR39F58, mid-late) were grown at a crop density of 8 plants m^{-2} in four rows with a row width of 0.75 m and a plot length of 30 m. Crop development was monitored in terms of silking date, BBCH 65. The GTS and KTS were determined at four to five dates after silking, respectively. To this end, four samples of ten plants were harvested by hand at a cutting height of 0.15 m from the two central rows of each plot at each sampling date. Fresh weight of the whole crops was measured. Then, the samples were separated into cob and stover. For the cobs, fresh weight was recorded and DM content was determined after drying at 105 °C for 36 hours. The DM content of the stover was determined after chopping and drying at 105 °C.

MaisProg is one of few models that not only predicts DM production but also provides a comprehensive simulation of various forage quality parameters (Herrmann *et al.,* 2005). It consists of two dynamically interacting sub-models for DM production and quality development driven by plant and soil characteristics, weather data, and soil water availability. Calculations start at sowing for the whole crop and at predicted silking for the cob. Following an AGPM approach (AGPM, 1990) in the PAGF model, the daily mean temperature contribution, T_d = tx – tb, was calculated, based on the daily mean temperature tx = 0.5 (tmin + tmax) and the base temperature tb = 6 °C. For tmax values exceeding 30 °C, tmax was set to 30 °C, if tx was less than 6 °C, T_d was set to 0 °C. The relationship between temperature sum and KTS has been calibrated based on multi-year field experiments conducted from 1984 to 2004 (Hertwig and Schuppenies, 2008). Starting at the observed silking date, BBCH 65, independent of the hybrid, a temperature sum of 625 °C is required to achieve BBCH 87 and a KTS of 55%.The goodness of the model predictions was assessed by the root mean square error (RMSE) and the coefficient of correlation.

Results and discussion

The different model approaches were validated in two steps. First, a retrospective analysis revealed that for all sampling dates, including all approaches, it was possible to predict GTS and KTS of silage maize with a relatively small average difference of less than 0.5% compared to the measured DM contents. However, the KTS approaches showed a better agreement between observed and simulated values, as indicated by lower RMSE and higher correlation coefficient values (Table 1). There was only marginal impact of hybrid or of year on model performance (data not shown). For farmers, the predictive ability of the models in the period 3 to 4 weeks ahead of silage maturity (mid-August to the end of August) is the most relevant, since appointments with contractors are made then. Thus, in a second step, we evaluated the model performance for sampling dates in mid- or late August. As expected, the goodness of model-fit was less for the earlier date of prediction and a larger differentiation among the different model approaches became apparent. While the simulated whole crop DM contents deviated substantially from the observed values, satisfactory agreement was found for the cob DM content predicted by MaisProg-KTS, while best model-fit was achieved by PAGF-KTS. The better performance can be attributed to several reasons. First of all, PAGF-KTS simulations start at the observed silking dates instead of simulated silking as in MaisProg-KTS. Furthermore, PAGF-KTS was developed for the specific region of north-eastern Germany, while MaisProg was calibrated with data from all over Germany.

Conclusions

The better performance of the KTS-based approaches compared to MaisProg-GTS indicate that under the conditions of frequent summer droughts, the dynamics of stover DM content is difficult to reflect in model algorithms. For early prediction of silage maturity, which is interesting for the management of large farms with varying environmental conditions or where contractors do most of the harvesting,

Table 1. Results of model validation for MaisProg-GTS, MaisProg-KTS and PAGF-KTS, based on data collected at Paulinenaue, north-eastern Germany, during 2007 to 2014.[1]

	DM content measured (%)	DM content predicted (%)	RMSE	Correlation coefficient
All dates of prediction (n=117)				
MaisProg-GTS	28.9	29.0	4.82	0.68
MaisProg-KTS	46.7	47.1	3.71	0.92
PAGF-KTS	46.7	46.4	2.81	0.96
Prediction late August (n=24)				
MaisProg-GTS	27.8	28.6	4.22	0.44
MaisProg-KTS	45.5	46.2	3.85	0.74
PAGF-KTS	45.5	45.1	2.50	0.92
Prediction mid August (n=24)				
MaisProg-GTS	24.8	26.0	3.26	0.42
MaisProg-KTS	38.6	39.1	4.83	0.71
PAGF-KTS	38.6	38.0	2.71	0.93

[1] DM = dry matter; PAGF = temperature-sum driven tool (predicting KTS); KTS = cob DM content; GTS = whole-crop DM content; RMSE = root mean square error.

visual assessment of silking date can improve prediction accuracy. This, however, will require more effort by farmers and/or advisers.

Acknowledgements

References

AGPM (1990) Besoins en temperatures des varietes de mais. *agpm info* 116, decembre 1990.

Herrmann A., Kornher A., Höppner F., Greef J.M., Rath J. and Taube F. (2006) Harvest time prediction of silage maize – model calibration, validation and implementation in practical agriculture. *Grassland Science in Europe* 11, 559-561.

Herrmann A., Kornher A. and Taube F. (2005) A new harvest time prognosis tool for forage maize production in Germany. *Agricultural and Forest Meteorology* 130, 95-111.

Hertwig F. and Schuppenies R. (2008) Blühzeitpunkt entscheidet über den Erntetermin. *Neue Landwirtschaft* 7, 2-4.

Lütke-Entrup N., Schwarz F. and Heilmann H. (2013) *Handbuch Mais*. DLG-Verlag GmbH, Frankfurt am Main, Germany.

Meier U. (ed.) (2001) *BBCH Monograph*. 2nd edition, Federal Biological Research Centre for Agriculture and Forestry, Germany. Available at: http://www.bba.de/veroeff/bbch/bbcheng.pdf.

Schuppenies R. and Pickert J. (2000) Wärmesumme gibt Aufschluss über optimalen Maiserntetermin. *Bauernzeitung* 32, 18-19.

Genotypic variation in vernalisation response and autumn growth in forage grass species

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Abstract

Depending on the grass species, development of stem-forming tillers is strictly regulated by temperature and/or day length (DL). We studied the regulation of tiller development and growth of timothy (*Phleum pratense* L.) and festulolium (*Festuca × Lolium*) by vernalisation, temperature and DL in field and growth chamber experiments. Our results show that there exists significant genotypic variation in traits important for biomass accumulation in different harvests. It seems that the extent of the spring growth flush is dependent on the vernalisation state of the plants. In autumn, growth in timothy is strictly regulated by DL, whereas in festulolium temperature is a more important regulator. Knowledge of these differences between grass species in their responses to environmental cues, and understanding of the genetic variation in these traits, provide unique opportunities for breeding as well as for the selection of best-performing genotypes for forage leys.

Keywords: adaptation, biomass, day length, festulolium, growth, timothy, vernalisation

Introduction

Climate change will affect silage production significantly in the future. In the Northern hemisphere the growing period will become longer and winters will become shorter. The adaptation of forage grass production to novel growing conditions will require new cultivars in which response to overwintering conditions (winter hardiness and vernalisation), day length (DL) and temperature are optimized.

Intensive silage production with frequent cutting during the growing season aims to provide high yields of herbage biomass with high nutritive quality. The number and weight of individual tillers determines the herbage yield. Stem-forming generative tillers are the heaviest and, in general, their proportion and digestibility determine the amount and quality of the silage yield (Virkajärvi *et al.*, 2012). The regulation of flowering varies between forage grass species so that the cultivated *Festuca* and *Lolium* species require double induction for flowering (vernalisation and long DL) whereas timothy can produce flowering tillers once the critical DL is exceeded (Heide, 1994). Also in timothy, vernalisation accelerates the development of flowering tillers (Jokela *et al.*, 2014) and the northern genotypes tend to be more responsive to both vernalisation and DL (Jokela *et al.*, 2015).

During winter, perennial forage grasses are exposed to vernalisation conditions resulting in release of stem growth and flowering (Seppänen *et al.*, 2010). Spring growth flush, which is a well-known phenomenon in forage grasses, is caused by rapid development of vernalized generative tillers (Seppänen *et al.*, 2010, Virkajärvi *et al.*, 2012). How the vernalisation requirement of a genotype affects herbage accumulation is yet not understood. It is known, however, that in timothy there exists substantial variation in vernalisation and DL requirement, and this variation could be utilized in breeding for adaptation to future growing conditions (V. Jokela, unpublished data).

Materials and methods

Vernalisation requirement was studied in field experiments during 2009-2013. Plant samples (n=4) were harvested from field-sown grass leys once a month during winter and the growth (number of tillers,

leaves and height) was monitored in a greenhouse (20/15 °C day/night, 16 h DL) until no change in the number of developing flowering or stem-forming tillers was observed. In separate growth chamber experiments, autumn growth (number of leaves and tillers, plant height and weight of tillers) was studied under three temperature (5, 10 or 15 °C) and two DL conditions (12, 14 h) resembling predicted future climate conditions. Genotypes of different origin as well as breeding lines and cultivars of timothy and festulolium were used in the experiments. The plant material used in each experiment is indicated in the selected results that are reported here. Timothy breeding lines of southern and northern origin were kindly provided by Boreal Plant Breeding Ltd, Finland, and Festulolium breeding lines by Graminor Ltd., Norway.

Results and discussion

Vernalisation affected height growth and potential for yield formation in timothy (Figure 1a). Genotypes of southern origin were able to produce generative tillers by November, whereas the northern or intermediate types with longer vernalisation requirements started stem growth in January and were dormant until then. It also seemed that long winter and too-long vernalisation time decreased the yield potential, as development became faster and the developed flowering tillers were shorter in May than in January (Figure 1a). Stem elongation is mainly related to fulfilment of vernalisation requirement although adequate DL is also necessary in timothy (Jokela *et al.*, 2014).

Biomass accumulation in autumn can be a result of an increase in the number and weight of leaves and shoots or height growth. We exposed timothy and festulolium genotypes to different DL and temperature conditions resembling predicted future conditions during autumn growth (Figure 1b.). Shorter DL decreased the biomass accumulation in both timothy and festulolium. In timothy DL regulated height growth, and genotypes of southern origin having shorter DL requirement for flowering were able to produce elongating true tillers at 14 h (data not shown). Our results show that the critical DL for flowering (Heide, 1994) is correlated with the genotype's ability to accumulate biomass during short DL in autumn. Timothy seemed to be more sensitive to growth temperature than festulolium, and in timothy there existed variation between southern and northern genotypes in their growth at low temperature (10 °C, 5 °C). In contrast, festulolium genotypes of northern and southern origin accumulated biomass under these conditions rather similarly. This was mainly due to increased weight of individual tillers.
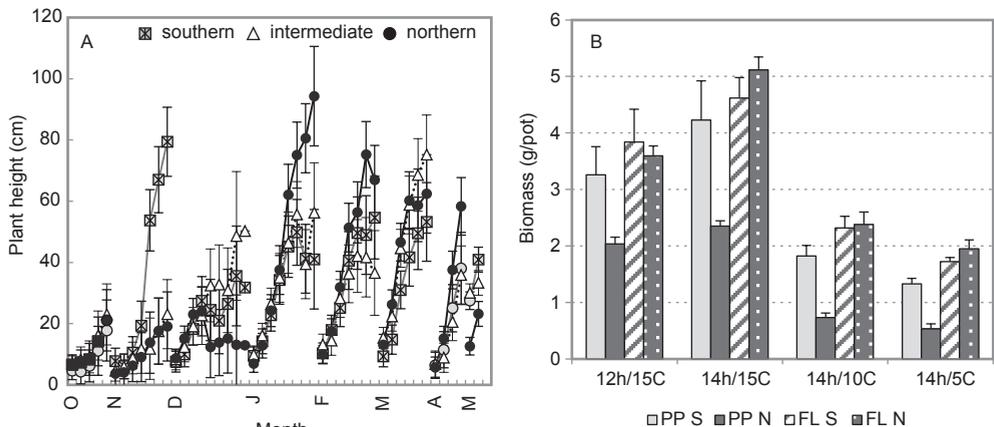

Figure 1. (a) The effect of vernalisation on height growth of timothy cultivars during winter. Samples were harvested once a month from the field and the height growth was monitored in a greenhouse. (b) Biomass accumulation of timothy (PP S- southern, PP N – northern) and festulolium (FL S –southern, FL-N northern) genotypes at different day length (12 and 14 h) and temperature (5, 10 and 15 °C).

Conclusions

In timothy, a wide variation in vernalisation requirement and DL response was found between genotypes. Southern cultivars had a shorter vernalisation requirement, which was demonstrated by an earlier release of stem growth during winter. However, a long vernalisation period during winter diminished these genotypic differences. Experiments on autumn growth revealed that timothy genotypes were more responsive than festulolium to both temperature and DL. At low growing temperature and short DL, biomass accumulation was modest in the northern timothy genotype. In contrast, northern festulolium genotypes also accumulated relatively high amounts of biomass at short DL (15 °C) and no differences between genotypes of northern and southern origin were observed. Our results have demonstrated that genetic variation exists between and within forage grass species. This variation could be utilized in grass breeding for adaptation to future climate conditions.

References

Heide O.M. (1994) Control of flowering and temperature in temperate grasses. *New Phytologist* 128, 347-362.

Jokela V., Virkajärvi P., Tanskanen J. and Seppänen M. (2014) Vernalization, gibberellic acid and photo period are regulators of yield formation in timothy (*Phleum pratense*). *Physiologia Plantarum* 152, 152-163.

Seppänen M.M., Pakarinen K., Jokela V., Andersen J., Pedersen A. and Virkajärvi P. (2010) Vernalization response of *Phleum pratense* L. and its relationship to canopy architecture, stem morphology and expression of *VRN1* and *VRN2* genes. *Annals of Botany* 106, 697-707.

Virkajärvi P., Pakarinen K., Hyrkäs M., Seppänen M. and Belanger G. (2012) Tiller characteristics of timothy and tall fescue in relation to herbage mass accumulation. *Crop Science* 52, 970-980.

The effect of cutting strategy on production and quality of high-yielding multispecies grasslands

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Abstract

There is an increasing focus on biodiversity and feed resources for pollinators. However, the integration of these elements into high-yielding temporary grasslands is a challenge. With the main aim of continuous flowering we examined three strategies with four cuts per year, in which the time of the spring cut varied. In total we had 10 different harvest times during the season. This was combined with 12 different species mixtures in two categories. One was high-yielding mixtures composed of perennial ryegrass (*Lolium perenne*), white clover (*Trifolium repens*) and red clover (*Trifolium pratense*), either alone or with either chicory (*Cichorium intybus*), ribwort plantain (*Plantago lanceolata*) or caraway (*Carum carvi*). The other category was lower-yielding two-species mixtures composed of one legume (red clover, lucerne (*Medicago sativa*) or birdsfoot trefoil (*Lotus corniculatus*)) and one spring-flowering non-leguminous forb (salad burnet (*Sanguisorba minor*) or dandelion (*Taraxacum officinale*)). Annual dry matter yield was only slightly affected by cutting strategy. Feeding value and weekly change in feed value differed considerably between species. Weekly decrease of digestibility of organic matter ranged from 0.4% in caraway to 5.0% in birdsfoot trefoil. For the two-species mixtures, birdsfoot trefoil was the least-useful companion legume for non-leguminous forbs.

Keywords: continuous flowering, forbs, cutting strategy, feeding value

Introduction

In high-output dairy farming systems, field size is often large and plant diversity low. This may, at least partly, be the reason that pollinators are declining in many parts of the world with negative consequences for pollination of field crops and wild plants. One way of negating the pollinator crisis is to increase plant diversity of leys by including species in the mixtures with complementary flowering throughout the season. It has been demonstrated that the diversity of pollinator species is positively related to the number of plant species (Ebeling *et al.*, 2008). Spring is often critical due to few natural feed resources and alternative resources in the grasslands could be helpful. The aim of the experiment was to examine if cutting strategy combined with field design could give continuous feed resources throughout the season for pollinators without compromising herbage production and quality.

Materials and methods

Two groups of mixtures were established in 2011 on loamy sand in a dairy crop rotation at Foulum research farm by undersowing in spring barley in a randomized plot experiment with three replicates and a seeding rate of 25 kg ha^{-1}. One group was grass-clover alone or with one forb (Mixture 1-4 in Table 1). The other group was composed of one legume and one non-leguminous forb (Mixture 5-10). The amounts of legume seeds were adjusted to the expected competitive ability (Table 1). No fertilizer N was applied. The plots were harvested following three strategies. Spring harvest was carried out over four weeks, with 14 days between strategy 1 and 2 and between strategy 2 and 3. First and second regrowth were six weeks in all strategies and the third regrowth was varied, since the last harvest was at the same date in mid-October for all strategies. Hereby, different morphological stages were obtained of the species simultaneous during the growing season. The plots were harvested in 2012 and 2013, botanical composition was analysed by hand separation of subsamples, and herbage quality in the species was analysed by near-infrared spectrometry in the spring cut.

Results and discussion

The cutting strategy had limited effect on annual dry matter yield (Table 1). Overall, highest yield was found with a late first cut and the lowest with a medium first cut, with the exception of mix 5 and 8 including birdsfoot trefoil. However, the seasonal production varied considerably with the same trend for all mixtures and was most pronounced in the first two cuts. On average, the percentage distribution of harvested dry matter (DM) over cuts 1 to 4 was in strategy 1: 21-41-21-16, strategy 2: 43-24-25-8 and strategy 3: 55-21-22-2. The yield of the two-species mixtures (no. 5-10) was lower than of mixtures with grass and clover (no. 1-4). However, the yield of two species including red clover was close to that of the grass-clover mixture, while the yields of mixtures with birdsfoot trefoil were significantly lower. The average yields in 2012 and 2013 were 12.6 and 8.9 Mg DM ha^{-1}, respectively. Lower yields in 2013 were partly due to drought stress and to an older sward.

The content of forbs in the grass-clover mixtures (no. 1-4) was for caraway and chicory at the same level (5-6% of DM) as the seeding rate (Table 1), whereas it was twice as high for plantain. The three forbs have previously shown competitive ability in productive grasslands (Søegaard *et al.*, 2011). On average, in mixtures 1-4 there were 38% grass, 15% white clover and 41% red clover (data not shown). The vigorous growth of grass and clover only left only limited space for unsown species/weeds (1-2%). In the two-species mixtures (no. 5-10) the content of birdsfoot trefoil (34%) was much lower than lucerne (66%) and red clover (71%), even though the seeding rate was considerable higher for birdsfoot trefoil. Thus, the weed content became high (26-46%) in the birdsfoot trefoil mixtures. In the two-species mixtures red clover showed a very high production, even though the seeding rate was only 0.5 kg ha^{-1}. In contrast to salad burnet, dandelion produced more when mixed with birdsfoot trefoil than with lucerne and red clover. Furthermore, the content of weeds was much lower in mixtures with dandelion than with salad burnet, indicating that the broad leaves of dandelion left less space for colonization by weeds than did the small leaves of salad burnet.

If the cutting strategy is to be used as a tool for continuous flowering, the challenge is to develop seed mixtures which minimize negative effects on the nutritive value of the herbage. We examined the sensitiveness of harvest time on nutritive value in the spring (Table 2). Red clover under very different growing conditions showed no significant differences on herbage quality, indicating limited effects of mixtures on herbage quality.

Table 1. Species, seed composition, annual yield with different strategies (early-medium-late spring cut) and annual weighted proportion of non-leguminous forb and weeds/unsown species (mean of strategies). Average of 1st and 2nd harvest year.

Mix	Species[1]	% of seed seed composition	Annual yield[2] (Mg dry matter ha^{-1})			% of dry matter	
			Strategy 1 (early)	Strategy 2 (medium)	Strategy 3 (late)	Non legumous forb[3]	Weed[3]
1	PR-WC-RC	82-15-4	10.3[b]	10.1[b]	11.4[a]	-	2[e]
2	PR-WC-RC-CI	78-14-4-5	10.2[b]	10.2[b]	11.7[a]	5[e]	1[e]
3	PR-WC-RC-CA	78-14-4-5	10.2[b]	9.9[b]	11.5[a]	6[de]	2[e]
4	PR-WC-RC-PL	78-14-4-5	11.4[ab]	10.1[b]	12.1[a]	11[d]	2[e]
5	SB-BT	50-50	7.7[a]	6.5[c]	7.1[b]	20[bc]	46[a]
6	SB-LU	94-6	8.9[a]	8.9[a]	9.9[a]	18[c]	16[c]
7	SB-RC	98-2	9.1[b]	8.3[c]	10.0[a]	18[c]	18[c]
8	DA-BT	50-50	7.6[a]	6.1[b]	6.2[b]	40[a]	26[b]
9	DA-LU	94-6	8.5[b]	7.7[b]	8.8[a]	24.3[b]	9.7[d]
10	DA-RC	98-2	10.0[a]	8.8[b]	10.5[a]	19.3[bc]	3.7[de]

[1] Species: PR (perennial ryegrass), WC (white clover), RC (red clover), BT (birdsfoot trefoil), LU (Lucerne), CI (chicory), CA (caraway), PL (plantain), SB (salad burnet) and DA (dandelion).

[2] Different letter in rows of annual yield indicate significant differences between cutting strategy ($P<0.005$).

[3] Different letter in columns indicate significant differences between mixtures ($P<0.005$).

Table 2. Nutritive value in the single species in spring growth. The value at harvest time 2 (strategy 2) and the rate (changes per week).[1,2]

	Mix	IVOMD		CP		NDF		WSC
		Time 2	Rate	Time 2	rate	Time 2	rate	
Perennial ryegrass	1	79.1[de]	-3.1[bc]	116[f]	-14[c]	495[a]	35[ef]	168[a]
White clover	1	84.7[bc]	-1.2[ef]	236[a]	-10[c]	278[e]	9[ab]	107[bcd]
Red clover	1	77.9[ef]	-1.8[de]	187[d]	-21[b]	307[d]	18[c]	134[b]
Red clover	7	76.9[efg]	-1.3[ef]	197[cd]	-23[b]	304[d]	18[c]	119[bc]
Lucerne	6	76.4[fg]	-3.5[b]	211[bc]	-22[b]	351[c]	33[e]	82[def]
Birdsfoot trefoil	5	74.7[g]	-5.0[a]	215[b]	-30[a]	352[c]	43[f]	57[f]
Chicory	2	90.4[a]	-2.0[de]	131[f]	-11[c]	292[de]	24[cd]	132[b]
Plantain	3	81.1[d]	-2.4[cd]	124[f]	-15[c]	315[d]	19[c]	97[cde]
Caraway	4	86.9[b]	-0.4[fg]	156[e]	-11[c]	310[d]	5[a]	75[ef]
Salad burnet	6	70.2[h]	-3.2[bc]	89[g]	-10[c]	409[b]	29[de]	108[bcd]
Dandelion	9	84.2[c]	0.3[g]	84[g]	5[d]	294[de]	17[bc]	95[cde]

[1] IVOMD = *in vitro* organic matter digestibility (% of organic matter; % of organic matter week[-1]); CP = crude protein (% of DM; % of DM week[-1]); NDF = neutral detergent fibre (% of DM; % of DM week[-1]); WSC = water soluble carbohydrates (% of DM).

[2] Different letters within columns indicates significant differences between species (*P*<0.005)

Between species the level and the weekly change varied considerably, indicating different suitability for inclusion under different cutting strategies. At harvest time 2, a high *in vitro* organic matter digestibility (IVOMD) combined with a low neutral detergent fibre (NDF) content was found in white clover, chicory, caraway and dandelion (Table 2). It was also accompanied by a modest change over time (change per week in Table 2). In contrast to these species, ryegrass, lucerne, birdsfoot trefoil and salad burnet had lower IVOMD and higher NDF levels and the weekly change was greater. Dandelion flowering peaked before the early cut of strategy 1 and it had only old inflorescences at the harvest time of strategy 2 and 3. This may be the reason for increasing IVOMD and crude protein during the one-month period between harvests of strategies 1 and 3 (Table 2).

Conclusion

Grasslands with services for pollinators and dairy production can be designed using a combination of grass, clover and forbs with high competitive ability, and smaller restricted areas with low competitive forbs, and combined with different cutting strategies. The results demonstrated possibilities for reaching the goal of integrating productivity and biodiversity.

References

Ebeling A., Klein A-M., Schumacher J., Weisser W.W. and Tscharntke T. (2008) How does plant richness affect pollinator richness and temporal stability of flower visits? *OIKOS* 12, 1808-1815.

Søegaard K., Eriksen J. and Askegaard M. (2011) Herbs in high producing organic grasslands – effect of management. In: Neuhoff D. (ed.) *Third Scientific Conference of ISOFAR*, Republic of Korea, Vol. 1, pp. 190-193. Available at: http://orgprints.org/20685.

Milk production with or without protein supplement in combination with forage at two protein levels

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Abstract

With the aim to study the effect of protein supplement, two concentrate diets, one consisting of cereal grain only, and one with protein supplements added, were combined with two grass-clover silages with different contents of crude protein (130 and 170 g kg^{-1} dry matter) and fed to 37 cows of the Swedish Red breed during 20 weeks. The silages, offered *ad libitum*, were of first cut, and to achieve the higher protein content additional pure red clover silage was added in a mixer wagon prior to feeding. The low protein silage was 95% dominated by timothy and meadow fescue. Concentrate type did not affect silage intake. Cows fed concentrate without protein supplement had a lower milk yield but a higher milk fat content (*P*<0.01), resulting in 30.9 kg and 35.3 kg energy corrected milk yield (ECM), respectively. There was no effect of silage type on milk yield or milk composition. The diet without protein supplement gave an increase in nitrogen efficiency by 20% compared with the diet with the protein supplement. The experiment was repeated a second year including only one silage quality. Results confirmed reduction in milk yield by excluding protein supplement, from 40.0 to 37.3 kg ECM (*P*<0.05).

Keywords: milk yield, grass-clover silage, cereal grain, feed protein level

Introduction

Milk production according to the rules for organic production often encounters problems with sufficient supply of feed protein. Shortage of organically produced protein feeds results in high prices. It is also attractive to base organic milk production on solely on-farm produced feeds. Cereal grain (wheat, barley and oats) in combination with high quality grass silage can be produced on most farms with a temperate climate. Milk production on such a diet is expected to be lower compared to a diet including protein concentrates such as soybean meal, but there is a lack of recent information about the likely reduction in milk yield. When excluding the protein supplement from the concentrate, and feeding a low protein concentrate consisting of cereals only, cows would be expected to perform better on protein-rich silage than on silage low in protein. The potential of forage protein to compensate for protein in concentrate supplement has, however, been questioned recently (Huhtanen, 2014). To study these questions two experiments were performed. In the first, the concentrate protein supplement was excluded from the diet for dairy cows using silage with high or low crude protein contents. In a second study the effect of excluding the concentrate protein supplement was studied using only one quality of silage. The response was evaluated in terms of milk yield and composition and feed intake. Economic calculations of milk income minus feed costs were made using the results of the experiments and current prices of feed and milk.

Materials and methods

Experiment I

Four diets with feeds described in Table 1 were fed to 37 dairy cows of the Swedish Red breed during 20 weeks of mid lactation. The diets are summarized as:
1. silage170 *ad lib* + cereals and protein concentrate;
2. silage170 *ad lib* + cereals;
3. silage130 *ad lib* + cereals and protein concentrate;
4. silage130 *ad lib* + cereals.

Table 1. Composition of feeds used. Means with standard deviation within brackets.

Item[1]	Cereals	Protein suppl. concentrate	Silage 170 experiment I	Silage 130 experiment I	Silage experiment II
DM, g kg^{-1}	894 (150)	920 (179)	350 (120)	364 (176)	252 (25.6)
ME, MJ kg^{-1} DM	13.0	15.5	11.3 (0.21)	11.6 (0.11)	11.6 (0.08)
AAT, g kg^{-1} DM	84	160	72	73	73
CP, g kg^{-1} DM	125 (17.7)	328 (6.2)	169 (4.3)	132 (3.7)	179 (6.5)
EE, g kg^{-1} DM	34	130	NA	NA	NA
Starch, g kg^{-1} DM	559	99	NA	NA	NA
NDF, g kg^{-1} DM	205	183	414 (19.9)	471 (13.9)	431 (22.0)

[1] DM = dry matter; ME = metabolisable energy; AAT = metabolizable protein; CP = crude protein; EE = ether extract; NDF = neutral detergent fibre; NA = not applicable.

Silages were of first cut; low protein (130) herbage was 95% dominated by *Phleum pratense* and *Festuca pratensis*. To obtain the high protein (170) silage, second-cut red clover silage was added in a mixer wagon (32% of dry matter (DM)).

Experiment II

In this experiment only one silage quality (Table 1) was fed to 32 dairy cows during 12 weeks in early to mid-lactation. Concentrates were identical in both experiments, consisting of 36% barley, 34% wheat and 25% oats (cereals) and soy expeller 47%, rapeseed cake 16%, oats 15% and whole rapeseed 11% (protein suppl.). Both cereals and protein concentrate were pelleted and contained binding material, minerals and vitamins.

Analysis

The data was statistically analysed by Proc GLM with SAS, version 9.1 (SAS Institute Inc., Cary, NC, USA). The effects of lactation number and interaction between silage type and concentrate type were non-significant and therefore omitted from the final model.

Results

Feed intake and production results of Experiment I are presented in Table 2. No effects of concentrate type on silage intake were detected ($P>0.05$). The higher intake of Silage130 seen as an effect of silage type was partly due to one malfunctioning feeding trough, resulting in 1.75 kg DM of Silage170 consumed by the cows assigned for Silage130. Reducing the intake of Silage130 by this quantity, to 14.7 kg DM, removed the difference in intake between the silages ($P>0.05$).

The production results showed that milk yield without protein supplement gave a lower milk production but a higher milk fat content ($P<0.01$), resulting in 30.9 and 35.3 kg energy corrected milk (ECM), respectively (Table 2). There was, however, no effect of silage type on the production parameters ($P>0.05$), with the exception of a tendency for lower live weight gains when Silage130 was fed ($P<0.10$). The diet without protein supplement gave an increase in nitrogen efficiency by 20% compared with the diet with the protein supplement.

The result of Exp II is shown in Table 3. Since no effect of silage protein content was shown in Exp I only one silage quality was used. Instead of offering silage *ad libitum* the diet was balanced with the aim of providing maximum metabolizable protein from the forage and cereal-only diet. This resulted in a less pronounced drop in milk production for cows on the cereal-only and silage diet.

Conclusions

Feeding grass-clover silage and cereals only, without protein concentrate, decreased fat corrected milk production by 7-12%. Increased silage crude protein content above 130 g per kg DM did not increase milk production when cows were fed a concentrate consisting of cereals only. The milk revenue minus

Table 2. Feed intake and production results in Experiment I. Least square means with standard error in brackets

Effect per day[1]	Effect of concentrate (n=37)			Effect of silage (n=37)		
	Cereals/conc	Cereals	Sign[2]	Silage170	Silage130	Sign[2]
Silage intake, kg DM	15.8 (0.58)	14.4 (0.58)	NS	13.8 (0.57)	16.4 (0.57)	**
Cereals, kg	1.9 (0.47)	7.1 (0.48)	***	4.8 (0.47)	4.2 (0.48)	NS
Protein conc, kg	4.0 (0.29)	0.0 (0.30)	***	2.0 (0.29)	1.9 (0.30)	NS
Energy intake, MJ	257 (9.7)	246 (10.0)	NS	239 (9.7)	264 (10.0)	*
AAT intake, g	1,854 (72.7)	1,572 (74.6)	*	1,641 (72.7)	1,788 (74.6)	NS
CP intake, g	3,887 (153.0)	3,096 (157.1)	**	3,588 (153.0)	3,396 (157.1)	NS
NDF intake, g	7,943 (256.8)	7,642 (263.7)	NS	6,874 (256.8)	8,710 (263.7)	***
Milk yield, kg	35.7 (0.97)	30.0 (1.00)	***	32.9 (0.96)	32.8 (0.99)	NS
ECM, kg	35.3 (0.86)	30.9 (0.89)	**	33.6 (0.85)	32.7 (0.87)	NS
Fat, %	4.01 (0.10)	4.40 (0.10)	**	4.21 (0.10)	4.21 (0.10)	NS
LWG, kg	36.8 (7.02)	25.2 (7.02)	NS	40.6 (7.02)	21.4 (7.02)	*
N efficiency[2], %	28.0 (1.14)	33.6 (1.17)	**	30.6 (1.14)	31.0 (1.17)	NS
CP content, g kg^{-1}	183	152		182	154	

[1] ECM = energy corrected milk yield; DM = dry matter; AAT = metabolizable protein; CP = crude protein; NDF = neutral detergent fibre; LWG = liveweight gain.
[2] $P<0.05$ = *; $P<0.01$ = **; $P<0.001$ = ***; NS = not significant.

Table 3. Feed intake and production results in Exp. II. Least square means (LSM) with standard error in brackets

Effect per day[1]	Cereals/conc	Cereals	Sign[2]
Silage intake, kg DM	10.4 (0.22)	12.0 (0.22)	***
Cereal intake, kg	8.5 (0.27)	10.6 (0.27)	***
Prot. Conc. intake, kg	4.2 (0.05)	0.0	***
Energy intake, MJ	273 (4.6)	58 (4.6)	*
AAT intake, g	1,980 (31.4)	1,649 (31.4)	***
CP intake, g	4,103 (61.4)	3,343 (61.4)	***
NDF intake, g	6,142 (108.2) (256.8)	6,586 (108.2)	**
Milk yield, kg	41.4 (0.93)	36.4 (0.93)	***
ECM, kg	40.0 (0.71)	37.3 (0.71)	*
Fat, %	3.76 (0.131)	4.15 (0.131)	*
LWG, kg	15.4 (4.91)	-5.3 (0.107)	**
N efficiency[2], %	31.5 (0.72)	35.4 (0.72)	***

[1] ECM = energy corrected milk yield; DM = dry matter; AAT = metabolizable protein; CP = crude protein; NDF = neutral detergent fibre; LWG = liveweight gain.
[2] $P<0.05$ = *; $P<0.01$ = **; $P<0.001$ = ***; NS = not significant.

feed-costs calculated, using feed prices in Sweden as of January 2015, resulted in better net revenue for milk income minus feed-cost per kg ECM for cows fed forage and cereals only. This was the case based on applying conventional prices but it was most evident when prices for organically produced feeds and organic milk was used.

Acknowledgements

References

Huhtanen P. (2014) Factors influencing the production value of forage protein. In: Udén P., Spörndly R., Eriksson T., Müller C. and Liljeholm M. (eds.). *Proceedings of the 5th Nordic Feed Science Conference*. Dept. of Animal Nutrition and Management. Swedish University of Agricultural Sciences, Uppsala, Sweden, pp. 124-129.

Influence of undigested and digested cattle slurry on grassland yield compared to mineral fertilizer

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Abstract

The of production biogas from cattle slurry is increasing in Estonia, but there is not enough information about the efficiency of using its by-product digestate as grassland fertilizer. Therefore a farm experiment was conducted to study the impact of cattle slurry digestate, undigested (raw) cattle slurry and inorganic compound fertilizer on grassland yield. Organic fertilizers were applied in amounts to provide 25 kg ha^{-1} P yr^{-1}. The application rates of cattle slurry digestate and cattle slurry provided 80.7 and 61.1 kg NH$_4$$^+$-N ha^{-1} yr^{-1} respectively, and the mineral compound fertilizer was 80 kg N ha^{-1} yr^{-1}. Grass yield was measured three times in the growing period. Our research showed that NH$_4$$^+$-N from cattle slurry digestate was not as effective as N from mineral fertilizer. Despite the higher NH$_4$$^+$-N application amount with digestate its yield was similar to the cattle slurry treatment.

Keywords: cattle slurry, cattle slurry digestate, grassland yield, fertilization

Introduction

In Estonia the production of biogas from cattle slurry is gaining popularity. It is promoted by the concentration of milk production in large dairy farms (60% of farms have more than 300 animals (Statistics Estonia, 2015)) and by the use of modern slurry technology on those farms. Digestate is the by-product of biogas production, and it is considered to be a valuable fertilizer due to the increased availability of nitrogen and the good short-term fertilization effect (Weiland, 2010). The use of digestate is considered to be environmentally beneficial since nutrient cycles can be closed and the need for mineral fertilizer reduced (Dieterich *et al.,* 2012).

Information about the fertilizer value of digestate for grassland remains inadequate, as most of the research has been conducted in small scale experiments, such as pot (Gunnarsson *et al.,* 2010; Fouda, 2011) or plot (Kováčiková *et al.*, 2013) experiments, and there is a lack of information about the use of cattle slurry digestate under farm conditions. Experimental results so far have shown that the yields when using digestate are comparable to those obtained when using mineral fertilizers at the same level of mineral N application (Gunnarsson *et al.*, 2010; Fouda *et al.*, 2011).

The aim of this research was to compare the effect of mineral fertilizer, cattle slurry and cattle slurry digestate on yield of meadow-type grassland consisting of red clover and grasses.

Materials and methods

An experiment was established in 2014 on grassland of Tartu Agro PLC, which consisted of red clover (*Trifolium pratense* L.) (25%), timothy (*Phleum pratense* L.) (30%), meadow fescue (*Festuca pratensis* Huds.) (30%) and perennial ryegrass (*Lolium perenne* L.) (15%). Treatments were: (1) control (no fertilizer was applied); (2) mineral fertilizer (NP 33-3); (3) cattle slurry; and (4) cattle slurry digestate in four replicates. Cattle slurry and cattle slurry digestate were applied to the soil in quantities according to a P rate of 25 kg ha^{-1}, which is the maximum permitted amount of manure application as determined by the Estonian Water Act. The application rates of NH$_4$$^+$-N when applying P 25 kg ha^{-1} were 80.7 and

61.1, with cattle slurry digestate and cattle slurry respectively. With mineral fertilizer 80 kg ha^{-1} yr^{-1} of N was applied to the grassland. All fertilizers were applied in three equal amounts: before the grass started to grow in spring, after the first harvest and after the second harvest. Organic fertilizers were applied with a slurry injector (Challenger Terra Gator 2244) and mineral fertilizer by broadcasting. Grassland yield and botanical composition were determined three times in the vegetative period: on 3 June, 21 July and 3 September. Yield was determined using a Haldrup plot harvester on 2×7 m plots (4 on each replication). The yield of one treatment was determined on total from 16 plots. The total experimental area was 21.0 ha.

All calculations were performed using the statistical package Statistica 12.0 (StatSoft.Inc) by one-way ANOVA and differences between averages were determined by the Fisher`s LSD test. The probability level was set at 0.05.

Results and discussion

Our results showed that the use of fertilizers did not have a significant ($P>0.05$) impact on total grassland yield (Table 1). When compared to the control, average yield was slightly higher ($P>0.05$) only when using mineral fertilizer; in both organic fertilizer treatments they tended to be lower ($P>0.05$). A significant ($P<0.05$) difference in yields appeared only between mineral and both organic treatments. The effect of cattle slurry and cattle slurry digestate on grassland production was similar. The limited impact of fertilization in this experiment was probably due to the high red clover content in the sward, which was on average 62.9%.

Sward total yield was significantly the highest ($P<0.05$) when using mineral N-fertilizer only in the first cut, when both the red clover and grasses fractions in the sward were high (Table 2). In the second and third cut the fraction of red clover in the sward declined and that of grasses increased. The increase in yield of grasses did not compensate for the decrease of the red clover fraction in the sward and therefore the total yields of the sward receiving mineral fertilizer in the second and third cut were slightly lower than for the control.

In both organic fertilizer treatments the red clover fraction of second and third cut was slightly higher when compared to the mineral treatment, but in contrast the grasses fraction there was lower. For this reason the yield of both organic fertilizer treatments was lower that of the treatment that received mineral fertilizer. We speculate that the lower effect of cattle slurry and its digestate on grassland yield may have been caused by the mechanical damage by injection method, as indicated also by Rodhe and Halling (2010). The total herbage yields of the cattle slurry and digestate treatments were similar, although yields of red clover and grasses in the sward were affected somewhat differently. Due to the higher NH_4^+-N application amount the yield of the grasses fraction in the digestate treatment was higher, and that of red clover lower, when compared to the cattle slurry treatment, although this difference was not statistically significant ($P>0.05$).

Table 1. Dry matter yields, Mg dry matter ha^{-1}.[1]

Treatment	Cut			Total
	1st	2nd	3rd	
Control	3.94[A]	3.99[A]	2.20[A]	10.13[AB]
Mineral	4.46[B]	3.77[A]	2.12[AB]	10.35[B]
Cattle slurry digestate	3.88[A]	3.83[A]	1.82[B]	9.53[A]
Cattle slurry	3.87[A]	3.67[A]	1.85[AB]	9.39[A]

[1] Within the same column, values with different letters are significantly different ($P<0.05$).

Table 2. Dry matter yields (Mg ha^{-1}) of species functional groups in different cuts.[1]

Treatment	Red clover	Sown grasses	Unsown species
1st cut			
Control	2.84^{A*}	0.95^A	0.15^A
Mineral	2.72^A	1.60^B	0.14^A
Cattle slurry digestate	2.57^A	1.17^{AB}	0.14^A
Cattle slurry	2.41^A	1.17^{AB}	0.29^A
2nd cut			
Control	2.58^A	1.21^A	0.21^A
Mineral	2.00^A	1.65^A	0.12^A
Cattle slurry digestate	2.08^A	1.54^A	0.21^A
Cattle slurry	2.32^A	1.14^A	0.21^A
3rd cut			
Control	1.75^A	0.43^A	0.02^A
Mineral	1.02^B	1.05^B	0.05^A
Cattle slurry digestate	1.14^B	0.66^{AB}	0.02^A
Cattle slurry	1.26^B	0.54^A	0.05^A

[1] Within the same column and cut, values with different letters are significantly different ($P<0.05$).

Conclusions

Our research showed that in well-established grassland with high legume content NH_4^+-N from cattle slurry digestate is not as effective as N applied with mineral fertilizer. The main difference between digestate and mineral fertilizer was mainly expressed in their impact on the yield of the grasses fraction of the sward, which was slightly lower ($P>0.05$) when digestate was applied. The yields of cattle slurry and cattle slurry digestate were similar, in spite of the higher amount of NH_4^+-N application with digestate when compared to cattle slurry.

Acknowledgements

References

Dieterich B., Finnan J., Frost P., Gilkinson S. and Müller S. (2012) The extent of methane (CH4) emissions after fertilization of grassland with digestate. *Biology and Fertility of Soils* 48, 981-985.

Fouda S.E. (2011) *Nitrogen availability of biogas residues*. PhD thesis. Technische Universität München, Munchen, Germany, 110 pp.

Gunnarsson A., Bengtsson F. and Caspersen S. (2010) Use efficiency of nitrogen from biodigested plant material by ryegrass. *Journal of Plant Nutrition and Soil Science* 173, 113-119.

Halling M.A. and Rodhe, L. (2010) Grassland yield response to knife/tine slurry injection equipment – benefit or crop damage? *Grassland Science in Europe* 15, 175-177.

Kováčiková Z., Vargová V. and Jančová, Ľ. (2013) Effect of digestate application on herbage quality and quantity of permanent grassland. *Agriculture* 59, 88-98.

Statistics Estonia (2015) Available at: http://www.stat.ee.

Weiland P. (2010) Biogas production: current state and perspectives. *Applied Microbiology and Biotechnology* 85, 849-860.

Herbage energy to protein ratio of binary and complex legume-grass mixtures

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Abstract

Herbage with a greater ratio of energy availability to protein degradability increases dairy cow N-use efficiency. We determined the variation in this ratio among 18 binary legume-grass mixtures and 8 complex mixtures combining three or four grass species with one of two legume species. Species included in those two experiments were birdsfoot trefoil (*Lotus corniculatus* L.), lucerne (*Medicago sativa* L.), white clover (*Trifolium repens* L.), cocksfoot (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pratensis* L.), meadow bromegrass (*Bromus biebersteinii* Roemer & J.A. Schultes), meadow fescue (*Festuca pratensis* L.), reed canarygrass (*Phalaris arundinacea* L.), tall fescue (*Schedonorus phoenix* (Scop.) Holub), and timothy (*Phleum pratense* L.). Carbohydrate and protein fractions of the Cornell Net Carbohydrate and protein system were measured in herbage from two clippings of the first post-seeding year at two sites in eastern Canada. The water soluble carbohydrate to crude protein ratio ranged from 0.39 to 0.70 among binary mixtures and from 0.64 to 1.04 among complex mixtures, while the ratio of non-structural carbohydrates to non-protein N and rapidly degradable proteins ranged from 3.62 to 5.28 and from 4.33 to 5.64, respectively. Our results confirm the possibility of improving the balance between energy and proteins through the choice of species in legume-grass mixtures.

Keywords: herbage species, yield, carbohydrates, frequent clipping

Introduction

Enhanced efficiency of N utilization and enhanced milk yield were reported for late-lactation cows fed only lucerne with greater non-structural carbohydrate concentration (Brito *et al.*, 2009) or high sugar grasses with some concentrates (Miller *et al.*, 2001). For improved N utilization by dairy cows, a dietary combination of high energy availability and reduced total N concentration, or reduced N solubility, has been suggested for better microbial protein synthesis in the rumen (Bryant *et al.*, 2012). Greater concentrations of NSC along with low concentrations of non-protein N and rapidly degradable proteins (protein fractions A and B1 of the carbohydrate and protein system (CNCPS), respectively) in herbage should improve N utilization by dairy cows. Two ratios can be considered: water soluble carbohydrate (WSC)/crude protein (CP) and non-protein N (NSC)/(NPN + rapidly degradable proteins (RDP)). Very little information exists for these ratios in herbage mixtures grown in eastern Canada.

Materials and methods

Two experiments were conducted in the same field at each of two sites: Lévis and Normandin, QC, Canada. In the first experiment, 18 simple binary mixtures of one legume species (birdsfoot trefoil (*Lotus corniculatus* L.), lucerne (*Medicago sativa* L.), or white clover (*Trifolium repens* L.) and one grass species (cocksfoot (*Dactylis glomerata* L.), Kentucky bluegrass (*Poa pratensis* L.), meadow bromegrass (*Bromus biebersteinii* Roemer & J.A. Schultes), meadow fescue (*Festuca pratensis* L.), reed canarygrass (*Phalaris arundinacea* L.), tall fescue (*Schedonorus phoenix* (Scop.) Holub), or timothy (*Phleum pratense* L.)) were compared. In the second experiment, the 8 complex mixtures were made of one of 2 legume species

(a grazing-type lucerne or birdsfoot trefoil) and one of 4 grass mixes (GM1 = timothy, meadow fescue, Kentucky bluegrass; GM2 = timothy, meadow fescue, reed canarygrass, Kentucky bluegrass; GM3 = tall fescue, meadow bromegrass, cocksfoot, Kentucky bluegrass; GM4 = tall fescue, meadow bromegrass, reed canarygrass, Kentucky bluegrass). In both experiments, treatments were replicated three times in a split-plot layout with legume species as main plots and grass species as subplots. Treatments were considered fixed effects, while sites and replicates were considered random effects in the analyses of variance.

In the first post-seeding year (2011), plots were frequently clipped with a self-propelled flail harvester to 7-cm height when timothy reached around 25 cm in height. Only samples from the first two clippings were analysed because they were taken in the period with the greater variation in nutritive attributes due to flowering. The first and second clippings from successive regrowth were taken on 2 and 22 June 2011 at Lévis, and on 6 and 27 June 2011 at Normandin, respectively. Concentrations of WSC, CP, ether extract (EE), ash, neutral detergent fibre (NDF), NPN, and RPD were determined and NSC concentration was calculated (NSC=100-CP-EE-Ash-NDF) in a subset of samples. These nutritive attributes were then estimated by near infrared reflectance spectroscopy in all herbage samples (Simili da Silva *et al.*, 2013).

Results and discussion

Binary mixtures of lucerne with meadow fescue (L-Mf, Figure 1a), timothy (L-Ti), or tall fescue (L-Tf) along with those of birdsfoot trefoil with meadow fescue (B-Mf) or tall fescue (B-Tf) had greater WSC/CP ratio (0.70, 0.65, 0.62, 0.63, and 0.62, respectively) than the average of all mixtures (0.52); L-Mf, B-Mf, and B-Tf mixtures had greater dry matter (DM) yield (1.74, 1.67 and 1.51 Mg ha^{-1}, respectively) than the average of all binary mixtures (1.48 Mg ha^{-1}). Binary mixtures of meadow fescue with lucerne (L-Mf) or birdsfoot trefoil (B-Mf) provided the best combination of a high ratio of WSC/CP and yield. All binary mixtures with lucerne, except the lucerne-meadow bromegrass mixture (L-Mb), had greater NSC/(NPN+RDP) ratio (4.41 to 5.28) than the average (4.11). Binary mixtures of Kentucky bluegrass with lucerne (L-Kb) or white clover (C-Kb) were the least productive.

The two ratios used to characterize the energy to protein balance varied significantly among the eight legume-grass complex mixtures (square symbols, Figure 1a,b) and this variation was due to both legume species and grass mixes. Lucerne-based complex mixtures had greater WSC/CP (Figure 1a) and NSC/(NPN+RDP) (Figure 1b) ratios than birdsfoot trefoil-based mixtures. The grass mix 2 (timothy, meadow
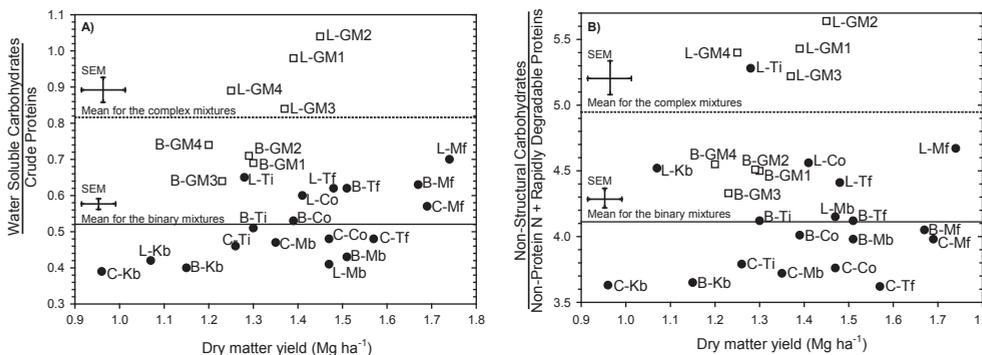

Figure 1. Ratios of (A) water soluble carbohydrates/crude protein and (B) of non-structural carbohydrates/(non-protein N + rapid degradable proteins) as a function of dry matter yield of 18 legume-grass binary mixtures (●, Experiment 1) and 8 legume-grass complex mixtures (□, Experiment 2). Values are averages of two clippings at two sites. B = birdsfoot trefoil, C = white clover, L = lucerne, Co = cocksfoot, Kb = Kentucky bluegrass, Mb = meadow bromegrass, Mf = meadow fescue, Rc = reed canarygrass, Tf = tall fescue, Ti = timothy, GM1 = grass mix 1 = Ti + Mf + Kb, GM2 = Ti + Mf + Rc + Kb, GM3 = Tf + Mb + Co + Kb, and GM4 = Tf + Mb + Rc + Kb.

fescue, reed canarygrass and Kentucky bluegrass) provided the best combination of high readily-available energy to protein ratios (WSC/CP = 0.87; NSC/(NPN+RDP) = 5.08) and high DM yield. The complex mixtures including lucerne and meadow fescue had the best readily-available energy to protein ratios and DM yield.

Conclusions

These results from the first two clippings of the first production year at two sites provide useful and novel information on the desired species composition of binary and complex legume-grass mixtures that combine high readily-available energy to protein ratios and DM yield. They confirm the possibility of improving the balance between herbage readily-available energy and proteins through the choice of species. Research is ongoing to determine the feasibility of maintaining this desired composition throughout the growing season and over several cropping years.

References

Brito A.F., Tremblay G.F., Lapierre H., Bertrand A., Castonguay Y., Bélanger G., Michaud R., Benchaar C., Ouellet D.R. and Berthiaume R. (2009) Alfalfa cut at sundown and harvested as baleage increases bacterial protein synthesis in late-lactation dairy cows. *Journal of Dairy Science* 92, 1092-1107.

Bryant R.H., Gregorini P. and Edwards G.R. (2012) Effects of N fertilisation, leaf appearance and time of day on N fractionation and chemical composition of *Lolium perenne* cultivars in spring. *Animal Feed Science and Technology* 173, 210-219.

Miller L.A., Moorby J.M., Davies D.R., Humphreys M.O., Scollan N.D., MacRae J.C. and Theodorou M.K. (2001) Increased concentration of water-soluble carbohydrate in perennial ryegrass (*Lolium perenne* L.): Milk production from late-lactation dairy cows. *Grass and Forage Science* 56, 383-394.

Simili da Silva M., Tremblay G.F., Bélanger G., Lajeunesse J., Papadopoulos Y.A., Fillmore S.A.E. and Jobim C.C. (2013) Energy to protein ratio of grass-legume binary mixtures under frequent clipping. *Agronomy Journal* 105, 482-492.

Nitrogen fertilizer replacement value of concentrated liquid fraction on grassland and effects on farm level

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Abstract

In the Netherlands, initiatives are taken to process animal manure. In a pilot of manure processing a liquid fraction of pig slurry with mainly mineral nitrogen (N) and potassium (K) is produced. The liquid fraction is concentrated into mineral concentrate (MC). To determine the nitrogen fertilizer replacement value (NFRV) on grassland, field experiments took place on sand and clay. The N yields with MC, calcium ammonium nitrate (CAN) and liquid ammonium nitrate (LAN) were compared. The responses to MC and LAN were lower than expected, compared to CAN. This resulted in NFRVs for MC that varied between 44 and 82%, with CAN as a reference fertilizer. To consider the consequences at farm level, a farm is simulated. By replacing 80 kg N ha^{-1} of CAN with 10 m^3 ha^{-1} of MC, the farm saves €4,864 for fertilizers but yield reduction is 12 Mg DM of grass silage, which equals €2,040. This indicates that the MC should cost €7.40 m^{-3} maximum to reach an equal income on the alternative farm compared with the reference farm. If the NFRV were to reach 100%, the MC should cost €12.80 m^{-3} maximum, the costs of the replaced mineral fertilizers N and K$_2$O.

Keywords: liquid fraction, pig slurry, mineral concentrate, apparent N recovery, NFRV

Introduction

In the Netherlands, initiatives are taken to process animal manure to increase mineral efficiency and to export phosphorus (P) surplus. From 2009, a pilot is taking place of manure processing on industrial scale. Manure is separated into a liquid fraction with mainly mineral nitrogen (N) as ammonium and potassium (K) for application on farms in the Netherlands, and a solid fraction with mainly organic N and P for export. The liquid fraction is concentrated into mineral concentrate (MC) by reversed osmosis (Velthof *et al.*, 2012). For an efficient use of MC it is necessary to know the N fertilizer replacement value (NFRV). It was expected that the NFRV of MC on grassland would be slightly lower than 90% because of ammonia volatilization. To determine the NFRV on grassland, grassland field experiments took place from 2009 to 2012.

Materials and methods

In grassland experiments the N uptake after application of MC of pig slurry, calcium ammonium nitrate (CAN) and liquid ammonium nitrate (LAN), both with 50% ammonium, 50% nitrate, were compared at three application rates: 100, 200 and 300 kg N ha^{-1}, divided over three successive cuts, and a control (0 N). All plots received the same rate of P and K, and more sulphur than recommended in the fertilizer recommendation, from MC and/or from mineral fertilizers. The MC and LAN were injected approximately 5 cm into the soil. The CAN, P and K were applied with an accurate granulate spreader for experimental fields or by hand by experienced people. On the 0 N plots, the application machines were used without fertilizer. In 2009 and 2010 MC (from three producers), CAN and LAN were applied in one, two or three successive cuts; in 2011 the same treatments were applied, but MC was from one producer; finally, in 2012 MC was from one producer and CAN and LAN were applied in three successive cuts. In 2009 and 2010, the soil types were clay and sand, in 2011 sand, and in 2012 relatively wet sand and sand under hydrological circumstances considered as normal (for the Netherlands). On all

plots dry matter (DM) yield and N content of the grass were measured through the whole growing season in five cuts. At the end of the growing season soil mineral N (0-90 cm) was measured.

The results of annual DM yield, N yield and mineral soil N were statistically analysed with the Residual Maximum Likelihood method (Reml) (Harville, 1977). The initial model comprised type of fertilizer, year, soil type, N level, N level^2, number of fertilized cuts and the interactions. The random model was replicate×site. Non-significant terms and interactions were deleted. With the resulting model for N yield the NFRV was calculated by dividing the Apparent N Recovery (ANR) of MC by the ANR of the reference (CAN). ANR was calculated as (N yield at N-fertilization minus N yield at zero N-fertilization)/N-fertilization (Schroder *et al.*, 2007).

To consider the consequences oat farm level, a farm is simulated with DairyWise, a whole farm budgeting program (Schils *et al.*, 2007). The simulated farm is a dairy farm, 50 ha on sandy soil: 12 ha of forage maize, 38 ha of grassland, 110 dairy cows producing 8,600 kg milk, 41% calves, 39% heifers. The legal application standards are 250 kg N ha^{-1} animal manure (including pasture excretion), legal NFRV 45% for animal manure, 250 kg plant available N ha^{-1} (animal manure N × 45% + mineral fertilizer N). The reference scenario is a farm applying all mineral N as CAN compared with an alternative scenario that is a farm that replaces 80 kg N ha^{-1} with 10 m^3 MC ha^{-1} grassland, NFRV 75%, 8 kg N and 8 kg K$_2$O m^{-3}.

Results and discussion

The responses of DM and N yield to N-fertilization were positive for all fertilizers. The resulting model was:

$$Nyield_{year×site} = Constant_{year×site} + \beta_{year×fertilizer\ type×site} × Nfertilization + \mu_{replicate×site} + \varepsilon_{plot×site}$$

In which: Nyield is N yield (in kg N ha^{-1}) for specific year and site, Constant (in kg N ha^{-1}) is intercept for specific year and site, β is a coefficient depending on year, fertilizer type and site for N fertilization, and N fertilization is N application rate (in kg N ha^{-1}), μ is the random model, ε is residual variance. Other factors or interactions were not significant ($P<0.05$).

With the model results of CAN, LAN and MC, the ANRs and NFRVs are calculated, respectively (Table 1). The variance between years was large, including responses to the reference fertilizers CAN and LAN. The responses to MC and LAN were lower than expected compared to the response to CAN. Overall the NFRV of MC with CAN as reference was 75% on sand and 58% on clay. On sand the lowest NFRV of MCs was 61% in 2009 and the highest was 82% on dry sand in 2012. On clay NFRVs were 44% in 2009 and 67% in 2010. The lower NFRV on clay soil was (mathematically) caused by a relatively high ANR of CAN, the ANR of MCs on clay was in the same range as on sand. A high ANR of CAN, however, is normal for this site (Schils and Snijders, 2004).

It is not clear why, in most of the experimental years, the response of DM and N yield to liquid fertilizers (LAN and MC) is lower than to CAN. The application method was accurate and control plots (0N) with slits from the application machine showed an equal yield as plots without slits.

The NFRV of MC was in general lower than of LAN. This difference might be explained by ammonia volatilization as MC has a high ammonia concentration and pH (ca. 8). The mineral soil N under MC and LAN, however, was not different from those under CAN. It was unlikely that the non-recovered N was lost through leaching. Possibly it was lost through gaseous N emissions (ammonia volatilization) and/or stored as organic N in the soil.

Table 1 Apparent nitrogen recovery (ANR, kg N kg^{-1} N) of calcium ammonium nitrate (CAN), liquid ammonium nitrate (LAN) and mineral concentrate (MC), and nitrogen fertilizer replacement value (NFRV), on sand and clay in 2009 to 2012, based on nitrogen yield, with CAN and LAN as reference.

Year	Soil	ANR, kg N kg^{-1} N			NFRV, %			
					Reference: CAN		Reference: LAN	
		CAN	LAN	MC	MC	LAN	MC	CAN
2009	Sand	0.58	0.41	0.35	61	70	86	143
	Clay	0.78	0.45	0.34	44	58	76	174
2010	Sand	0.74	0.55	0.58	78	74	105	135
	Clay	0.84	0.54	0.56	67	65	104	155
2011	Sand	0.65	0.65	0.52	80	100	80	100
2012	Dry sand	0.70	0.71	0.57	82	102	80	98
	Wet sand	0.84	0.78	0.65	77	92	83	109
Overall	Sand	0.68	0.57	0.51	75	84	89	119
	Clay	0.81	0.51	0.47	58	62	92	160

The relatively low NFRV has economic consequences for the use on high productive dairy farms. The farm applying MC saves €3,040 for CAN (€1 kg^{-1} N) and €1,824 for K$_2$O (€0.60 kg^{-1} K$_2$O) but cannot replace 20 kg N ha^{-1} from MC that is not represented in the NFRV due to the legal application standards. The yield reduction at farm level is 12 ton DM of grass silage, which equals €2,040 (€0.17 kg^{-1} DM). The decrease of feeding value by lower N fertilization rate is not taken into account. This indicates that the MC should cost €7.40 m^{-3} maximum to reach an equal income on the alternative farm compared with the reference farm. In 2014, however, MC was sold for €14 m^{-3} by the processing companies. If the NFRV would reach 100%, MC should cost €12.80 m^{-3} maximum, the costs of the replaced mineral fertilizers N and K$_2$O.

References

Harville D.A. (1977) Maximum likelihood approaches to variance component estimation and to related problems. *Journal of American Statistical Association* 72, 320-338.

Schils R. and Snijders P. (2004) The combined effect of fertiliser nitrogen and phosphorus on herbage yield and changes in soil nutrients of a grass/clover and grass-only sward. *Nutrient Cycling in Agroecosystems* 68, 165-179.

Schils R.L.M., de Haan M.H.A., Hemmer J.G.A., Van den Pol-van Dasselaar A., De Boer J.A. and Evers A.G. (2007) DairyWise, a whole-farm dairy model. *Journal of Dairy Science* 90, 5334-5346.

Schroder J.J., Uenk D. and Hilhorst G.J. (2007) Long-term nitrogen fertilizer replacement value of cattle manures applied to cut grassland. *Plant and Soil* 299, 83-99.

Velthof G.L., Hoeksma P., Schroder J.J., Van Middelkoop J.C., Van Geel W., Ehlert P.A.I., Holshof G., Klop G. and Lesschen J.P. (2012) Agronomic potential of mineral concentrate from processed manure as fertiliser. In: *Proceedings 716, International Fertiliser Society, 20th Annual Conference, International Fertiliser Society,* 6-7 December 2012.

Optimizing N management through improving transitions of temporary grassland and maize in rotation

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Abstract

Crop rotation in which grass and maize are alternated may contribute to efficient production of feeds for dairy production. However, in particular on dry sandy soils, proper transitions from the arable into the grassland phase and *vice versa* are crucial to control N leaching. From 1993 to 2010 we implemented four different systems on the experimental dairy farm De Marke on the basis of a grass-grass-grass-arable-arable-arable rotation scheme. Each consecutive system was implemented to solve problems of the former system. This paper presents results on how various sources of information contributed to developments of crop rotation schemes on De Marke. Fodder beet was replaced by maize as first-year arable crop to avoid storage problems associated with fodder beet. This change tended to result in higher nitrate leaching to groundwater under first- and last-year arable crops. This was solved by leaving out N fertilization in the first-year maize. Smoothing the transition of arable land into new temporary grassland resulted in a more continuous presence of vegetation during winter. However, this had no clear effect on nitrate leaching to groundwater.

Keywords: barley, dairy, fodder beet, nitrate leaching, system development

Introduction

Silage maize is a highly valued crop on dairy farms, in particular on dry sandy soils, because of its high production potential, its capacity to use nutrients and water efficiently and its value in the ration as a complement to grass silage. However, maize is associated with high nitrate leaching to groundwater and with a poor soil quality in terms of soil organic matter content. It is crucial to solve these problems by improving management practices. Application of crop rotation in which maize is alternated with grassland is widely accepted as a method to preserve soil quality. On the experimental dairy farm 'De Marke', located in the eastern part of the Netherlands, a crop rotation was developed with the focus on reducing nitrate leaching, in particular during the delicate transitions from grassland to arable land and *vice versa*.

Materials and methods

'De Marke' is a prototype dairy farm and defines, in addition to a location, a research approach. Since the start, the farm has been continuously developed to meet as close as possible pre-defined targets using a method called system development. This is a cyclic procedure, consisting of: design of strategies and measures, implementation of the design, monitoring, analysis and evaluation of its performance (Aarts, 2000). This procedure was also applied on the production of grass and fodder crops. To support this process a monitoring programme was established comprising land use and crop management, nutrient flows (on farm scale and on field scale), crop yields, soil fertility, N mineralization, nitrate leaching and conversion of feeds by the cattle in meat and milk. Nutrient flows were established on each of 30 parcels of 1-3 ha. Nitrate leaching was established annually by sampling the upper metre of groundwater in a density of 3 boreholes per ha in February. The rotation systems were evaluated through extensive analyses of data and expert meetings. The climate is sufficiently stable to allow comparison of performance of rotation systems that were practised in subsequent periods of at least three years. Nitrate leaching was corrected for dilution by inter-annual variation of precipitation (Boumans *et al.*, 2001). System development resulted

in four rotation schemes (A, B, C and D). In all systems, on maize land, Italian ryegrass was sown as a catch crop between the rows in June and ploughed-in in the first week of March.

Results and discussion

From 1993-1996 fodder beet was the first arable crop after grassland (system A, Figure 1). A major concern in crop rotation is to capture the high amounts of N that are released by ploughing-in the former grassland sod in the first-year arable land. Fodder beet has a high N uptake capacity (Nevens and Reheul, 2002). Therefore, beet was considered the most suitable crop in the first-year arable land. However, storage of beet was technically problematic and their incorporation in the ration of the cattle put pressure on the conversion of feeds into milk. Therefore, in system B (1996-1999) fodder beet was replaced by first-year maize. This change entailed a risk of increasing nitrate leaching. Indeed, the nitrate concentrations in groundwater in first-year fodder crops (Figure 2a), tended to be higher in system B than in system A, although the differences were not significant. The same holds for nitrate leaching in the final-year fodder crops in system B compared to system A (Figure 2b), which might be explained by a delayed effect of the replacement of fodder beet by first-year maize. This is consistent with the observation of higher residual N in soil after first-year maize than after fodder beet (data not shown), which could have caused the increase of nitrate leaching in later arable years. Therefore, this urged us to improve the tuning of the N fertilization to the crop needs. N-application rates for maize were established by correcting the required N rates for release of N from the ploughed-in grass in first-year maize and second-year maize (90 and 45 kg N per ha respectively), which implies that no fertilization was required in first-year maize. This approach was not yet fully implemented in system B – with application rates of 50-100 kg N per ha.
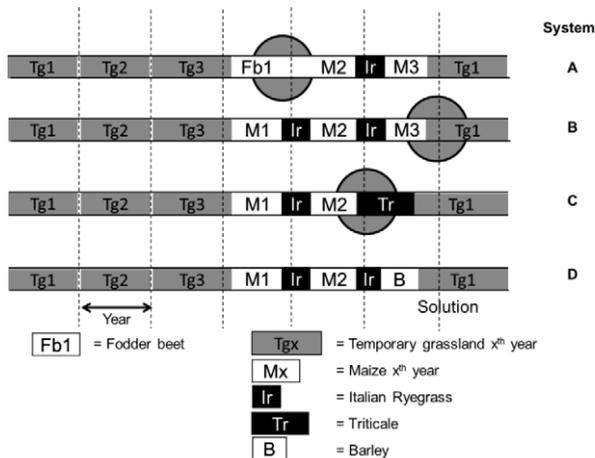
Figure 1. Rotation systems at 'De Marke'; grey circles mark components that needed improvement.
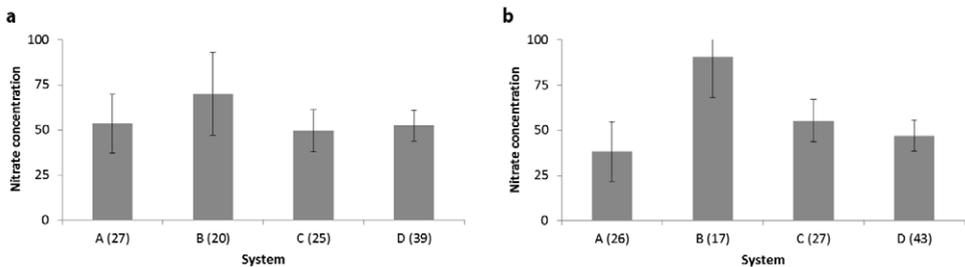
Figure 2. Mean nitrate concentration (mg l^{-1}) in the upper metre of groundwater for crop rotation systems (A, B, C and D). (a) first-year arable land; (b) final-year arable land. n = number of observational units; vertical bars show 95% confidence limits.

Since 2000, fertilization was completely omitted in first-year maize (system C). This adjustment probably contributed to the recurrence of a tendency to lower nitrate concentrations in groundwater in system C and D (Figure 2a).

A major concern during the transition from arable land to grassland is to minimize N leaching through preventing the incidence of bare soil without vegetation that can capture mobile N. In systems A and B, at the end of the arable phase, grass was sown directly after harvest of maize to form a new temporary grassland sod (Figure 1). However, maize was often harvested by the end of September, which is too late for establishment of the new grass sod before the onset of winter. Therefore, in system C (2000 to 2003) triticale was implemented to replace maize as the last arable crop. Triticale was sown after the second maize crop, to function during winter as a catch crop instead of Italian ryegrass. It was assumed it would develop faster in winter than perennial ryegrass. After winter, it was harvested in mid-summer, after which grass was sown and could develop more strongly before the onset of winter. However, triticale was still associated with excessive nitrate leaching (Verloop, 2013). This was explained as an effect of the mediocre development of triticale as a catch crop after maize (Figure 1). The development of triticale was below expectations and in harsh winters it tended to completely disappear. This observation led to replacement of triticale by spring barley in combination with Italian ryegrass as catch crop in the preceding maize (system D). The barley was harvested in summer after which grass was sown. The effects of these adjustments in the final-year arable crops were probably corroborated with the effects of the replacement of fodder beet with maize (system B). However, when system B is neglected in the analysis, we see that our efforts to provide an increasingly smoothened transition for arable crop to grassland was not clearly reflected by a tendency to lower nitrate leaching (compare system A, C and D in Figure 2b).

Conclusions

System development on the experimental dairy farm De Marke on dry sandy soil shows that:

Replacement of fodder beet as first-year arable crop after grassland by maize seems to be associated with higher nitrate leaching to groundwater under first- and last-year arable crops, unless N fertilization in maize is left out.

Replacement of maize by subsequent crops of triticale and spring barley as last-year arable crops to obtain a more continuous green cover during winter did not clearly affect nitrate leaching to groundwater in the transition from arable into temporary grassland.

References

Aarts H.F.M. (2000) *Resource management in a 'De Marke' dairy farming system*. PhD Thesis, Wageningen University, Wageningen, the Netherlands.

Boumans L.J.M., Fraters B. and Van Drecht, G. (2001) Nitrate in the upper groundwater of 'De Marke' and other farms. *Netherlands Journal of Agricultural Science* 49, 163-177.

Nevens F. and Reheul D. (2002) The nitrogen- and non-nitrogen-contribution effect of ploughed grass leys on the following arable forage crops: determination and optimum use. *European Journal of Agronomy* 16, 57-74.

Verloop, K. (2013) *Limits of effective nutrient management in dairy farming: analyses of experimental dairy farm De Marke.* PhD thesis, Wageningen University, Wageningen, the Netherlands.

Sward quality and yields of grassland in a dairy farm with reduced fertilizer N rates

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Abstract

The objective of this study was to explore under farming conditions the effect of reduced fertilizer N application rates on the dynamics of botanical composition and yields of grass-clover-swards. In both temporary and permanent grassland the percentage of highly productive grasses (good grasses) declined at a constant rate of 3.0 to 6.3% points y^{-1} during the aging of the sward. Good grasses were replaced by less-productive grasses and herbs. The percentage of clover did not show a significant trend. Reduced N fertilization did not significantly change these dynamics. The percentage of white clover and, in some cases, high-yielding grasses in the sward, enhanced the yields of nitrogen and herbage dry matter, while the percentage of herbs reduced yields.

Keywords: white clover, permanent grassland, temporary grassland, botanical composition

Introduction

In Dutch intensive dairy production, there is a high appreciation for grassland swards that consist mainly of productive grasses mixed with clover to fix nitrogen (N). This appreciation has been formalized in a classification system for grasses based on their potential yields and feed nutritional value (Sikkema, 1990). A distinction is made between good (GG), mediocre (MG) and inferior grasses (IG). Farming conditions may hamper maintenance of the optimal sward quality and lead to the replacement of GG by MG, IG and herbs (H). In particular, drought stress and the level of N fertilization could affect the sward quality (Oomes, 1992). Possibilities have been explored on the experimental farm 'De Marke', since 1989 to produce milk without violating environmental standards for N and P. Aiming for a higher system of N-use efficiency and lower N losses, in 2003 the N fertilization in grass (NF) was reduced from 214-247 to 146-177 kg ha^{-1}. In this study, we analysed the effects of reducing NF rates on the dynamics of sward quality and effects of sward quality on grass yields.

Materials and methods

The study is based studies on the experimental farm 'De Marke' in the Netherlands. The climate is favourable for grass production (annual precipitation of 792 mm and a temperature of 14 °C in summer). However, plant-available water on the deep-draining sandy soil is a major growth-limiting factor. The farm area consists of permanent grassland (PG) and a crop rotation in which three years of temporary grassland (TG) and three to five years of arable crops are alternated (Verloop, 2013). Part of the grassland is subjected to rotational grazing. PG is renovated when the sward condition is considered inadequate according to the recommendations, i.e. about once every six years. To establish a new grassland sward, 28 kg ha^{-1} perennial ryegrass, 7 kg ha^{-1} timothy and 9 kg ha^{-1} white clover are sown. Herbicides are used occasionally to control dandelion. The farm area (55 ha) was divided into 30 parcels. Botanical composition and the total 'sprout density of vegetation' (SDV) were monitored by visual observations on each parcel. The botanical composition was expressed in terms of sward quality distinguishing GG, MG and IG for grasses, H for herbs and L for legumes (Table 1). Dandelion was the dominant herb; thus, H can be considered a proxi of dandelion. Similarly, L is a proxi of white clover. For each parcel the crop management, grazing intensity and nutrient flows (inputs, yields) were recorded (Verloop, 2013). Each parcel was included as an observation unit in the analysis of the dynamics of sward quality. In most parcels the change of sward quality as the grassland sward aged was constant and could thus be described

Table 1. Species observed in grassland at 'De Marke' and their classification (acc. to Sikkema, 1990).[1]

Name (scientific name)	Class[2]	Name (scientific name)	Class
Perennial ryegrass (Lolium perenne)	GG	Annual meadow-grass (Poa annua)	IG
Timothy (Phleum pratense)	GG	Soft-brome (Bromus hordeaceus)	IG
Italian ryegrass (Lolium multiflorum)	GG	White clover (Trifolium repens)	L
Meadow fescue (Festuca pratensis.)	GG	Red clover (Trifolium pratense)	L
Cock's-foot (Dactylis glomerata)	MG	Dandelion (Taraxacum officinale)	H
Rough meadow-grass (Poa trivialis)	MG	Chickweed (Stellaria media)	H
Couch-grass (Elytrigia repens)	MG	Broad-leaved dock (Rumex obtusifolius)	H
Creeping bentgrass (Agrostis stolonifera)	MG	Shepherd's purse (C. bursa-pastoris)	H
Yorkshire fog (Holcus lanatus)	MG	Smooth hawk's beard (Crepis capillaris)	H
Smooth meadow-grass (Poa pratensis)	MG	Common yarrow (Archillea millefolium)	H

[1] Together representing >96% of the botanical composition of the sward.

[2] GG = good grasses; MG = mediocre grasses; IG = inferior grasses.

by linear functions. Therefore, we expressed the change of sward quality by regression coefficients (RC), e.g. $\Delta GG \, \Delta t^{-1}$. We compared RC values for 1989-2003 (HighN) with those for 2004-2012 (LowN) to explore effects of the management changes (Table 2). Moreover, we analysed which sward components significantly affect yields of nitrogen (NY) and dry matter (DMY) – ranging from 118 to 378 and 5,347 to 14,412 kg ha^{-1}, respectively – using all data, except the first-year TG and PG to avoid bias caused by establishment of the new sward. In this analysis, we compared the performance of basic regression models for NY and DMY – comprising only the effects of year, NF and grazing intensity – with extended models in which GG, MG, IG, H and L were also adopted.

Results and discussion

Table 3 presents information on sward quality and its change over time for PG and TG in the HighN and LowN management systems. GG declined significantly over time in PG and TG (Table 3), the two types following similar patterns. The decline of GG is associated with an increase of H, MG and, occasionally, with IG. The measures SDV and L show no significant trend over time. For sward quality and the dynamics of sward quality there were no significant differences between the HighN and LowN management systems, or between PG and TG. Moreover, regression analysis in > first-year grassland showed no significant relationship between NF and sward quality.

L and H had significant effects on the N yield ($P<0.01$). Adoption of L and H to the basic model resulted in a better description of the N yield (increase of R^2_{adj} from 17 to 69%). L enhanced the N yield by 4.4 kg ha^{-1} per % and H reduced the N yield by 3.6 kg ha^{-1} per %. Effects of GG, GM and GI on the yield of N and dry matter were not significant. The effects of L and H on the N yield were twice as strong in

Table 2. The N fertilization level (NF) and grazing intensity (GI) in a HighN (1989-2003) and LowN (2004-2012) system (kg ha^{-1}); means of all observations (with range given in brackets).

	Permanent grassland		Temporary grassland	
	NF[1]	GI[2]	NF	GI
HighN	214 (120-300)	94 (35-185)	247 (120-310)	65 (0-216)
LowN	146 (124-219)	42 (0-138)	177 (99-240)	28 (0-155)

[1] Calculated as $0.5 \times$ N-manure rate + $0.15 \times$ N-grazing rate + N-mineral fertilizer rate (kg ha^{-1}).

[2] The excretion of N during grazing (kg ha^{-1}) was used as a proxi of the grazing intensity.

Table 3. The sward quality in first-year grassland (FY, %) and the change of sward quality over time (regression coefficient, RC, % point y[-1]); number of observations (n).[1,2]

System	Land use (n)	Parameter	SDV	GG	L	MG	IG	H
HighN	PG (12)	FY[3]	92	79	11.3	1.7	3.8	4.3
		RC[4]	-0.6	-3.9*	-0.6	2.9*	0.4	1.3*
	TG (15)	FY	87	82	12.4	0.4	2.9	2.2
		RC	0.3	-3.0	-0.5	1.4*	0.5	1.5*
LowN	PG (6)	FY	89	84	3.2	4.0	4.7*	5.0
		RC	0.6	-6.3*	1.8	4.1*	1.2	-0.8*
	TG (10)	FY	88	87	10.5	0.7	0.4	1.6
		RC	-0.8	-4.4*	0.0	0.5	0.8	3.2*

[1] Abbreviations used: SDV = sprout density; GG = good grasses; L = legumes; MG = mediocre grasses; IG = inferior grasses; H = herbs; PG = permanent grassland; TG = temporary grassland.

[2] Values with an * are different from 0 at P<0.05, according to Student t-test.

[3] Standard deviations for SDV, GG and L are 8, 9 and 9%, respectively, and 2 to 3% for MG, IG and H.

[4] Standard deviations for the RCs of SDV, GG and L are 6, 4 and 4% point y[-1], respectively, and 2 to 3% point y[-1] for MG, IG and H.

the LowN as in the HighN system. L and GG had significant effects on the dry matter yield (P<0.05). Adoption of L and GG to the basic model resulted in an increase of R^2_{adj} from 17 to 31%. L enhanced the dry matter yield by 70 kg ha^{-1} per % and GG increased the dry matter yield by 51 kg ha^{-1} per %. The positive effect of L on yields can be explained as a result of the capacity of L to bind nitrogen. Our results indicate that effects of sward quality on yields are significant under practical farming conditions and not neutralized by other sources of variability on the farm. The stronger stimulating effects of L on grass yields in the LowN than in the HighN system indicates that the N-binding effect of L is more effective under a regime of tight N fertilization. The maintenance of GG seems more effective at lower N rates, not because the share of GG is lower, but because it has a stronger effect on yield.

Conclusions

This study has shown for the experimental farm 'De Marke' that:
- The dynamics of sward quality was not significantly affected by reduction of N fertilization.
- The share of good grasses declines during aging of both permanent and temporary grassland swards at a constant rate of 3.0 to 6.3% points per year.
- The botanical composition of the grass sward has significant and substantial effects on the nitrogen and dry matter yields of the grassland.

References

Oomes M.J.M. (1992) Yield and species density of grasslands during restoration management. *Journal of Vegetation Science* 3(2), 271-274.

Sikkem K. (1990) *Handleiding voor graslandkartering*. CABO-verslag 126. CABO, Wageningen, the Netherlands.

Verloop K. (2013) *Limits of effective nutrient management in dairy farming: analyses of experimental dairy farm De Marke*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

High productivity on *Nardus stricta* L. grasslands from the Carpathian Mountains of Romania

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Abstract

In the mountainous region of Romania about 200,000 ha is covered by grassland, which is mainly dominated by *Nardus stricta* L. We have studied the influence of mineral fertilization on productivity, canopy composition and forage quality of *Nardus stricta* L. permanent grassland in the intra-mountainous depression of Vatra Dornei (North-Eastern Carpathians, 820 m.a.s.l.). Fertilisation was applied at rates of $N_{100-200}$ $P_{100-200}$ kg ha^{-1} in one or several applications. These mineral fertilizer rates resulted in changes in the dominant species of *Nardus stricta* L. grasslands, by increasing the percentage of *Festuca rubra* L. and *Agrostis capillaris* L. Productivity increased by 119-224%, as well as forage quality compared to the unfertilized control.

Keywords: permanent grassland, mineral fertilization, productivity, forage quality, biodiversity

Introduction

In Romania, the area covered with mountain grassland dominated by *Nardus stricta* L. species is about 200,000 ha, of which 2,000 ha are protected by Natura 2000. Most of it is located in areas where animal rearing represents the main activity for the local population. Within this context, it is necessary to find efficient solutions that will lead to the improvement of productivity of the natural grasslands by ensuring the provision of fodder for the animals. Research on grasslands has emphasised the role of fertilizers, canopy composition, environmental conditions and grassland management on the productivity and quality of fodder, thus ensuring a superior animal productivity (Andueza *et al.*, 2010; Galka *et al.*, 2005; Poetsch *et al.*, 2014; Štýbnarová *et al.*, 2010; Vellinga *et al.*, 2004; Vintu *et al.*, 2008).

This study investigated the rates of mineral fertilizers leading to a high productivity and superior forage quality on the *Nardus stricta* L. grasslands from the Romanian Carpathians.

Materials and methods

A monofactorial experiment was carried out on *Nardus stricta* L. grassland in the Cosna area of the Romanian Carpathians (47°22'36.2'N; 25°11'27.4'E; 840 m elevation) on a soil with 13.6 mg kg^{-1} P and 381 mg kg^{-1} K. The forage from the grasslands in the area is mainly used for feeding dairy cattle. The experiment was laid out in randomized blocks design with three adjacent replicates, and each plot measured 20 m^2, of which the harvestable area was 12 m^2. The influence of nitrogen and phosphorus mineral fertilizers was investigated. Fertilizers were applied either entirely during early spring or in two applications during the year, with the following seven treatments: V_1 – control (unfertilised); V_2 – $N_{100}P_{100}$; V_3 – $N_{140}P_{140}$; V_4 – $N_{200}P_{200}$; V_5 – $N_{100}P_{100}$ + $N_{40}P_{40}$; V_6 – $N_{100}P_{100}$ + $N_{100}P_{100}$; V_7 – $N_{80}P_{80}$ + $N_{60}P_{60}$.

Dry matter (DM) productivity, canopy composition and forage quality were measured. The Kjeldahl method was used to determine crude protein content, the Van Soest method was used for measuring the acid detergent fibre (ADF), neutral detergent fibre (NDF) and acid detergent lignin (ADL), while the vegetation study was conducted by the geobotanical method, using the Braun-Blanquet scale, and the

analysis of biodiversity with the help of the PC-ORD program. The chemical tests for the fodder were conducted on samples from the first cut, at the beginning of July, the data representing the average for the years 2012-2014. The experiment was started in 2009. The statistical interpretation of data was carried out with the analysis of variance (ANOVA) and LSD test ($P<0.05$-0.001).

Results and discussion

Fertilization of mountain grasslands with mineral fertilizers improved the canopy composition, productivity and forage quality. The $N_{100\text{-}200}P_{100\text{-}200}$ treatment contributed, within the framework of natural factors from the area, to significant yield improvements, with values between 130-224%, when the amount was applied entirely in early spring, and values of 119-141% when applied in several applications, because the first cut represented around 80% of total yield. On average, over three years, values of 1.59 Mg ha^{-1} DM were obtained for the unfertilized control, and statistically higher yields for fertilized treatments of 3.49-5.15 Mg DM ha^{-1} ($N_{80}P_{80}+N_{60}P_{60}$, respectively $N_{200}P_{200}$) (Table 1).

Mineral fertilization resulted in significant changes in the chemical composition of the fodder, by increasing the crude protein content and reducing the values for the components of the cell walls (NDF, ADF, ADL), thus improving the forage quality. Fertilizer use led to an increase in crude protein content from 6.69 (control) to 11.62 g kg^{-1} ($N_{100}P_{100} + N_{100}P_{100}$) and a reduction of NDF content from 63.77 to 52.66 g kg^{-1}, ADF from 41.29 to 33.50 g kg^{-1}, and ADL from 10.21 to 9.46 g kg^{-1} (Table 2).

By analysing the effect of fertilizers on canopy composition, represented by a graphic (Figure 1), we noticed significant changes in the fertilized communities. Thus, the canopy composition of the fertilized treatments did not overlap that of the unfertilized control, which proves that their similarity is very low. Furthermore, it can be seen that the treatments V_2 and V_3, respectively, V_4 and V_7, have a rather high similarity, since their overlapping in the graphic is significant. This leads us to conclude that changes in canopy composition depend on the fertilizer application rates and their manner of application.

Conclusions

Fertilization by nitrogen and phosphorus at high application rates caused significant changes in canopy composition by reducing the share of the dominant species *Nardus stricta* L. and increasing the share of species with a higher fodder value, such as *Festuca rubra* L. or *Agrostis capillaris* L. These changes in the vegetation and soil fertilization led to high yields, with rates of 119-224% compared to the unfertilized

Table 1. Influence of fertilization on the *Nardus stricta* L. grassland yield (Mg ha^{-1} dry matter).

Fertilizer rate	Year			Average 2012-2014	
	2012	2013	2014		
	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	Mg ha^{-1}	%
Unfertilized control	1.88	1.54	1.34	1.59	100
$N_{100}P_{100}$	3.48***	3.59***	3.89***	3.65**	230
$N_{140}P_{140}$	4.16***	4.28***	4.31***	4.25**	267
$N_{200}P_{200}$	4.66***	4.92	5.87***	5.15***	324
$N_{100}P_{100}+N_{40}P_{40}$	3.93***	3.43**	3.71***	3.69*	232
$N_{100}P_{100}+N_{100}P_{100}$	3.76**	3.32**	4.40***	3.83*	241
$N_{80}P_{80}+N_{60}P_{60}$	3.57***	3.14**	3.75***	3.49*	219
* $P{\leq}0.05$	0.54	1.10	0.62	1.51	
** $P{\leq}0.01$	0.76	1.54	0.88	2.12	
*** $P{\leq}0.001$	1.07	2.17	1.23	2.99	

Table 2. Influence of mineral fertilization on forage quality from the *Nardus stricta L.* grassland (g kg^{-1} dry matter).[1]

Fertilizer rate	CP	NDF	ADF	ADL
Unfertilized control	6.69	63.77	41.29	10.21
$N_{100}P_{100}$	7.60	55.15*	33.50**	9.59**
$N_{140}P_{140}$	8.56	56.79*	34.44**	9.75*
$N_{200}P_{200}$	10.35**	55.27*	34.98**	9.43**
$N_{100}P_{100}+N_{40}P_{40}$	10.62**	52.66**	33.77**	9.69*
$N_{100}P_{100}+N_{100}P_{100}$	11.62***	55.01*	34.35**	9.84
$N_{80}P_{80}+N_{60}P_{60}$	10.65**	55.78*	36.92*	9.60**
* $P \leq 0.05$	2.10	6.91	4.40	0.39
** $P \leq 0.01$	3.01	9.72	6.11	0.55
*** $P \leq 0.001$	4.20	13.70	8.63	0.80

[1] CP = crude protein; ADF = acid detergent fibre; NDF = neutral detergent fibre; ADL = acid detergent lignin.
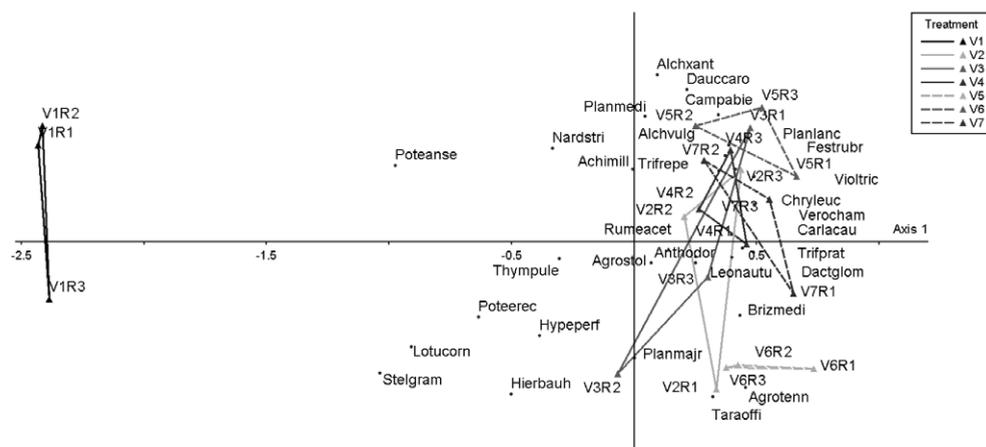
Figure 1. Order of canopy composition influenced by fertilization. (V$_1$...V$_7$ – fertilizer rates; R1, R2, R3 – replicates).

control, ensuring the supply of significant quantities of superior quality forage for the development of animal rearing in the mountainous area of the Romanian Carpathians.

References

Andueza D., Cruz P., Farruggia A., Baumont R., Picard F. and Michalet-Doreau B. (2010) Nutritive value of two meadows and relationships with some vegetation traits. *Grass and Forage Science* 65, 325-334.

Galka A., Zarzycki J. and Kopeca M. (2005) Effect of different fertilisation regimes on species composition and habitat in a long-term grassland experiment. *Grassland Science in Europe* 10, 132-135.

Poetsch E.M., Asel A., Schaumberger A. and Resch R. (2014) Impact of climate change on grassland productivity and forage quality in Austria. *Grassland Science in Europe* 19, 139-141.

Štýbnarová M., Svozilová M., Hakl J., Karabcová H., Pozdíšek J. and Otrhálková P. (2010) Effect of different management on the yields, forage quality and botanical composition of permanent grassland. *Grassland Science in Europe* 15, 741-743.

Vellinga T.V., André G., Schils R.L.M. and Oenema O. (2004) Operational nitrogen fertilizer management in dairy farming systems: identification of criteria and derivation of fertilizer application rates. *Grass and Forage Science* 59, 364-377.

Vintu V., Samuil C., Sirbu C., Saghin G. and Iacob T. (2008) The influence of grassland management on biodiversity in mountainous region of NE Romania. *Grassland Science in Europe* 13, 183-185.

Detection of genetic diversity for drought tolerance in perennial ryegrass (*Lolium perenne* L.)

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Abstract

Water shortage is one of the most important constraints limiting yield in agricultural production. Global climate change will also limit yield of one of the most important grass species in Europe, perennial ryegrass (*Lolium perenne* L.). To improve drought tolerance of perennial ryegrass by breeding new varieties, natural genetic diversity for this trait was screened in field trials. 200 accessions, comprising genebank material from all over Europe and breeding material as well as some drought-tolerant grass species for comparison, were tested under natural drought conditions. Appropriate methods for an efficient selection of drought-tolerant genotypes were evaluated within the presented project. On a plot basis the visual scoring of biomass growth provided a suitable data base for selection with good correlation to drought symptoms and yield data. Broad genetic diversity for drought tolerance was observed within the material, which can be used for detailed investigation of drought-tolerance mechanisms and the development of new drought-tolerant varieties.

Keywords: *Lolium perenne* L., genetic diversity, drought stress, phenotyping

Introduction

Global climate change will have major impact on plant production in Central Europe. Perennial ryegrass (*Lolium perenne* L.) as one of the most important grass species in Central Europe, is known to be susceptible to drought stress (Sheffer *et al.*, 1987). It will be particularly affected by temporal fluctuations in soil water content. Since technical management, such as irrigation cannot be applied economically on grasslands, breeding of drought-tolerant varieties is one of the most promising approaches for securing future grassland yields. Breeding progress in drought-tolerance breeding is slow due to a lack of steady selection environments with regular drought stress and a low heritability of the trait 'yield under drought stress'. To overcome this problem, secondary selection traits are used with higher heritability's which ensure higher selection gain on the one hand and good correlation to yield performance under drought conditions on the other hand. This paper presents results from phenotyping diverse perennial ryegrass accessions under natural drought environments.

Materials and methods

Diverse accessions of perennial ryegrass (186 in total: 73 historical varieties and wild collections; 111 varieties and candidate varieties from breeding companies) supplemented by varieties from *Festulolium*, meadow fescue and tall fescue were sown in autumn 2011 at five potentially drought-prone locations (Bornhof, Kaltenhof, Malchow, Triesdorf in Germany; Les Rosiers sur Loire in France) in an alpha-lattice design with four replicates. Locations Bornhof and Malchow were omitted from data analysis due to missing drought stress at these locations in 2013. Biomass production before each cutting date was visually scored on a 1 to 9 scale with 1 for poor biomass growth and 9 as the maximum within each

location. The drought-stress response (leaf rolling, wilting, and leaf senescence) was also visually scored on a 1 to 9 scale with 1 indicating no symptoms and 9 for strong expression of symptoms. Heading dates were scored at location Kaltenhof in 2012 in days after 1st of April and accessions were grouped in heading date <54 days (early to mid-heading) and >54 days (mid to very late heading) according to the official classification of German variety authorities. ANOVA, calculation of repeatability's and heritability's as well as adjusted means were conducted with the software package Plabstat version 3A (Utz, 2005). Mean comparison analysis was calculated with the software package R version 3.1.2.

Results and discussion

The testing of a total of 200 accessions for the trait biomass production and visual drought response revealed a wide genetic variation. Biomass scoring at cutting date 4 (in mid-summer 2013 after a mild drought period at the locations Kaltenhof and Triesdorf) showed a significant genotypic variance component, with a heritability of 54.6%. In contrast, the visual scoring of drought response showed no significant genotypic variance and thus, a heritability of 0% in the analysis over three locations (Kaltenhof, Triesdorf, Les Rosiers sur Loire). When considering only the location Les Rosiers sur Loire with severe drought conditions early in summer, repeatability was at 57.9% indicating the importance of a selection environment which allows good differentiation for drought tolerance. Figure 1 compares the results from the analysis of 200 accessions by visual scoring of biomass before cutting date 4 at two locations (Kaltenhof and Triesdorf; after drought period in summer) and the visual scoring of drought response during drought period at the location Les Rosiers sur Loire in 2013. Considering the different ploidy levels, the tetraploid accessions in our collection showed on average significantly fewer drought symptoms ($P<5.42\times10^{-8}$), with some diploid accessions also showing good drought performance. Visual biomass scoring after the summer drought period was significantly higher among the tetraploid accessions ($P<2.2\times10^{-16}$). One possible explanation is a generally increased tolerance to abiotic stresses in polyploid plants compared to their diploid counterparts. This relation was already described for other plant species.
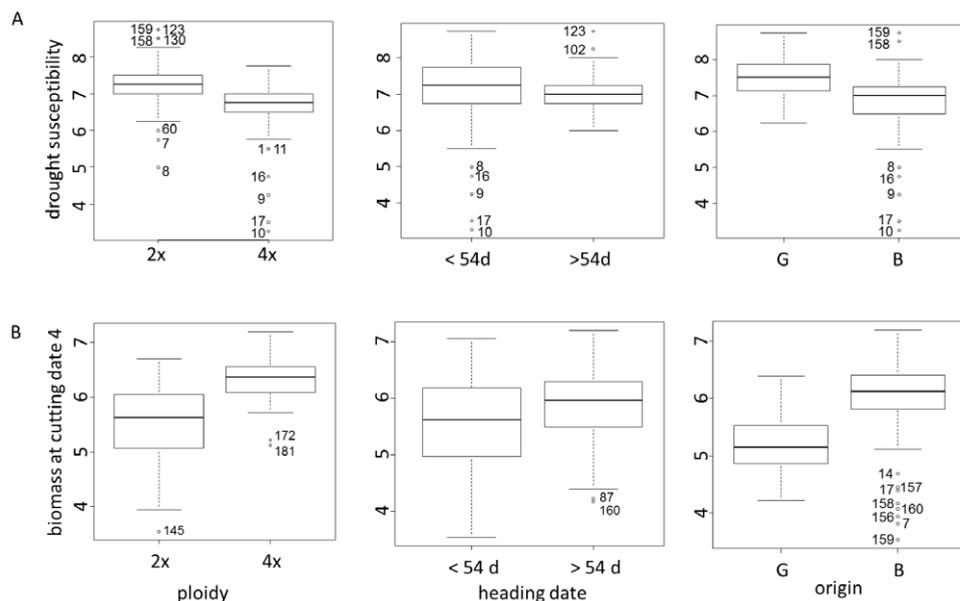
Figure 1. (a) visual scoring of drought response at location Les Rosiers sur Loire in the second cut year 2013 and (b) visual biomass scoring before cutting date 4 of second year cut 2013 (Kaltenhof and Triesdorf trials). The upper and lower edges of the boxes represent the 1st and 3rd quartiles, the black line within the boxes the median and the upper and lower whiskers the 1.5 fold interquartile distance. Diploid (2×) and tetraploid (4×) plant material, of early (<54 days) and late heading (>54 days), from gene bank (G) and breeding (B).

Polyploid plants are supposed to deplete soil moisture to a greater degree before reaching leaf water potentials that cause closure of stomata (Maherali *et al.*, 2009). Additionally, the activity of peroxidase and relative water content in tetraploid plants under drought conditions was found to be higher than in diploid plants (Liu *et al.*, 2011). There was no difference in drought tolerance observed between early and late heading accessions but significant difference in biomass production ($P<0.0009$), with slightly higher biomass production in the late flowering accessions. When considering the different origins of the plant material (breeding material vs gene bank material), a significantly higher mean drought tolerance was observed in the breeding material ($P<3.86\times10^{-12}$). As expected, breeding material showed a significantly higher biomass production ($P<1.85\times10^{-8}$), since it has been already selected for yield performance and all tetraploid accessions are in this group.

Conclusions

A wide variation of biomass production potential and drought-tolerance performance was successfully found among the 200 diverse accessions of perennial ryegrass as well as within the accessions. Tetraploid accessions in our test-set seemed to have enhanced higher stress tolerance compared to the diploid perennial ryegrass, whereas heading date had hardly any influence on these traits. Gene-bank material showed, on average, a lower biomass production than breeding material; this reflects selection work in this material in the past, which can also be seen under drought conditions.

References

Liu S., Chen S., Chen Y., Guan Z., Yin D. and Chen F. (2011) *In vitro* induced tetraploid of *Dendranthema nankingense* (Naki) Tzvel. shows an improved level of abiotic stress tolerance. *Scientia Horticulturae* 127, 411-419.

Maherali H., Walden A.E. and Husband B.C. (2009) Genome duplication and the evolution of physiological responses to water stress. *New Phytologist* 184, 721-731.

Sheffer K.M., Dunn J.H. and Minner D.D. (1987) Summer drought responses and rooting depth of three cool-season turfgrasses. *HortScience* 22, 296-297.

Utz H.F. (2005) *PLABSTAT – plant breeding statistical program version 3A*. Institut für Pflanzenzüchtung, Saatgutforschung und Populationsgenetik, Universität Hohenheim, Stuttgart, Germany.

Session 3.
High output and high (eco)efficiency

Eco-efficient pasture based dairy farm systems: a comparison of New Zealand, The Netherlands and Ireland

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Abstract

European and New Zealand dairy farmers pursue high productivity, while meeting the requirements of environmental legislation. Due to market constraints, New Zealand dairy farming has traditionally relied on low-input grazed perennial ryegrass (*Lolium perenne* L.) – white clover (*Trifolium repens* L.) pastures and on grazed forage crops in seasons with low pasture production. However, in the past three decades the use of synthetic nitrogen (N) increased, allowing higher stocking rates and more milk production per hectare, but increasing N surplus per hectare and therefore potential N loss to the environment. The use of supplements has also increased, with an increasing number of farmers investing in infrastructure to feed cows off-pasture during the winter. This is seen to benefit the animal as well as the environment because supplements provide the opportunity to reduce surplus N intake, and collected urine and faeces can be applied efficiently on pastures or crops. In Europe, indoor systems, use of supplements and efficient manure application methods are common. There is interest in improving production and utilisation of home-grown pastures and crops to reduce costs and overall environmental footprint. This is where the challenge for European and New Zealand dairy systems meet: there is a common need to examine how crops and forages can be used to improve N efficiency in the soil-plant-dairy cow system. Combining best practices and recent advances in European and New Zealand research provides scope for cost- and nutrient-efficient and highly productive dairy farm systems.

Keywords: milk production systems, nitrogen surplus, eco-efficiency, grazing management, multispecies swards, forage crop, farm dairy effluent

Introduction

Despite different market circumstances and farming systems, European and New Zealand dairy farmers pursue high production, while meeting environmental goals of their respective communities. In Europe, intensification was propelled after the Second World War by production targets and subsidies, and side-effects became apparent in the 1970s and 1980s (e.g. Cartwright *et al.*, 1991; Henkens and Van Keulen, 2001). Many EU countries developed policies to reduce the impact of agriculture on the environment. For example, the Netherlands implemented legislation to reduce nutrient losses from manure in 1984, and the European Union introduced the Nitrate Directive in 1991 (European Community, 1991). By contrast, New Zealand is only just embarking on the route to legislation aimed at maintaining or improving freshwater quality. Deterioration in water quality of main rivers (nutrient enrichment and reduced visual clarity) was observed (McColl and Hughes, 1981) and shown to be correlated with pastoral, plantation and urban land cover (Ballantine and Davies-Colley, 2013; Larned *et al.*, 2004). To protect New Zealand lakes, rivers, aquifers and wetlands, the National Policy Statement for Freshwater Management was published by the New Zealand Government in 2011 (Ministry for the Environment, 2011). This requires the New Zealand Regional Councils to develop and implement water quality standards and accompanying regulation to achieve or maintain these by 2030. Risks to water quality

include the potential for erosion (sediment deposition), nutrient loss and microbial contamination, e.g. *Escherichia coli*. Causes of erosion and microbial contamination are clear, and measures to reduce these risks have been defined and in some cases implemented via voluntary agreements, e.g. the Dairying and Clean Streams Accord in 2003 (Fonterra *et al.,* 2003), followed by the Sustainable Dairying: Water Accord in 2013 (DairyNZ *et al.,* 2013). Nutrient loss, however, specifically nitrate leaching, is a more difficult issue to target. At present, Regional Councils are developing limits for nutrient loss to water for different land uses. Dairy farming has been identified as a sector with relatively high nitrate leaching levels, compared with low-input summer-dry sheep and beef farming (the dominant land use systems in New Zealand), and is likely to face substantial regulation limiting farm-scale estimated nitrate leaching or nitrogen (N) surplus.

The New Zealand dairy industry relies heavily on exports: 95% of the milk produced is exported, mainly as whole-milk powder (Statistics New Zealand, 2014). This makes the industry vulnerable to fluctuating global prices and income. For example, 2013-2014 was a record season with a listed milk solids (MS; fat plus protein) price of €5.34 kg MS^{-1} (at €0.63 per NZ$; LIC and DairyNZ, 2014). By December 2014, the country's largest milk processor announced a forecast milk price for 2014-2015 of €2.96 kg MS^{-1} (Fonterra, 2015). Due to these market fluctuations, and the absence of subsidies, New Zealand dairy farming has traditionally relied on low-input year-round grazed perennial ryegrass-white clover pastures, complemented by forage crops (mainly brassicas) in seasons with low pasture production. When urea manufacture began in New Zealand in the 1980s, synthetic N fertiliser use increased, and consequently, New Zealand dairy farming intensified rapidly (PCE, 2004). At the same time the use of supplements on New Zealand dairy farms increased. Both increased feed production from N fertiliser, and the use of bought-in supplements support higher stocking rates and more milk production per hectare. However, using more inputs to produce more milk increases the N surplus per hectare and therefore potential and actual N loss to the environment (e.g. Basset-Mens *et al.*, 2009; De Klein *et al.*, 2010; Oenema *et al.*, 2011).

In most European countries over the past 25 years there has been a shift away from pasture-based systems to greater use of conserved forage-based systems, especially forage maize. It is common to keep dairy cows off-pasture: restricted-duration grazing is often implemented during the growing season, and during late autumn and winter cows are kept indoors. Milk prices for European dairy farmers have been relatively stable and high, due to a system of intervention purchasing and exports refunds. Hence higher production costs have been accepted. However, milk production within the EU is now entering a new phase. The milk quota system will be abolished on the 1st of April 2015, and the intervention price support for butter and skim milk powder will be significantly reduced. This will result in much greater volatility in EU milk prices because of fluctuating world supply/demand. This volatility in prices is likely to become a continuing feature of EU dairy markets, requiring systems of milk production that are resilient in the future. On top of this, changing subsidy frameworks, fluctuating prices for imported feed and increasing costs for energy (and therefore inputs such as synthetic fertiliser), labour, machinery and housing, and environment and animal welfare concerns associated with intensive systems, have sparked increasing interest in improving production and utilisation of home-grown pasture and crops (e.g. Peyraud *et al.*, 2014).

This is where the challenge for European and New Zealand dairy systems meet: there is a common need to determine how crops and forages can be used to increase the efficiency of N flows through the soil-plant-dairy cow system, while improving or maintaining productivity and profitability. This paper assesses the current N efficiency and N losses of well-managed dairy farms in New Zealand and in two European countries, the Netherlands and Ireland, and how the weaker points have been targeted by recent research on the use of home-grown pasture and crops. Experiences from both sides of the world could complement each other to deliver profitable, highly productive and eco-efficient dairy farms.

Structure of New Zealand, Dutch and Irish dairy sectors

The New Zealand dairy industry produced in the June 2013 – May 2014 season a total of 1.83×10^9 kg milk solids (fat plus protein, MS; LIC and DairyNZ, 2014). This is nearly double the production in the 1999-2000 season (0.98×10^9 kg MS), while the number of herds declined in the same period from 13,861 to 11,927. Apart from a rapid growth in number of cows per herd (from 236 to 413 cows per herd), accompanied by a growth in farm size (from 93 to 144 effective hectares per farm), MS produced per cow and per hectare also increased: from 288 kg MS cow^{-1} and 768 kg MS ha^{-1} in 1999-2000 to 371 kg MS cow^{-1} and 1,063 kg MS ha^{-1} in 2013-2014. The majority of herds calve once per year, in late winter-early spring, making the New Zealand dairy industry highly seasonal.

Regional differences are apparent. The two regions with the highest number of dairy cows are the Waikato and Canterbury, with 24% and 18% of the national herd respectively. Waikato has traditionally been the largest milk-producing region, with rain-fed, summer-dry pasture-based systems. Canterbury has seen a rapid increase in dairying in the past decade, with dryland pastures previously grazed by sheep converted to irrigated pastures and crops for winter grazing. Farms in Canterbury are larger and more intensive than in the Waikato (average 232 ha stocked at 3.49 cows ha^{-1} versus 112 ha and 2.95 cows ha^{-1}, respectively). Note that these statistics refer only to effective hectares on the dairy platform (i.e. pasture area grazed during lactation). This excludes off-farm cropping areas where many non-lactating cows are wintered in Canterbury.

Beukes *et al.* (2012) estimated the N surplus and eco-efficiency for the Waikato region to be 155 kg N ha^{-1} year^{-1} and 6.4 kg MS kg N surplus^{-1}, respectively. Earlier, Ledgard *et al.* (1997) estimated an N surplus of 131 kg N ha^{-1} year^{-1} and an eco-efficiency of 4.6 kg MS kg N surplus^{-1} for the average New Zealand farm of that time. The increase in N surplus and eco-efficiency between 1997 and 2011 illustrates the increased use of inputs, and increased productivity, of NZ dairy systems over that period.

Dutch milk production systems are based on year-round calving, predominantly restricted grazing during spring, summer and autumn, and housing of cows during late autumn, winter and early spring. Virtually all systems use supplements throughout the year, both roughage and concentrates. Regulations dictate that manure is exported off-farm where imported nutrients are above a certain threshold. Growing maize on the dairy farm, in rotation with pasture, is common.

The Dutch dairy industry produced 107×10^6 kg MS (converted as MS = (l/0.97)×0.08) in 2014, similar to 1998 (96×10^6 kg MS). The number of farms declined in the same period from 32,000 to 17,000 and the number of cows declined from 1.6×10^6 to 1.5×10^6. The average number of dairy cows per farm increased from 48 to 75, and the average milk production per cow increased from 594 to 660 kg MS cow^{-1} from 1998 to 2014 (Land- en tuinbouwcijfers: www3.lei.wur.nl/ltc; Centraal Bureau voor de Statistiek: www.cbs.nl; Zuivel.nl www.zuivel.nl). The average N surplus in the Netherlands was 180 kg N ha^{-1} year^{-1} in 2011; a substantial reduction from 330 kg N ha^{-1} year^{-1} in 1998, reflecting the tighter environmental regulations. Nitrogen use efficiency (NUE) improved from 20% to 31% in the same period (Oenema *et al.,* 2011).

Milk production in Ireland comes predominately from grass-based seasonal compact spring-calving systems. The current national average milk production per cow for Ireland is 358 kg MS cow^{-1}; stocking rate is 1.90 cows ha^{-1}, and 875 kg of concentrates per cow and 148 kg of synthetic N ha^{-1} are used. Based on this, the average surplus N ha^{-1} on Irish dairy farms is 144 kg, and the eco-efficiency 4.7 kg MS kg N surplus^{-1} (Teagasc, 2013). Studies carried out before the introduction of the Good Agricultural Practice regulations in 2006 (Anonymous, 2006) would suggest that N surplus, both per ha and per kg MS,

Table 1. Farm characteristics of nutrient-efficient dairy farms in New Zealand (NZ-C = Canterbury; NZ-W = Waikato; farmlets in the research project Pastoral 21), the Netherlands (NL-1 = certified organic; high N-use efficiency; NL-2 = high productivity; NL-3 = overall optimisation including grazing; farms in the project cows & opportunities) and Ireland (IL-S = Solohead; IL-C = Curtin; research farms).

	New Zealand		the Netherlands			Ireland	
	NZ-C	NZ-W	NL-1	NL-2	NL-3	IL-S	IL-C
Climate							
Average annual rainfall (mm)	594	1121	750-900	750-900	750-900	1,036	1,022
Mean annual temperature (°C)	11.8	13.7	10.0	10.0	10.0	9.6	9.8
Annual potential evapotranspiration (mm)	886	835	560-590	560-590	560-590	510	545
Farm size (ha)							
Grassland	8.5	13	43	31	26	10	48
Grassland with restrictions (nature conservation)	0	0	0	4	0	0	0
Maize	0	0	13	11	12	0	0
Kale (winter grazing); oats	1.6	0	0	0	0	0	0
Other crops	0	0	8	0	0	0	0
Pasture							
Pasture production (Mg DM ha^{-1} yr^{-1})	16.1	15.3	9.6	14.4	11.8	12.8	14.9
Harvested as silage (Mg DM ha^{-1} yr^{-1})	0.8	0.5	8.9	14.4	7.7	4.3	2.5
Kale + oats production (Mg DM ha^{-1} yr^{-1})	12 + 7.7	0	0	0	0	0	0
Stocking rate (cows ha^{-1} pasture + crop)	2.9	2.6	1.6/2.2[1]	2.9/4.0	2.3/3.2	2.3	2.9
Average liveweight dairy cows (kg)	527	495	600-650	600-650	600-650	572	540
Ration lactating cows							
Grazing time cows pasture + crop (h year^{-1})	7,540	5,840	477	0	1,800	5,610	6,840
Crude protein ration during lactation (%)	22	20	14	15	15	18	14
MS production (kg fat + protein; NL: MS = (l/0.97) × 0.08)							
kg MS cow^{-1} year^{-1}	510	442	561	668	668	482	441
kg MS ha^{-1} year^{-1}	1,513	1,158	915	1,872	1,537	1,108	1,280
Soil type	freely drained sandy loam/ stony silt loam	silt loam; some pugging in wet periods	sand; freely drained	clay; some pugging in wet periods	sand; freely drained	poorly drained clay loam	freely drained acid brown earth
Years	11-14	11-14	00-05	00-09	00-09	01-12	00-11

[1] For NL stocking rate is given as cows ha^{-1} without and with young stock; young stock were reared on farm. NZ and IL farms did not rear young stock on farm.

have significantly decreased since that time (by 40 and 32%, respectively) and NUE increased (by 27%), mostly due to decreased synthetic fertilizer N input and improvements in N management, with a notable shift towards spring application of organic manures.

Performance of well-managed dairy farms in New Zealand, the Netherlands and Ireland

Data have been collected from examples of well-managed dairy farms in New Zealand (NZ), the Netherlands (NL) and Ireland (IL); i.e. with productivity and N efficiency above average for the respective countries (Table 1). The two New Zealand examples are research farmlets in the project Pastoral 21, and aim to demonstrate the gains in efficiency of production and N use, and reductions in N leaching, through improved management practices plus animals of high genetic merit as compared with

Table 2. Nitrogen (N) balance and N losses of nutrient-efficient dairy farms in New Zealand (NZ-C = Canterbury; NZ-W = Waikato; farmlets in the research project Pastoral 21), the Netherlands (NL-1 = certified organic; high N use efficiency; NL-2 = high productivity; NL-3 = overall optimisation including grazing; farms in the project cows & opportunities) and Ireland (IL-S = Solohead; IL-C = Curtin; research farms).

	New Zealand		the Netherlands			Ireland	
	NZ-C	NZ-W	NL-1	NL-2	NL-3	IL-S[1]	IL-C
Input (kg N ha^{-1})							
Synthetic fertiliser	179	46	0	158	128	110	250
Fixation clover[2]	157	201	26	7	2	84	0
Supplements imported	9	3	75	309	199	47	25
Manure imported	0	0	2	0	24	0	0
Rainfall (deposition)	2	2	36	36	36	6	6
Irrigation	10	0	0	0	0	0	0
Removed (kg N ha^{-1})							
Milk and meat	113	88	65	145	115	80	98
Supplements	17	0	1	0	0	0	0
Farm dairy effluent/manure	35	7	0	108	64	0	0
N surplus farm (kg ha^{-1}) [3]	168/228 (192)	157	73	257	210	167	183
NUE farm (%) [4]	46	38	47	50	46	32	35
Eco-efficiency (kg MS kg N surplus^{-1})	7.9	7.4	12.5	7.3	7.3	6.6	7.0
Losses estimated (kg N ha^{-1} year^{-1}) [3]							
Volatilisation (NH$_3$-N)	80/52 (79)	72	50	76	52	61	n/a
of which from urine	73/14 (64)	47	n/a[4]	n/a	n/a	27	n/a
Denitrification (N$_2$O-N and N$_2$-N)	5/69 (15)	41	n/a	n/a	n/a	64	n/a
Nitrate leaching	24/159 (46)	17	40	<5	72	12	25

[1] The results shown for IL-S are based on the average for 2010 and 2011. The results for the other farm systems are for the years given in Table 1.

[2] For NZ farms N fixation of clover is modelled with Overseer, using an assumed, medium clover content, pasture production estimated from N intake required to sustain measured milk production and supplement N input; synthetic N input results in an estimated reduction in N fixation. For NL farms N fixation is calculated as % clover × pasture production (Mg DM) × 45 kg N ha^{-1}. For IL farms N$_2$ fixation was measured using the difference method in the earlier years and the ^{15}N natural abundance method in more recent years. In both instances a correction factor of 1.27 for N assimilated in below-ground plant matter was used (Burchill, 2014).

[3] Values for NZ-C are given for the milking platform (pasture used during lactation; first value) and for the support block where kale is grown for winter grazing, followed by an oats catch crop harvested for silage (second value). The value in brackets is for the whole farm system.

[4] NUE = nitrogen use efficiency; n/a = not available.

current practice in New Zealand (Chapman *et al.*, 2013; Glassey *et al.*, 2014). They reflect the differences between Waikato (NZ-W) and Canterbury dairy systems (NZ-C), as described above. Management practices were defined through modelling (Beukes *et al.,* 2011, 2012), and expected N loss was estimated using Overseer® (Wheeler *et al.,* 2006; 'Overseer' from this point), a nutrient model commonly used in New Zealand to estimate the N flows. Grazed pasture provides 90-95% of the lactation diet; pastures are predominantly of perennial ryegrass-white clover swards. The farmlets implement a range of options to mitigate N leaching: reduced synthetic N use and optimal timing of N application (NZ-C and NZ-W), including herbs (chicory and plantain) in pastures on the milking platform and low-N forage crops in winter to reduce CP content of the diet (NZ-C). They also use loafing pads for part of the day to reduce the time that cows are on pasture in autumn (late lactation) and winter (dry cows) (NZ-W), and optimal application regimes for farm dairy effluent (FDE; soiled water from the milk shed with dry matter (DM) content below 2%, Houlbrooke *et al.*, 2011) (NZ-W; no FDE application at NZ-C), and tight control of pasture quality (NZ-C and NZ-W). Young stock being raised off-farm and using high genetic merit cows allow reduced stocking rate (cows ha^{-1}) and high utilisation of pasture grown. Loafing pads allow for capturing excreta, which is then, usually together with FDE, applied on pasture or crops
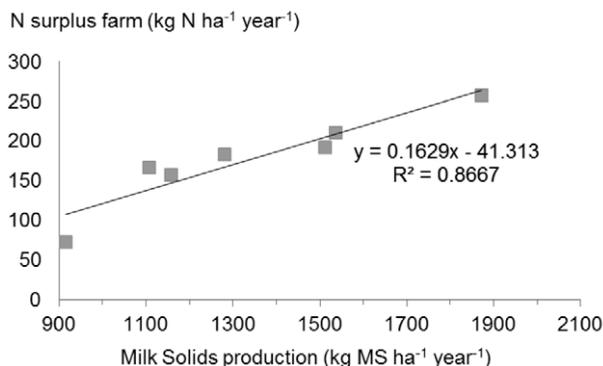
Figure 1. Relationship between N surplus and milk solids production of seven nutrient efficient dairy farms from New Zealand, the Netherlands and Ireland (see Tables 1 and 2).

more evenly as compared with grazing, and at times when pasture or crop productivity ensures good responses (Aarts, 2000; Oenema *et al.*, 2006). Reducing grazing intensity in autumn and winter may contribute to reduced nitrate leaching, as the utilisation by pasture or crop of N from excreta declines with lower temperatures and reduced light (Cuttle and Bourne, 1993; Lord, 1993; Titchen *et al.*, 1993; Verloop *et al.*, 2006). Reductions in nitrate leaching of 30-40% have been measured in New Zealand trials when cows were taken off pasture over the autumn and winter months (De Klein *et al.*, 2010). An additional benefit of restricted duration of grazing is reduced sward damage in wet periods; hence improved pasture production (Beukes *et al.*, 2013).

The Dutch examples are well-managed commercial dairy farms, participants of the long-running project 'cows and opportunities' (Oenema *et al.*, 2001). This project was initiated by the Dutch farmers' union and government in 1998 to explore options for commercial dairy farmers to meet strict environmental targets, and followed the prototype developed on experimental farm 'De Marke' (Aarts, 2000). Intensive coaching by researchers and extension specialists was provided.

Management changes implemented to reduce nutrient losses were reduced synthetic N fertiliser applications and optimised use of home-produced organic manure, reduced crude protein (CP) content of the ration, restricted grazing, reduced relative number of young stock on farm and sowing a catch crop after harvesting maize. The three Dutch farms in Tables 1 and 2 were identified from the group of 17 participants as being the 'best farms' in terms of N-use efficiency (NL-1; certified organic farm), productivity (NL-2; high input farm) or overall optimisation including grazing (NL-3). These farms illustrate the relatively high dependency of Dutch milk production systems on imported feed, the restricted use of grazing (if any), and therefore high proportion of pasture being harvested for silage.

The Irish examples are two research farms: a system with perennial ryegrass-white clover pastures at Solohead Research Farm (IL-S; Burchill, 2014; Humphreys *et al.*, 2008a, 2009; Necpálová *et al.*, 2013; Tuohy *et al.*, 2014), and the Curtin Research Farm (IL-C; Heubsch *et al.*, 2013; McCarthy *et al.*, 2015). The IL-C site is representative of soils vulnerable to nitrate leaching, and represents between 4 and 10% of the riskier soils in Ireland (Ryan *et al.*, 2006). Nitrate N concentrations in the aquifer below the farm declined from 16 mg l^{-1} in 2002 to 6.6 mg l^{-1} in 2011 (Huebsch *et al.*, 2013), well below the drinking water standard of 11.3 mg NO_3-N or 50 mg NO_3 l^{-1}. This was associated with a reduction in synthetic fertilizer usage, improvement in timing of slurry application, moving an FDE irrigation system to a less-karstified area of the farm, the use of low-N supplements to reduce N surplus intake by the animals, and the use of minimum cultivation reseeding on the farm. At IL-S, nitrate leaching has been consistently low

(<35 kg N ha^{-1} year^{-1}) over 11 years (Humphreys *et al.*, 2007; 2008b; Necpálová *et al.*, 2012), associated with the impermeable nature of the soil.

MS production per cow was highest for the Dutch farms, but only the highest-input farm (NL-2) achieved a higher MS production per hectare (Table 1). The N balance and N loss of the example farms are shown in Table 2. The N surplus was highly correlated with MS production (Figure 1). The eco-efficiency, expressed as kg MS kg N surplus^{-1}, was remarkably similar; only the Dutch organic farm achieved a much higher eco-efficiency than the other farms. The NUE varied between systems, but was not related to MS production or N surplus. Soil type and climate impact on the ability of plants to utilise nutrients efficiently. For example, the NUE of NL-2 (clay) was similar to that of NL-3 (sand), and NUE of Canterbury (irrigated) was similar to that of Waikato (summer-dry) even though N applied to pasture (synthetic N, manure, clover N fixation, irrigation) was significantly higher for the NL-2 and Canterbury systems.

Compared with the respective country averages, the example farms achieved better efficiency of N inputs (NUE) and eco-efficiency (kg MS produced per kg N surplus). NUE and eco-efficiency are important indicators for impact on the environment on a global scale. The N surplus of the New Zealand and Irish farms and the highest-input Dutch farm, however, are above the average for their respective countries. N surplus is often seen as an indicator of the impact on the local environment, but soil type, climate and gaseous losses control how much of the N surplus eventually leaches to groundwater.

Pathways to reduce N losses while maintaining productivity

Modelling and measurements in the Netherlands have shown that the average soil-N surplus for grassland should not exceed 103 kg N ha^{-1} on dry sandy soils, 168 on wet sandy soils and 273 on clay soils to achieve ground water quality at drinking water standard (Schröder and Neeteson, 2008). The same soil N surplus results in higher leaching from dry sandy soils compared with soils with higher plant available water. For arable land these values are 48, 87 and 141 kg N ha^{-1}, respectively, reflecting that the same soil N surplus results in higher leaching from arable land compared with grasslands. The results from the example farms show that these levels of N surplus are still challenging. Only the organic farm achieved an N surplus well below the levels given by Schröder and Neeteson (2008).

The skill level demonstrated by the example farms may not be replicable on the majority of commercial farms, and the nutrient loss seen on these farms may not be sufficient in some regions. Therefore, while maximising nutrient utilisation remains paramount, new, easily adoptable and cost-efficient pathways to reduce N losses while maintaining productivity are needed for many dairy farms. A mixture of European and New Zealand options may provide these solutions: use of multispecies pastures, N-efficient crops and crop rotations, and capture and efficient use of effluents and manures through restricted-duration grazing. This is explored further in the following sections.

Use of multispecies swards to maintain pasture productivity, intake and milk production when reducing synthetic N use

The simplicity of managing grass monocultures and the low price of synthetic N have, in the past, inhibited the use of legumes for forage production under intensive systems (Peyraud *et al.*, 2014). However, increasing political emphasis on environmental preservation, combined with sharp increases in the price of synthetic N, have encouraged greater emphasis on incorporating legumes into high-output ruminant production systems. Strategically designed multispecies swards can potentially improve the delivery of provisioning services from pasture-based production systems. Finn *et al.* (2013) compared mixture and monoculture swards across a large number of European sites using cutting managements. They reported significant and consistent over-yielding in mixtures. In order to expand the applicability

of these findings to other production systems, a common experiment was carried out within the recently-completed EU FP7 project 'Multisward' comparing highly-fertilised grass monoculture and moderately-fertilised legume-based multispecies swards under rotational grazing in terms of primary (plant biomass) and secondary (animal) production (Collins *et al.*, 2014). The objective was to establish whether multispecies swards could capitalise on the species diversity effects observed by Finn *et al.* (2013) and thus provide productive grazed pastures. The results for primary production in multispecies swards under rotational grazing by sheep, beef cattle and dairy cows clearly showed that there was no detriment to DM yield in legume-based multispecies swards compared with perennial ryegrass monocultures receiving high external N inputs (Collins *et al.*, 2014). Indeed, in some instances multispecies swards were more productive than the latter. Consequently, considerable N-savings can be achieved through the use of multispecies swards.

The benefits of greater herbage production and nutritive value are not realised unless the grazing animal efficiently consumes and utilises the herbage (Sanderson *et al.*, 2013). Previous grazing trials with dairy cows on multispecies swards have demonstrated either no differences in milk production or herbage intake (Soder *et al.*, 2006), or a positive effect on herbage intake and milk yield (summarised by Lüscher *et al.* (2014)). Inclusion of one legume species (white clover) in a perennial ryegrass pasture already showed increased herbage intake and milk yield (Pflimlin, 1993; Schils *et al.*, 1997; Ribeiro-Filho *et al.*, 2003). Thus, there remains considerable scope for further evaluation of the effects of multispecies swards on animal production and product quality compared with monocultures of perennial ryegrass or binary mixtures of perennial ryegrass and white clover. A number of experiments were carried out within the Multisward project in which multispecies swards were grazed directly or were used in zero-grazed experimental systems. Some common themes emerged from these experiments. In many of the studies, animal intake (in sheep, beef cattle and dairy cows) was positively related to mixture complexity. In the study using dairy cows (Roca-Fernández *et al.*, 2014), milk output was greater from multispecies swards compared with perennial ryegrass monocultures, despite the fact that the total number of grazing days per season was unaffected by pasture treatment. Annual milk output per ha was greater on a mixture of perennial ryegrass plus two legumes than on monocultures of perennial ryegrass, with no further increase between the former treatment and two multispecies sward treatments in which chicory and tall fescue were added. Thus, it appeared that the presence of legume species in the sward was the critical factor involved in increasing milk output per ha. This higher output was due to higher forage intake, resulting in higher milk production per cow, rather than greater pasture productivity or major differences in forage quality between the sward types. Feed conversion efficiency observed for milk production was not affected by sward type, and any increase in herbage intake in the multispecies swards was recovered in milk yield.

These results suggest that using multispecies swards comprising a small number of strategically chosen species (perennial ryegrass and clover) for forage production would be a viable option for achieving sustainable intensification of grassland-based agricultural production, and a decrease in the environmental burden of forage production through a reduction in synthetic N inputs.

Maintaining sufficient clover content in grazed pastures to deliver productivity benefits

Capturing the benefits of white clover may be limited by the fact that the proportion of white clover in long-term pasture is typically low (<20%), and subject to large temporal and spatial variability (e.g. Steele and Shannon, 1982), for reasons that have been elucidated by Schwinning and Parsons (1996). Grazing management is an important tool for promoting higher clover content with low (<4 cm) defoliation height favouring clover (Acuña and Wilman, 1993; Frame and Boyd, 1987). This effect is generally attributed to reduced shading of the clover growing points and stolon nodes by grass (Thompson, 1993),

inducing increased stolon branching and successful development of new clones (Pinxterhuis, 2000). Continuous, hard grazing by sheep in spring, followed by rotational grazing, will increase the proportion of clover in pasture (Brock, 1988). Similar clover responses have been observed in some (Hoogendoorn *et al.*, 1992), but not all (Phelan *et al.*, 2013) studies with dairy cows.

Even with optimal grazing management and fertiliser regimes, the proportion of clover in long-term pastures remains low. Alternative approaches, such as spatially (e.g. strips side by side) and temporally (offering at different times of day) separating grass and clover within the same field to reduce interspecific competition (Sharp *et al.*, 2012a) may increase the overall proportion of clover in the pasture and diet (Rutter *et al.*, 2010; Sharp *et al.*, 2012b). However care must be taken to ensure that N fixed by the clover becomes available to associated non-legume pasture species, otherwise nitrate leaching losses from the pure white clover swards can be as high as from heavily N-fertilised grass (MacDuff *et al.*, 1990). Spatial separation removes the senescence pathway, but transfer of N via dung and urine of the grazing animals will still occur.

Use of herbs to reduce urinary N excretion of dairy cows otherwise grazing on perennial ryegrass-white clover pastures

Care must be taken to focus not only on production and exchange of synthetic N by legume fixed N. In New Zealand perennial ryegrass-white clover pasture-based systems, N intake often substantially exceeds animal requirements (Brookes and Nichol, 2007; Pacheco and Waghorn, 2008), increasing the urinary N excretion. It is well established that urinary N excretion of grazing animals is the largest contributor to nitrate leaching risk in pasture-based grazed systems, due to the spatial distribution pattern of urine during grazing and its high N concentrations (Ball and Ryden, 1984; Di and Cameron, 2002; Eriksen *et al.*, 2004; Haynes and Williams, 1993; Jarvis, 2000; Ryden *et al.*, 1984; Scholefield *et al.*, 1993; Verloop *et al.*, 2006; Whitehead, 1995). Multispecies swards containing herb species may offer a strategy to reduce the environmental footprint of livestock farming, through affecting the amount and/or concentration of N excreted in urine while maintaining productivity. In an indoor study with cut forage, Woodward *et al.* (2012) found that both urinary N concentration and urinary N output were lower from cows fed a multispecies sward containing ryegrass, white clover, chicory and plantain than a simple perennial ryegrass-white clover pasture (2.6 g versus 6.2 g N l^{-1} and 100 versus 200 g N cow^{-1} day^{-1}, respectively). This result may be due to the lower N intake of the cows offered multi-species rather than simple forage (350 vs 466 g N cow^{-1} day^{-1}), reflecting the well-defined relationship between N intake and urinary N output (Kebreab *et al.*, 2001). In related grazing work, milk production was similar but urinary N concentration and estimated urine N excretion were lower for cows grazing multispecies swards containing chicory and/or plantain compared with standard perennial ryegrass-white clover pastures (Totty *et al.*, 2013). The lower N concentration per urine patch should increase the fraction of urinary N that is captured by the plants before it is leached or lost to the atmosphere (Di and Cameron, 2007). Recent modelling of the potential of diverse pastures to reduce leaching at the whole of farm scale has indicated a reduction of 11 and 19%, where 20 and 50% of the farm area was sown to diverse pastures, respectively (Beukes *et al.*, 2014).

A further approach to reduce nitrate leaching is to increase the uptake of N from soil once excreted in the urine patch. Modelling has suggested that diverse pastures containing deeper rooted species have a greater potential to limit nitrate leaching (Snow *et al.*, 2013). In a lysimeter-based study, however, nitrate leaching from urine patches with the same N loading was similar in perennial ryegrass-white clover pasture and pastures containing additional herbs (Malcolm *et al.*, 2014). Although roots were found deeper in the soil profile in the diverse pasture, cool season growth of the chicory and plantain was lower which limited the uptake of N from soil during winter. Mixtures based on plant species with

greater cool-season growth (e.g. Italian ryegrass; *Lolium multiflorum* Lam.) reduced nitrate leaching to a greater degree (Malcolm *et al.*, 2014).

The above points to the importance of carefully selecting functionally complementary grass, legume and herb species, if productivity and environmental benefits of multispecies grazed pastures are to be achieved (Pembleton *et al.*, 2014).

Integration of crops on dairy farms to increase productivity and N use efficiency

In the Netherlands, grazing by continuous stocking during the growing season is being replaced by continuous housing or restricted grazing coupled with supplementary feeding (Van den Pol-van Dasselaar, 2011). Continuous stocking is currently practised on only about 10-20% of farms, with 30% having no grazing of lactating cows and 50-60% practising some form of restricted grazing. With continuous stocking, pasture intake and quality are variable and difficult to quantify. Restricted grazing and the use of supplements allow better control over diet and other factors (e.g. weather) (Reijs *et al.*, 2013), and reduce the urinary N excretion on pasture. For example, feeding maize silage can reduce the N content of urine by up to 70% compared with grass silage (Ledgard, 2006) and reduce the kg NO_3-N leached per kg MS produced by 21-32% compared with continuous pasture (Ledgard *et al.*, 2006).

To achieve their industry's goals for increased production (3.6% per annum; Luxton, 2005), New Zealand dairy farms will also need to increase use of supplementary feeds (Clark *et al.*, 2001; Minneé *et al.*, 2009). At present, fodder crops are often grown as a break crop when renewing pasture. Forage crops that can be grazed are often selected to fill a demand for feed during periods of low pasture production, e.g. winter wet or summer dry conditions (Bryant *et al.*, 2010). On experimental dairy farms, crops on 12.5% of the farm area have been shown to increase the total amount of ME and milk solids produced as well as the operating profit (MacDonald *et al.*, 2012).

There are a number of forage crops (e.g. kale, fodder beet, maize, turnip, oats, triticale) that are well suited to supply feed during periods of low pasture production (Beare *et al.*, 2006; De Ruiter *et al.*, 2009; Minneé *et al.*, 2009; Wilson *et al.*, 2006). Recent research in New Zealand has focussed on crops and crop management systems that meet the physiological requirement of dairy cows (i.e. dry and lactating) while reducing the nutrients returned (especially N) in excreta (urine and dung) in grazed systems. However, because the returns in excreta can vary considerably (Selbie *et al.*, 2014), other research emphasises the partitioning of N to urine and dung and their individual constituents (e.g. urea, creatinine, hippuric acid), the formation of secondary compounds and their effects on N transformation (e.g. nitrification, denitrification) and transport in the soil following deposition.

Sustaining high levels of DM production while reducing the risk of N losses may depend on the type and sequence of crops grown and the soil management practices used during crop establishment and grazing. Very high levels of annual supplementary feed production (>45 Mg DM ha^{-1} year^{-1} in New Zealand) can be achieved from tight-fitting crop sequences that are based on seasonally adapted crops with a high efficiency of light capture (De Ruiter *et al.*, 2009). However, achieving these levels of production also requires high inputs of water and nutrients (especially N) that may increase the risk of N losses during crop production and following winter grazing (Beare *et al.*, 2010). Improving the ability to predict the availability of mineral N and its uptake by various crops (as for Dutch conditions with the online tool NDICEA, www.ndicea.nl) is important for identifying high production crops and crop sequences that improve N use efficiency and minimise the excess consumption of N and its return to the environment in urine and dung.

Winter feeding of forage crops in New Zealand usually involves strip grazing at high stocking rates to harvest the DM (>10 Mg DM ha^{-1}) under wet conditions. This is associated with a high risk of soil compaction from stock treading and high loadings of livestock excreta that pose an increased risk of NO_3 leaching, N_2O emissions and P in run-off (Judson *et al.*, 2010; Monaghan *et al.*, 2007). One approach to mitigate the N losses in these systems is to manipulate the diet so that animals consume less N relative to requirements (Jenkinson *et al.*, 2014; Miller *et al.*, 2012). However, the concentration of N in urine of cows grazing kale and fodder beet can already be low (1.9 to 3.0 g N l^{-1}) (Edwards *et al.*, 2014), reflecting the low CP content and overall N intake of these crops. This means that it may be challenging to reduce N excretion further, and alternative strategies may be needed to manage animal performance and environmental outcomes. Options are restricted-duration grazing of crops (Jenkinson *et al.*, 2014); early establishment of crops (e.g. multi-graze crops or crop mixtures) or cool season grasses (e.g. Italian ryegrass) following winter grazing of crops, to 'mop up' excess N and, thereby, reduce the risk of N losses in late winter or early spring (Malcolm *et al.*, 2014); and using no-tillage at establishment of forage crops, which has been shown to markedly reduce soil compaction during winter grazing on imperfectly drained soils, the associated emission of N_2O that follows urine deposition, and the regrowth of multi-graze crops such as triticale (Thomas *et al.*, 2008, 2013).

Use of farm dairy effluent and animal manure on crops to close nutrient cycles

The growth of New Zealand's dairy industry in the last 20 years has resulted in increasing volumes of FDE (Bolan *et al.*, 2009; Houlbrooke *et al.*, 2004). Increased use of off-paddock structures also increased the volume of other manures. The use of FDE and manures to grow crops is gaining interest in New Zealand as farmers look to 'close the loop' on N management between dairy and cropping farms. Some arable crops have a high demand for nutrients and are able to extract nutrients from a greater soil depth, compared with many pasture species. For example, maize crops grown on deep, free-draining soils can have an effective rooting depth of 150-180 cm (Grignani *et al.*, 2007) which is 2-3 times greater than many C3 pasture grasses (Kristensen and Thorup-Kristensen, 2004). The high DM yields of maize crops make them an effective sink for N, P and K, and capable of mopping up nutrients from depths well below the root zone of many pastures. Maize silage crops can be very effective at removing N (282-314 kg ha^{-1}), P (42-57 kg ha^{-1}) and K (267-566 kg ha^{-1}) from pastures that have received regular applications of FDE (Johnstone *et al.*, 2009, 2010). Johnstone *et al.* (2009) showed that average silage maize yields of 26.1 Mg DM ha^{-1} can be achieved in the first year of cropping FDE paddocks without any application of synthetic fertiliser. The nutrient reserves were adequate to meet all or most of the N requirements of second-year maize crops as well. Similar results were found in the Netherlands (Pinxterhuis *et al.*, 2013). This may provide a low cost approach to improving the nutrient-use efficiency and reducing the overall N footprint of the system. The high availability of mineral N following the cultivation of pasture, however, poses a risk of increased N leaching when the following crop does not fully utilise the N.

Between 20 and 50% of the total N applied in FDE may be released during the first year after application. The composition of FDE is highly variable and is affected by the age, breed and physiological state (e.g. dry vs lactating) of the cows, the composition of the feed (e.g. pasture and supplement) and the volume of wash-down water used. In the UK, the farmer decision tool MANNER is available that predicts the fertiliser N value of applied slurries and manures (Nicholson *et al.*, 2013). In the Netherlands manure is usually sampled and analysed, and standard calculations are available to predict the release of plant-available nutrients (Commissie Bemesting Grasland en Voedergewassen, 2012). On-going research in New Zealand is focussed on identifying a simple practical method for characterising the composition of FDE that can be applied to forecast the release of plant available nutrients over one or more growing seasons. Incorporating these projections into fertiliser forecasting tools such as AmaizeN (Li *et al.*, 2009) would help farmers to maximise crop yields and avoid excess fertiliser use.

Improved timing and advanced application technologies (surface or injected) are expected to enhance the nutrient-use efficiency and reduce the losses from FDE applied to pasture and crops in New Zealand. For example, shallow injection, trailing shoe and surface band spreading of slurry on pastures reduce ammonia volatilisation considerably compared with surface spreading, thereby making more N available to plants (Houlbrooke *et al.* 2011). On maize, placement in spring was associated with lower potential N leaching and higher DM yields as compared with autumn placement (Schröder *et al.*, 1993), and further improvements were seen when banded injection of cattle slurry was used to place developing maize plants in the proximity of the slurry injection slots (Schröder *et al.*, 1997).

Conclusions

Improved nutrient-use efficiency of dairy production systems, as shown by the New Zealand, Dutch and Irish farms presented in this paper, may well be sufficient to achieve environmental goals in many regions of Europe and New Zealand, but in other regions further reductions in nutrient losses may be necessary to achieve environmental goals. Where further mitigations are needed, multispecies swards containing functionally complementary species (grass, legume and herb), and integration of crops in nutrient efficient pasture/crop rotations, may provide viable options. Both options reduce the N surplus in the diet and therefore urinary N excretion. For New Zealand and Europe a combination of these options and current good practices seems interesting to explore: grazed pastures consisting of a combination of grasses, legumes and herbs; grazed crops in periods of the year where pasture production does not meet demand; loafing pads to restrict the duration of grazing of pastures and crops; application of captured manure and farm dairy effluent at places and times when maximal response can be expected; reducing or using no tillage when establishing crops or renewing pasture; and synchronising soil and synthetic N supply to plant demand.

Dairy production systems combining these options are likely to require a new skill-set of operators. Therefore the development of these systems must be in collaboration with these operators and must be accompanied by management information packages and decision tools to support on-farm change effectively.

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References

Aarts H.F.M. (2000) *Resource management in a 'De Marke' dairy farming system*. PhD thesis, Wageningen University, Wageningen, the Netherlands, 222 pp.

Acuna P.G. and Wilman D. (1993) Effects of cutting height on the productivity and composition of perennial ryegrass-white clover swards. *Journal of Agricultural Sciences* 121, 29-37.

Anonymous (2006) *Statutory Instruments 378 2006. European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006*. Government Publications Office, Dublin, Ireland. 49 pp.

Ball P.R. and Ryden J.C. (1984) Nitrogen relationships in intensively managed temperate grasslands. *Plant and Soil* 76, 23-33.

Ballantine D.J. and Davies-Colley R.J. (2013) Water quality trends in New Zealand rivers: 1989-2009. *Environmental Monitoring and Assessment* 186, 1939-1950.

Basset-Mens C., Ledgard S.F. and Boyes M. (2009) Ecoefficiency of intensification scenarios for milk production in New Zealand. *Ecological Economics* 68, 1615-1625.

Beare M.H., Tabley F., Gillespie R.N., Maley S., Harrison-Kirk T. and De Ruiter J.M. (2010) Nitrate leaching from high production forage crop sequences. *Proceedings of the New Zealand Grassland Association* 72, 23-28.

Beare M., White S. and Wilson D. (2006) Managing winter forage crops sustainably. In: *Proceedings of the 2006 South Island Dairy Event*, pp. 231-244.

Beukes P.C., Gregorini P., Romera A.J., Woodward S.L., Khaembah E.N., Chapman D.F., Nobilly F., Bryant R.H. and Edwards G.R. (2014) The potential of diverse pastures to reduce nitrogen leaching on New Zealand dairy farms. *Animal Production Science. Online Early,* DOI: http://dx.doi.org/10.1071/AN14563.

Beukes P.C., Romera A.J., Clark D.A., Dalley D.E., Hedley M.J., Horne D.J., Monaghan R.M. and Laurenson S. (2013) Evaluating the benefits of standing cows off pasture to avoid soil pugging damage in two dairy farming regions of New Zealand. *New Zealand Journal of Agricultural Research* 56, 1-15.

Beukes P.C., Romera A.J., Gregorini P., Clark D.A. and Chapman D.F. (2011) Using a whole farm model linked to the APSIM suite to predict production, profit and N leaching for next generation dairy systems in the Canterbury region of New Zealand. In: Chan F., Marinova D. and Anderssen R.S. (eds.) *MODSIM2011, 19th International Congress on Modelling and Simulation*. Modelling and Simulation Society of Australia and New Zealand, December 2011, pp. 760-766.

Beukes P.C., Scarsbrook M.R., Gregorini P., Romera A.J., Clark D.A. and Catto W. (2012) The relationship between milk production and farm-gate nitrogen surplus for the Waikato region, New Zealand. *Journal of Environmental Management* 93, 44-51.

Bolan N.S., Laurenson S., Luo J. and Sukias J. (2009) Integrated treatment of farm effluents in New Zealand's dairy operations. *Bioresource Technology* 100, 5490-5497.

Brock J.L., Hay M.J.M., Thomas V.J. and Sedcole J.R. (1988) Morphology of white clover (*Trifolium repens* L.) plants in pastures under intensive sheep grazing. *Journal of Agricultural Science* 111, 273-283.

Brookes I.M. and Nichol A.M. (2007) The protein requirements of grazing livestock. In: Rattray P.V., Brookes I.M., Nicol A.M. (eds.) *Pasture and supplements for grazing animals.* Occasional Publication No 14, New Zealand Society of Animal Production, Hamilton, New Zealand, pp. 173-187.

Brown H.E., Maley S., Wilson D.R. (2007) Investigations of alternative kale management: Production, regrowth and quality from different sowing and defoliation dates. *Proceedings of the New Zealand Grassland Association* 6, 29-33.

Bryant J.R., Lambert M.G., Brazendale R., Holmes C.W. and Fraser T.J. (2010) Effects of integrated cropping and pasture renewal on the performance and profit of dairy farms. *Proceedings of the New Zealand Grassland Association* 72, 29-34.

Burchill W. (2014) *Biological N_2 fixation and N loss as N_2O and N_2 in a white clover-based system of dairy production*. PhD thesis. Department of Botany, School of Natural Sciences, Trinity college Dublin, Ireland.

Cartwright N., Clark L. and Bird P. (1991) The impact of agriculture on water quality. *Outlook Agriculture* 20, 145-152.

Chapman D., Pinxterhuis I., Dalley D., Lynch B., Edwards G., Cameron K., Di H., Beukes P. and Romera A. (2013) Boosting the bottom line while also farming within nutrient limits? Yes, we can! In: *Proceedings of South Island Dairy Event Conference 2013*, Christchurch, New Zealand, pp. 80-94.

Clark D.A. and Jans F. (1995) High forage use in sustainable dairy systems. In: Journet M., Grenet E., Frace M.H., Theiez M. and Demarquilly C. (eds.) *Recent developments in the nutrition of herbivores*. INRA, France, pp. 496-526.

Clark D.A., Matthew C. and Crush J.R. (2001) More feed for New Zealand dairy systems. *Proceedings of the New Zealand Grassland Association* 63, 283-288.

Collins R.P., Delagarde R. and Husse S. (2014) Biomass production in multispecies and grass monoculture swards under cutting and rotational grazing. *Grassland Science in Europe* 19, 719-721.

Commissie Bemesting Grasland en Voedergewassen (2012) *Bemestingsadvies*. Commissie Bemesting Grasland en Voedergewassen, Wageningen, the Netherlands, 189 pp. Available at: www.bemestingsadvies.nl.

Cuttle S.P. and Bourne P.C. (1993) Uptake and leaching of nitrogen from artificial urine applied to grassland on different dates during the growing season. *Plant and Soil* 150, 77-86.

DairyNZ, Fonterra Co-operative Group Ltd, Miraka Ltd, Open Country Dairy Ltd, Synlait Ltd, Tatua Co-Operative Dairy Company Ltd, Westland Milk Products Ltd and Dairy Companies Association of New Zealand (DCANZ) (2013) *Sustainable Dairying: Water Accord*, 13 pp.

De Klein C.A.M., Monaghan R.M., Ledgard S.F. and Shepherd M. (2010) A system's perspective on the effectiveness of measures to mitigate the environmental impacts of nitrogen losses from pastoral dairy farming. In: *Proceedings of the 4th Australasian Dairy Science Symposium 2010*, pp. 14-28.

De Ruiter J.M., Fletcher A., Maley S., Sim R. and George M. (2009) Aiming for 45 t/ha per annum: yield of supplementary feed crops grown in sequences designed for maximum productivity. *Proceedings of the New Zealand Grassland Association* 71, 107-116.

Di H.J. and Cameron K.C. (2002) Nitrate leaching in temperate agroecosystems: sources, factors and mitigation strategies. *Nutrient Cycling in Agroecosystems* 46, 237-256.

Di H.J. and Cameron K.C. (2007) Nitrate leaching losses and pasture yields as affected by different rates of animal urine nitrogen returns and application of a nitrification inhibitor – a lysimeter study. *Nutrient Cycling in Agroecosystems* 79, 281-290.

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005) Optimising financial return from grazing in temperate pastures. In: Murphy J.J. (ed.), *Utilisation of grazed grass in temperate animal systems. Proceedings of a satellite workshop of the XXth International Grassland Congress*, July 2005, Cork, Ireland, pp. 131-148.

Edwards G.R., De Ruiter J.M. Dalley D.E., Pinxterhuis J.B., Cameron K.C., Bryant R.H., Di H.J., Malcolm B.J. and Chapman D.F. (2014) Urinary nitrogen concentration of cows grazing fodder beet, kale and kale-oat forage systems in winter. In: *Proceedings of the 6th Australasian Dairy Science Symposium*, pp. 144-147.

Eriksen J., Vinther F.P. and Soegaard K. (2004) Nitrate leaching and N2-fixation in grasslands of different composition, age and management. *Journal of Agricultural Science* 142, 141-151.

European Community (1991) Council Directive 91/676/ECC of 12 December 1991 concerning the protection of waters against pollution caused by nitrates from agricultural sources. *Official Journal of the European Union* L 375, 31/12/1991, 1-8.

Finn J.A., Kirwan L., Connolly J., Sebastia M.T., Helgadóttir Á., Baadshaug O.H., Bélanger G., Black A., Brophy C., Collins R.P., Čop J., Dalmannsdóttir S., Delgado I., Elgersma A., Fothergill M., Frankow-Lindberg B.E., Ghesquiere A., Golinska B., Golinski P., Grieu P., Gustavsson A-M., Höglind M., Huguenin-Elie O., Jørgensen M., Kadziuliene Z., Kurki P., Llurba R., Lunnan T., Porqueddu C., Suter M., Thumm U. and Lüscher A. (2013) Ecosystem function enhanced by combining four functional types of plant species in intensively managed grassland mixtures: a 3-year continental-scale field experiment. *Journal of Applied Ecology* 50, 365-375.

Fonterra Co-operative Group Ltd (2015) *Fonterra revises 2014-15 forecast milk price*, Media release. Available at: http://tinyurl.com/oe2djy5.

Fonterra Co-operative Group Ltd (2013) *New Zealand Dairy Product Safety – Questions and Answers*. 2 pp.

Fonterra Co-operative Group Ltd, Regional Councils and unitary authorities, the Ministry for the Environment and the Ministry of Agriculture and Forestry (2003) *Dairying and Clean Streams Accord*, 5 pp.

Frame J. and Boyd A.G. (1987) The effect of fertilizer nitrogen rate, white clover variety and closeness of cutting on herbage production from perennial ryegrass/white clover swards stocked with beef cattle. *Grass and Forage Science* 42, 85-96.

Glassey C., Griffiths W., Woodward S., Roach C., Shepherd M., Phillips P. and McDonald K. (2014) Development of a dairy production system in the Waikato to maintain profitability and decrease nitrate leaching. In: *Proceedings of the 5th Australasian Dairy Science Symposium 2014*, pp. 157-160.

Grignani C., Zavattoro L., Sacco D. and Monaco S. (2007) Production, nitrogen and carbon balance of maize-based forage systems. *European Journal of Agronomy* 26, 442-453.

Haynes R.J. and Williams P.H. (1993) Nutrient cycling and soil fertility in the grazed pasture ecosystem. *Advances in Agronomy* 49, 119-199.

Henkens P.H. and Van Keulen H. (2001) Mineral policy in the Netherlands and nitrate policy within the European Community. *Netherlands Journal of Agricultural Science* 49, 117-134.

Heubsch M., Horan B., Blum P., Richards K.G., Grant J. and Fenton O. (2013) Impact of agronomic practices of an intensive dairy farm on nitrogen concentrations in a karst aquifer in Ireland. *Agriculture, Ecosystems and Environment* 179, 187-199.

Hodgson J. (1975) The influence of grazing pressure and stocking rate on herbage intake and animal performance. In: Hodgson J. and Jackson D.K. (eds.) *Pasture utilisation by the grazing animal*, Hurley, British Grassland Society, pp. 70-78.

Hoogendoorn C.J., Holmes C.W. and Chu A.C.P. (1992) Some effects of herbage composition, as influenced by previous grazing management, on milk production by cows grazing on ryegrass/white clover pastures. 2. Milk production in late spring/summer: effects of grazing intensity during the preceding spring period. *Grass and Forage Science* 47, 316-325.

Houlbrooke D.J., Horne D.J., Hedley M.J., Hanly J.A. and Snow V.O. (2004) A review of literature on the land treatment of farm-dairy effluent in New Zealand and its impact on water quality. *New Zealand Journal of Agricultural Research* 47, 499-511.

Houlbrooke D., Longhurst B., Orchiston T. and Muirhead R. (2011) *Characterising dairy manures and slurries*. Envirolink tools report AGRX0901. AgResearch, Hamilton, New Zealand. 114 pp.

Jarvis S.C. (2000) Progress in studies of nitrate leaching from grasslands soils. *Soil Use Management* 16, 152-156.

Humphreys J., Casey I.A., Darmody P., O'Connell K., Fenton O. and Watson C.J. (2008b) Quantities of mineral N in soil and concentrations of nitrate-N in groundwater in four grassland-based systems of dairy production on a clay-loam soil in a moist temperate climate. *Grass and Forage Science* 63, 481-494.

Humphreys J., Casey I.A., and Laidlaw A.S. (2009) Comparsion of milk production from clover-based and fertilizer-N-based grassland on a clay-loam soil under moist temperate climatic conditions. *Irish Journal of Agricultural and Food Research* 48, 189-207.

Humphreys J., Lawless A., Healy M., Boland A. and Mc Namara K. (2007) *Aspects of management options for pasture-based dairy production stocked at two cows per hectare*. End of Project Report No. 5150. Teagasc, Oak Park, Carlow, Ireland.

Humphreys J., O'Connell K. and Casey I.A. (2008a) Nitrogen flows and balances in four grassland-based systems of dairy production on a clay-loam soil in a moist temperate climate. *Grass and Forage Science* 63, 467-480.

Jenkinson B.A.B., Edwards G.R. and Bryant R.H. (2014) Grazing behaviour, dry matter intake and urination patterns of dairy cows offered kale or fodder beet in winter. *New Zealand Society of Animal Production* 74, 23-28.

Johnstone P., Parker M., Kaufler G., Arnold N. and Pearson A. (2009) Using maize to maize to manage dairy shed effluent – maximising the margin and minimising the footprint. In: Currie, L.D. and Christensen, C.L. (eds.) *Farming's Future. Occasional Report No. 23*. Fertiliser and Lime Research Centre, Massey University, Palmerston North, New Zealand, 557.

Johnstone P., Parker M., Kaufler G., Arnold N., Pearson A., Mathers D. and Wallace D. (2010) Growing maize silage in dairy effluent paddocks for two consecutive seasons – effect on crop yield and soil nitrogen. *Proceedings of the New Zealand Grassland Association* 72, 117-120.

Judson H.G., Dalley D.E., Edwards G.R., Stephens D.R. and Gibbs S.J. (2010) Improving winter feeding outcomes in South Island dairy herds. In: *Proceedings of the 4th Australasian Dairy Science Symposium*, 137-143.

Kebreab E., France J., Beever D.E. and Castillo A.R. (2001) Nitrogen pollution by dairy cows and its mitigation by dietary manipulation. *Nutrient Cycling in Agroecosystems* 60, 275-285.

Kristensen H.L. and Thorup-Kristensen K. (2004) Root growth and nitrate uptake of three different catch crops in deep soil layers. *Soil Science Society American Journal* 68, 529-537.

Larned S.T., Scarsbrook M.R., Snelder T.H., Norton N.J. and Biggs B.J.F. (2004) Water quality in low-elevation streams and rivers of New Zealand: recent state and trends in contrasting land-cover classes. *New Zealand Journal of Marine and Freshwater Research* 38, 347-366.

Ledgard S. (2006) Nitrogen management – why is it important and what can we do about it? In: *Proceedings of the Dairy3 Conference* 4, pp. 23-31.

Ledgard S.F., Penno J.W. and Sprosen M.S. (1997) Nitrogen balances and losses on intensive dairy farms. *Proceedings of the New Zealand Grassland Association* 59, 49-53.

Ledgard S., Sprosen M., Judge A., Lindsey S., Jensen R., Clark D. and Luo J. (2006) Nitrogen leaching as affected by dairy intensification and mitigation practices in the Resource Efficient Dairying (RED) trial. In: Currie L.D. and Hanly J.A. (eds.) *Occasional Report No. 19*. Fertiliser and Lime Research Centre, Massey University, Palmerston North, New Zealand, pp. 263-268.

Li F.L., Johnstone P.R., Pearson A., Fletcher A., Jamieson P.D., Brown H.E. and Zyskowski R.F. (2009) AmaizeN: A decision support system for optimizing nitrogen management of maize. *Wageningen Journal of Life Sciences* 57, 93-100.

LIC and DairyNZ (2014) *New Zealand Dairy Statistics 2013-2014*. LIC and DairyNZ, Hamilton, New Zealand. 52 pp.

Lord E.I. (1993) Effect on nitrate leaching risk of cutting instead of grazing intensive pasture in late summer. In: Hopkins A. (ed.) *Forward with Grass into Europe. Occasional Symposium No 27*, British Grassland Society, Reading, UK, pp. 139-141.

Lüscher A., Mueller-Harvey J.F., Soussanna J.F., Rees R.M. and Peyraud J.L. (2014) Potential of legume-based grassland-livestock systems in Europe: a review. *Grass and Forage Science* 69, 206-228.

Luxton J. (2005) *Dairy industry capability needs review. A report to Dairy Insight*. Dexcel & Fonterra, Hamilton, New Zealand.

Macdonald K.A., Clough J., de Ruiter J.M., Glassey C.B., Sears T. and Sears N. (2012) Integrating high yielding crops into a Taranaki dairying system. *Proceedings of the New Zealand Grassland Association* 74, 17-23.

MacDuff J.H., Jarvis S.C. and Roberts D.H. (1990) Nitrates: leaching from grazed grassland systems. In: Calvet R. (ed.) *Nitrates, agriculture, eau*. INRA, Paris, France, pp. 405-410.

Malcolm B.J., Cameron K.C., Di H.J., Edwards G.R. and Moir J.L. (2014) The effect of four different pasture species compositions on nitrate leaching losses under high N loading. *Soil Use and Management* 30, 58-68.

McCarthy J., Delaby L., Hennessy D., McCarthy B., Ryan W., Pierce K.M., Brennan A. and Horan B. (2015) The effect of stocking rate on soil solution nitrate concentrations beneath a free draining dairy production system in Ireland. *Journal of Dairy Science*, in press.

McColl R.H.S. and Hughes H.R. (1981) *The effects of land use on water quality – a review*. Water and soil miscellaneous publication 23. Government Printer, Wellington, New Zealand, 59 pp.

Miller M., Bryant R.H. and Edwards G.R. (2012) Dry matter intake and nitrogen losses of pregnant, non-lactating dairy cows fed kale with a range of supplements in winter. *Proceedings of the New Zealand Society of Animal Production* 72, 8-13.

Ministry for the Environment (2011) *National Policy Statement for Freshwater Management 2011.* Ministry for the Environment, Wellington, New Zealand. 11 pp.

Minneé E.M.K., Fletcher A.L., de Ruiter J.M. and Clark D.A. (2009) Forage crop sequences for pastoral systems in northern New Zealand. *Proceedings of the New Zealand Grassland Association* 71, 93-100.

Monaghan R.M., Wilcock R.J., Smith L.C., Tikkisetty B., Thorrold B.S. and Costall D. (2007) Linkages between land management activities and water quality in an intensively farmed catchment in southern New Zealand. *Agriculture, Ecosystems and Environment* 118, 211-222.

Necpálová M., Fenton O., Casey I. and Humphreys J. (2012) N leaching to groundwater from dairy production involving grazing over the winter on a clay-loam soil. *Science of the Total Environment* 432, 159-172.

Necpálová M., Phelan P., Casey I. and Humphreys J. (2013) Soil surface N balances and soil N content in a clay-loam soil under Irish dairy production systems. *Nutrient Cycling in Agroecosystems* 96, 47-65.

Nicholson F.A., Bhogal A., Chadwick D., Gill E., Gooday R.D., Lord E., Misselbrook T., Rollett A.J., Sagoo E., Smith K.A., Thorman R.E., Williams J.R. and Chambers B.J. (2013) An enhanced software tool to support better use of manure nutrients: MANNER-NPK. *Soil Use and Management,* 29, 473-484.

Oenema J. (2014) *Transitions in nutrient management on commercial pilot farms in the Netherlands*. PhD thesis Wageningen University, Wageningen. 199 pp.

Oenema J., Koskamp G.J. and Galama P.J. (2001) Guiding commercial pilot farms to bridge the gap between experimental and commercial dairy farms; the project 'Cows & Opportunities. *Netherlands Journal of Agricultural Science* 49, 277-296.

Oenema J., van Keulen H., Schils R.L.M. and Aarts H.F.M. (2011) Participatory farm management adaptations to reduce environmental impact on commercial pilot dairy farms in the Netherlands. *Netherlands Journal of Agricultural Science* 58, 39-48.

Oenema O., Vellinga T.V. and van Keulen H. (2006) Nutrient management under grazing. In: Elgersma A., Dijkstra J., Tamminga S. (eds.), *Fresh herbage for dairy cattle*. Springer, Dordrecht, the Netherlands, pp. 63-83.

Pacheco D. and Waghorn G.C. (2008) Dietary nitrogen – definitions, digestion, excretion, and consequences of excess for grazing ruminants. *Proceedings of the New Zealand Grassland Association* 70, 107-116.

PCE (2004) *Growing for food: Intensive farming, sustainability and New Zealand's environment*. Parliamentary Commissioner for the Environment, Wellington, New Zealand. 236 pp.

Pembleton K.G., Tozer K.N., Edwards G.R., Jacobs J.L. and Turner L.R. (2014) Simple versus diverse pastures – opportunities and challenges in dairy systems. *Proceedings of the 5th Australasian Dairy Science Symposium 2014*, 206-216.

Peyraud J.L., Van den Pol-van Dasselaar A., Collins R.P., Huguenin-Elie O., Dillon P. and Peeters A. (2014) Multi-species swards and multi scale strategies for multifunctional grassland-based ruminant production systems: an overview of the FP7-MultiSward project. *Grassland Science in Europe* 19, 695-715.

Pflimlin A. (1993) Conduite et utilisation des associations graminée-trèfle blanc. *Fourrages* 135, 407-428.

Phelan P., Casey I.A. and Humphrey J. (2013). The effect of post grazing height on sward clover content, herbage yield, and dairy production from grass-white clover pasture. *Journal of Dairy Science* 96, 1598-1611.

Pinxterhuis, J.B. (2000) *White clover dynamics in New Zealand pastures*. PhD thesis, Wageningen University. Wageningen, the Netherlands, 153 pp.

Pinxterhuis J.B., De Boer H.C., Van Eekeren N.J.M. and Stienezen M.W.J. (2013) Integrating maize and triticale in grass/clover based dairy systems: examining yields and autumn soil nitrate levels. *Proceedings of the New Zealand Grassland Association* 75, 251-255.

Reijs J.W., Daatselaar C.H.G., Helming J.F.M., Jager J. and Beldman A.C.G. (2013) Grazing dairy cows in North-West Europe – Economic farm performance and future developments with emphasis on the Dutch situation. LEI Wageningen UR, The Hague, the Netherlands, 124 pp.

Ribeiro-Filho H.M.N., Delagarde R. and Peyraud J.L. (2003) Inclusion of white clover in strip-grazed perennial ryegrass pastures: herbage intake and milk yield of dairy cows at different ages of pasture regrowth. *Animal Science* 77, 499-510.

Roca-Fernández A.I., Peyraud J.L., Delaby L., Lassalas J. and Delagarde R. (2014) Interest of multispecies swards for pasture-based milk production systems. *Grassland Science in Europe* 19, 728-730.

Rutter S.M. (2010) Grazing preference in sheep and cattle: implications for the production, the environment and animal welfare. *Canadian Journal of Animal Science* 90, 285-293.

Ryan M., Brophy C., Connolly J., McNamara K. and Carton O.T. (2006) Monitoring of nitrogen leaching on a dairy farm during four drainage seasons. *Irish Journal of Agricultural and Food Research* 45, 115-134.

Ryden J.C., Ball P.R. and Garwood E.A. (1984) Nitrate leaching from grassland. *Nature* 311: 50-52.

Sanderson M.A., Archer D., Hendrickson J., Kronberg S., Liebig M., Nichols K., Schmer M., Tanaka D. and Aguilar J. (2013) Diversification and ecosystem services for conservation agriculture: outcomes from pastures and integrated crop-livestock systems. *Renewable Agriculture and Food Systems* 28, 129-144.

Schils R.L.M., Baars T. and Snijders P.J.M. (1997) *Witte klaver in grasland – Teelt, gebruik en bedrijfsvoering*. Praktijkonderzoek Veehouderij, Lelystad, the Netherlands. 59 pp.

Scholefield D., Tyson D.C., Garwood E.A., Armstrong A.C., Hawkins J. and Stone A.C. (1993) Nitrate leaching from grazed grassland lysimeters: Effects of fertilizer input, field drainage, age of sward and patterns of weather. *Journal of Soil Science* 44, 601-613.

Schröder J.J. and Neeteson J.J. (2008) Nutrient management regulations in the Netherlands. *Geoderma* 144, 418-425.

Schröder J.J., Ten Holte L. and Brouwer G. (1997) Response of silage maize to placement of cattle slurry. *Netherlands Journal of Agricultural Science* 45, 249-261.

Schröder J.J., Ten Holte L., Van Keulen H. and Steenvoorden J.H.A.M. (1993) Effects of nitrification inhibitors and time and rate of slurry and fertiliser N application on silage maize yield and losses to the environment. *Fertilizer Research* 34, 267-277.

Schwinning S. and Parsons A.J. (1996) Analysis of the coexistence mechanisms for grasses and legumes in grazing systems. *Journal of Ecology* 84, 799-813

Selbie D.R., Buckthought L.E. and Shepherd M.A. (2014) The challenge of the urine patch for managing nitrogen in grazed pasture systems. *Advances in Agronomy* 129, 229-292.

Sharp J.M., Edwards G.R. and Jeger M.J. (2012b) Impact of spatial heterogeneity of plant species on herbage productivity, herbage quality and ewe and lamb performance of continuously stocked, perennial ryegrass-white clover swards. *Grass and Forage Science* 68, 537-547.

Sharp J.M., Edwards G.R. and Jeger M.J. (2012b) Impact of the spatial scale of grass-legume mixtures on sheep grazing behaviour, preference and intake, and subsequent effects on pasture. *Animal* 6: 1848-1856.

Snow V.O., Smale P.N. and Dodd M.B. (2013) Process-based modelling to understand the impact of ryegrass diversity on production and leaching from grazed grass-clover dairy pastures. *Crop and Pasture Science* 64, 1020-1031.

Soder K.J., Sanderson M.A., Stack J.L., and Muller L.D. (2006) Intake and performance of lactating cows grazing diverse forage mixtures. *Journal of Dairy Science* 89, 2158-2167.

Statistics New Zealand (2014) *Dairy export prices and volumes move upwards over 20 years*. Statistics New Zealand, Wellington, New Zealand. Available at: http://tinyurl.com/k534w3b.

Steele K.W. and Shannon P. (1982) Concepts relating to the nitrogen economy of a Northland intensive beef farm. In: Gandar, P. (ed.) *Nitrogen Balances in NZ Ecosystems*. DSIR, Palmerston North, New Zealand, pp. 85-89.

Teagasc (2013) *Sectoral road map: dairying*. Teagasc, Carlow, Ireland. 2 pp. Available at: http://tinyurl.com/lvgcwdh.

Thomas S.M., Beare M.H., Francis G.S., Barlow H. and Hedderley D. (2008) Effects of tillage, simulated cattle grazing and soil moisture on N_2O emissions from a winter forage crop. *Plant and Soil* 309, 131-145.

Thomas S.M., Clemens G., Dunlop C., Beare M.H. and Meenken E.D. (2013) Effects of herbicide application, tillage and winter grazing of a forage crop on nitrous oxide emissions during pasture renewal. *Advances in Animal Biosciences* 4, 426.

Thompson L. (1993) The influence of radiation environment around the node on morphogenesis and growth of white clover (*Trifolium repens*). *Grass and Forage Science* 48, 271-278.

Titchen N.M., Phillips L. and Wilkins R.J. (1993) A potential management system for reducing N losses from grazed grassland in autumn. In: Hopkins A. (ed.) *Forward with Grass into Europe. Occasional Symposium No 27*, British Grassland Society, Reading, UK, pp. 160-161.

Totty V.K., Greenwood S.L., Bryant R.H. and Edwards G.R. (2013) Nitrogen partitioning and milk production of dairy cows grazing simple and diverse pastures. *Journal of Dairy Science* 96, 141-149.

Tuohy P., Fenton O., Holden N.M. and Humphreys J. (2014) The effect of treading by two breeds of dairy cow with different live-weights on the soil physical properties and poaching damage on a poorly drained clay-loam soil. *Journal of Agricultural Science (Cambridge)*, in press. DOI: http://dx.doi.org/10.1017/S0021859614001099.

Van den Pol-Van Dasselaar A., De Vliegher A., Hennessy D., Peyraud J.L. and Pinxterhuis J.B. (2011) *Research methodology of grazing*. Report Wageningen UR Livestock Research 405, Lelystad, the Netherlands, 19 pp.

Verloop J.J., Boumans L.J.M., Van Keulen H., Oenema J., Hilhorst G.J. and Aarts H.F.M. (2006) Reducing nitrate leaching to groundwater in an intensive dairy farming system. *Nutrient Cycling in Agroecosystems* 74, 59-74.

Wheeler D.M., Ledgard S.F., Monaghan R.M., McDowell R. and de Klein C. (2006) OVERSEER® nutrient budget model – what it is, what it does. In: Currie L.D., Hanly J.A. (eds.) *Implementing sustainable nutrient management strategies in agriculture*. Fertiliser and Lime Research Centre, Palmerston North, Occasional Report No 19, 231-236. Overseer® is freely available at: www.overseer.org.nz.

Whitehead D.C. (1995) *Grassland nitrogen*. CAB International, Wallingford, UK, 397 pp.

Wilson D.R., Reid J.B., Zyskowski R.F., Maley S., Pearson A.J., Armstrong S.D., Catto W.D. and Stafford A.D. (2006) Forecasting fertiliser requirements of forage brassica crops. *Proceedings of the New Zealand Grassland Association* 68, 205-210.

Woodward S.L., Waghorn G.C., Bryant M.A. and Benton A. (2012) Can diverse pasture mixtures reduce nitrogen losses? In: *Proceedings of the 5th Australasian Dairy Science Symposium*, pp. 463-464.

Quantifying sustainability of dairy farms with the DAIRYMAN-sustainability-index

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Abstract

Dairyman was an EU-Interreg IVB project for Northwest Europe which ran from 2009 to 2013 involving 10 regions. A pilot farm network was set up, comprising 127 dairy farms covering the partner regions. The farms were optimized regarding economic, ecological and social aspects, to provide a measure of sustainability. The collected data provided a clear overview of current production systems and the future potential in Northwest Europe. This paper describes the application of a multi-annual data-set used to assess and analyse development of sustainability of an individual farm. A multi-criteria assessment tool has been developed, the Dairyman sustainability index, incorporating economic, ecological and social indicators to describe and comprehend the complexity of the farm as a production system. Moreover this tool can visualize individual farm development and differences in milk production systems over time and between regions.

Keywords: sustainability, dairy systems, indicator, Dairyman sustainability index

Introduction

Dairy farming is an important economic activity in Northwest Europe (NWE) (Aarts, 2013). Although the climatic conditions are well suited and the infrastructure is excellent for dairying, the environmental performance of dairy farming is low. Aarts (2013) has considered that NWE dairy farming has very low efficiency in the use of fertilizers and feed. The poor utilization of these increasingly expensive resources threatens the economic viability of dairy farms. This raises questions about the sustainability of dairy farming in NWE. According to the Brundtland Commission (1987) the definition of sustainability of a system includes economic, ecological and social aspects. This means that sustainable dairy farms should be environmentally compatible, economically viable and socially acceptable (Dubois, 2002). Sustainability, as a special criterion for assessment of agricultural practices, has been a topic of discussion for many years (Briemle et al., 1996; Vavra, 1996). Von Wiren-Lehr (2001) pointed out that it is not possible to evaluate sustainability accurately even if complex models are deployed or time-consuming measurements are taken. Sustainability assessment tools can be classified by a diverse range of criteria, e.g. goal, intended end-users, geographical scope, data and time requirements. More specifically for dairy farming, a large set of indicators focusing on specific, mainly environmental, sustainability aspects has been proposed (e.g. Arnould et al., 2013; Belanger et al., 2012; Breitschuh et al., 2001; Bockstaller et al., 1997; Gaudino et al., 2014; Girardin, 2001; Huelsbergen, 2003; Kopfmueller et al., 2001; Schroeder, 2003). Guillaumin et al. (2007) and Lebacq et al. (2012) have overviewed sustainability indicators for livestock farming.

Dairyman was an EU Interreg NWE IVB project which ran from 2009 to 2013 and included 14 partners in 10 regions of Northwest Europe (the Netherlands (NL), Pays de la Loire (FL), Bretagne (FB), Nord Pas de Calais (FN), Northern Ireland (IN), Ireland (IR), Flanders (BF), Wallonie (BW), Luxembourg (LU), Baden-Wuerttemberg (GE)). The objective of the project was to investigate the state of sustainable milk production in the main milk producing regions of Europe and to compare production conditions in these areas. Within the project a network of 127 pilot dairy farms was set up and data from the farms were

recorded following a standardized protocol (Boonen *et al.*, 2013a) during three years (2009, 2010 and 2011). All farms created an individual management plan, including their targets for farm development within the time frame of the project. Additionally, a general report on the sustainability of milk production in each region was written and management tools to improve sustainability of dairy farms were tested. In order to compare current dairy farming systems, the project team initially considered single indicators, e.g. farm income or surpluses of nutrient balances, but concluded sustainability can be assessed more satisfactorily with an integrated system and a combination of indicators, instead of using single indicators. From several comparisons of available assessment tools and systems (Gasparatos *et al.*, 2008; Marchand *et al.*, 2014; Schader *et al.*, 2014), and from the evaluation of a tool development process (Triste *et al.*, 2014), some general requirements were identified for potential sustainability assessment tools. Issues included creating ownership amongst stakeholders to increase likelihood of adoption of the tool in practice, and the fact that the tool design had to be in accordance with aim (e.g. farm management vs policy support) and function (e.g. rapid assessment vs monitoring) of the tool. At the start of the project in 2009 several sustainability assessment methods had been already, or at least partly, developed, e.g. REPRO (Christen *et al.*, 2009), KSNL (Breitschuh *et al.*, 2008), RISE (Grenz *et al.*, 2009), IDEA (Zahm *et al.*, 2008) or MOTIFS (Meul *et al.*, 2008; De Mey *et al.*, 2011). However, as none of these methods completely fulfilled our criteria, we opted to create a new system, fulfilling the specific DAIRYMAN requirements. This paper will describe the development process of the Dairyman Sustainability Index (DSI) and some comparisons between the regions.

Material and methods

Stages in the tool development process were:
1. agreement on weighting of the ecological, economic and social aspects of sustainability;
2. choice of single indicators for each of the three sustainability aspects;
3. deciding on the contribution of each indicator within the appropriate sustainability aspect;
4. benchmarking (determination of targets to attain of each indicator).

Weighting of aspects

Based on the sustainability definition, the Group agreed that the economic, ecological and sociological aspects would each be considered equally with 100 points (Table 3).

Choice of sustainability indicators

In the first phase of the project, indicators chosen for the Dairyman sustainability index (DSI) were selected by the project partner LAZBW in Aulendorf – after intensive discussion and relying on data from a questionnaire answered by pilot farmers, farm advisers and teachers of agricultural schools in that region. In this questionnaire the partner proposed single indicators that had already been calculated for the Dairyman pilot farms and existing common farm indicators from other systems. In the Dairyman project the following farm data were available for three accountancy years (2009-2011) for all pilot farms:
- Descriptive data: information on the farm structure and management strategies (workers, size of herds, land use, etc.);
- Economic data: information on sources of revenues (milk, animals, crops and subsidies), operating costs (related to herds, grassland, crops, buildings and management), depreciation, interest and taxes;
- Ecological data: information on amount and composition of inputs (e.g. fertilization and feeding) and outputs (e.g. milk). These data allowed calculation of mineral balances (kg of N and P balance per ha), N and P efficiencies (ratio between output and input of nutrients at farm scale) and greenhouse gas emissions (only 2010);
- Biodiversity potential of 1-3 pilot farms per region for one year.

In the second step the Dairyman group discussed and modified the choice of indicators. All chosen indicators (Table 1) were clearly defined and could be easily calculated from the data already gathered from the pilot farm (Elsaesser *et al.*, 2013; Grignard *et al.*, 2012). Finally the retained indicators were:

Economic

For the economic indicators a net margin before taxes was calculated:

Net margin before taxes (NMBT) (€): Revenues – Annual expenses – Depreciation – Interest   (1)

As a lot of pilot farms were mixed farms (with beef or crop production in addition to dairy), we considered three economic indicators at the dairy component of the farm (Expressions 2, 3, and 6) and two economic indicators were calculated at the whole farm level (Expression 4 and Expression 5). The selected economic indicators were the following:

Income at dairy level (€100 kg^{-1} FPCM): $\dfrac{(\text{NMBT})_{\text{dairy}}}{\text{Milk production (kg FPCM)} / 100}$ (2)

Family labour income at dairy level (€ fLU^{-1}): $\dfrac{(\text{NMBT})_{\text{dairy}}}{(\text{Family Labour Units fLU})_{\text{dairy}}}$ (3)

Farm income (€ ·fLU^{-1}): $\dfrac{\text{NMBT}}{\text{Farm Labour Units}}$ (4)

Dependency on subsidies (%): $\dfrac{\text{Public payments}}{\text{NMBT}}$ (5)

Exposure to price fluctuations d. level (%): $\dfrac{(\text{variable costs} + \text{Depreciation} + \text{Interest} - \text{Paid labour})_{\text{dairy}}}{(\text{Revenues} - \text{Public Payments})_{\text{dairy}}}$ (6)

Ecological

1. N balance (kg · ha^{-1}): N input minus N output at farm level;
2. N balance per kg milk (kg · 1000 kg^{-1} milk): N input minus N output at farm level;
3. N efficiency (%): N output per N input at farm level;
4. P balance per ha (kg ha^{-1}): P input minus P output at farm level;
5. P balance per kg milk (kg 1000 kg^{-1} milk): P input minus P output at farm level;
6. P efficiency (%): P output per P input at farm level;
7. Payments for environmental activities: agro-environmental payments (€ ha^{-1}), e.g. for cultivation of nature protection land, subsidies for no use of pesticides, etc.;
8. Greenhouse gas emissions (kg CO$_2$-eq Mg milk^{-1}): greenhouse gas emissions for the dairy component of the farm.

Social aspects

As the Dairyman database had not included sociological factors, the Group developed a questionnaire, based on the original one developed by the LAZBW partner, and distributed it to every family worker on the 127 pilot farms. Answers to the questionnaire were scored and then integrated into the DSI. Some information concerning basic education, holidays, work load, employment had already gathered in the descriptive data set. The working conditions (quantity and quality) were most often cited as relevant social sustainability themes. The work load was the amount of working time on the farm. Work quality was taken to be the global perception of happiness at work (Coutey, 2014), including, e.g. pleasure at

work. Wide differences in social perceptions were found between countries (Foray *et al.*, 2013). Therefore taking account of both quantitative and perception data from farmers was justified.

1. Education (1.1 Basic education; 1.2 Training courses);
2. Working conditions (2.1 Personal satisfaction (work-life-balance? How often do you feel stressed? Are you happy with your salary? Activities outside the farm?); 2.2 Work load per family labour unit; 2.3 Holidays; 2.4 Free time);
3. Farm continuity (3.1 Preparation of farm succession; 3.2 Is there a potential successor?);
4. Social role and image: relation to neighbourhood, reputation within the area, organization of public events on the farm, etc.

Weighting of each indicator

In developing a multi-criteria index system it was important to attribute weights to the different indicators in the system. As explained before equal weights were assigned to ecological, economic and social aspects (Table 1). However, there was some discussion on whether different weights should be given to, for instance, different environmental indicators, e.g. N efficiency may be less important than N balance. Taking into account the approach taken by Belanger *et al.* (2012), Larochelle *et al.* (2007) and Meul *et al.* (2008) and the requirement for the sum of the indicators of each sustainability aspect to be 100 points, the relative contribution of points assigned to each indicator is presented in Table 1. The results are based on subjective decisions. They are a compromise and may not be ideal for all regions. These values are still under discussion, as different objectives of the partner regions influence these weights. For example, Ireland consider phosphorus to be the most important nutrient emission, so they would place emphasis on indicators dealing with phosphorus whereas in the Netherlands, Germany or Brittany nitrogen is the most important nutrient and so their values would reflect this.

Benchmarking

A final step was the definition of benchmarks, and scoring of the indicators. A possible option was absolute reference values (for instance regulations, thresholds), but these do not exist for all indicators in the DSI system. As an alternative the research team decided to use the results of the 127 pilot farms for the determination of reference values to evaluate the sustainability of the individual farms for the quantitative indicator set. Based on the distribution of scores for each indicator for the 127 farms the means for the lowest 10% (10% quantile) and for the highest 10% (90% quantile) for the reference year (2010) were calculated as reference points for the minimum and maximum score. Between these points a linear progression was used for the individual scoring (Table 2).

Table 1. Weightings for each sustainability indicator in the Dairyman sustainability index.

Economic aspects		Ecological aspects		Social aspects	
Income per kg milk	16%	N balance per ha	15%	Education	22%
Income per fLU	34%	N balance per kg milk	11%	Working conditions	42%
Total farm income	22%	N efficiency %	13%	Continuity of farm	16%
Dependency on subsidies	10%	P balance per ha	11%	Social role and image	20%
Exposure to price fluctuations	18%	P balance per kg milk	8%		
		P efficiency %	10%		
		Agri-env. pay. per farm	10%		
		Greenhouse gas emissions	22%		
	100%		100%		100%

Table 2. Statistical results (minimum and maximum value, 10% and 90% quantiles) of the indicators of the 127 DAIRYMAN pilot farms (2010) (see text for explanation).

Indicator	Min. value	10% quantile	90% quantile	Max. value
Economy				
Income at dairy level (€ 100 kg^{-1} milk)	-7.62	2.65	23.79	34.88
Income at dairy level (€ family labour unit^{-1})	-69,427	13,323	117,466	202,916
Total farm income (€ family labour unit^{-1})	-69,427	18,081	109,313	188,542
Dependency on subsidies (%)	-33	22	138	715
Exposure to price fluctuations (%)	42	53	104	149
Ecology				
N balance (kg ha^{-1})	17.1	82.4	268.0	373.3
N balance (kg 1000 kg^{-1} milk)	3.85	9.09	34.34	60.94
N efficiency (%)	11.79	19.41	47.54	64.40
P balance (kg ha^{-1})	-16.31	-4.62	17.88	43.90
P balance (kg 1000 kg^{-1} milk)	-4.56	-0.63	2.97	8.53
P efficiency (%)	19.45	35.89	157.88	411.60
Agro-environmental payments (€ ha^{-1})	0.00	0.00	122.55	317.95
Greenhouse gas emissions (kg CO_2-eq Mg^{-1} milk)	703.80	932.30	1,427.66	1,816.89
Social aspects				
Holidays (days year^{-1})	0	0	20	35
Working time (hours·fLU^{-1})	330	1,952	3,310	5,304

Results

Calculation of the Dairyman sustainability index

The total scores for economic, ecological and social aspects are calculated by multiplying the score (relative to the maximum of 1) with the weighting (proportion of the 100 points for the aspect of sustainability assigned to the indicator). For example, in Table 3, calculation of the 'Income per kg milk' score, included in the economic aspect of sustainability, is high as the value is close to the maximum and so is awarded 0.9. When multiplied by the proportion of the points awarded to 'Income per kg milk', i.e. 16, the weighted score is 14.4.

Table 3. Example of calculating the scoring points for economy with the Dairyman sustainability index.

Score	Income dairy (€ 100 kg milk^{-1})	Income dairy (€ fLU^{-1})	Farm income (€ fLU^{-1})	Dependency on subsidies (%)	Exposure to price fluctuations (%)
Minimum = 0	≤2.65	≤13,326	≤19,184	≥135.29	≥103.65
Medium = 0.5	13.22	65,462	66,369	77.51	78.13
Maximum = 1	≥23.79	≥117,567	≥113,553	≤19.73	≤52.61
Points (p)	max. 16	max. 34	max. 22	max. 10	max. 18
Real farm result	21.7	114,400	75,800	142	49
Score	0.9	0.97	0.6	0	1
Weighted	0.9×16=14.4	0.97×34=32.98	0.6×22.5=13.5	0×9.5=0	1×18=18
Total score (points)	14.4	33	13.5	0	18

Sum of scoring points for economy in total: 78.9 points out of 100 possible points.

The DSI offers the possibility to portray relationships in different regions and between various farms. Assessment results vary between the project regions. In Figures 1 to 3, the actual data from each pilot farm in each region are presented as box plots in which the box represents the range for the middle 80% of the farms, the lower projection the lowest 10% (10% quantile) and the higher projection the highest 10% of values (90% quantile). The upper and lower filled circles are the maximum and minimum value, respectively. Figures 1 to 3 show an example each of data for an indicator for the economic, ecological and social aspects of sustainability, i.e. the farm income per milk produced on dairy level (Figure 1), the N-balances (Figure 2) and the number of free days (Figure 3), respectively. It is important to emphasize that the values in Figures 1, 2 and 3 are not representative for the countries as a whole but relate only to each farm and the average for the pilot farms in that region. Scores for the DSI are calculated by combining the scores for indicators after their weighting and can show the present situation (Figure 4) or the development of farms retrospectively (Figure 5).

Farm development

Whereas comparisons of single indicators, e.g. farm income, depend strongly on fluctuations of costs for resources or prices for products, a combination of indicators, such as with the DSI, shows much smaller effects of market fluctuations as other associated economic factors are taken into account, diluting the effect of any one indicator. The DSI calculated on a yearly basis provides an acceptable assessment of dairy farming systems, if the scores are used and underlined by the results of single indicators as in Figure 4.
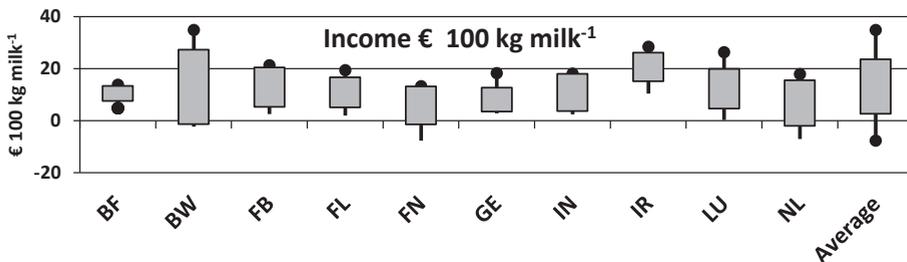
Figure 1. Example of an economic parameter of the Dairyman sustainability index – Income in € 100 kg ECM^{-1} (2010).
BF = Belgium Flanders (Number of pilot farms: n=13); BW = Belgium Wallonia (n=21); FB = France Brittany (n=11); FL = France Pays de la Loire (n=9); FN = France Nord Pas de Calais (n=7); GE = Germany Baden-Wuerttemberg (n=14); IR = Ireland (n=21); IN = UK Northern Ireland (n=9); LU = Luxembourg (n=6); NL = the Netherlands (n=16); Box plots are explained in the text.
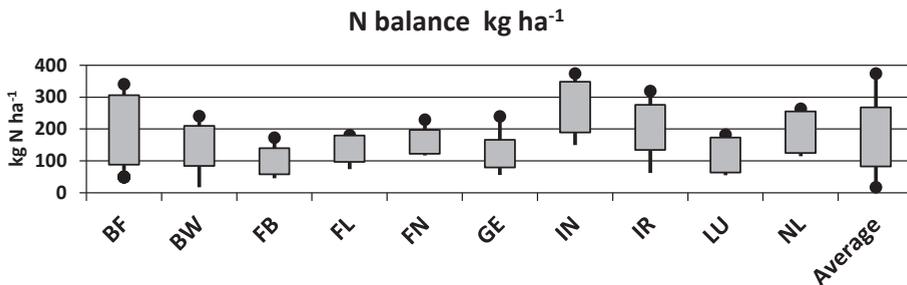
Figure 2. Example of an ecological parameter of the Dairyman sustainability index – Nitrogen balance in kg N ha^{-1} (2010).
BF = Belgium Flanders (Number of pilot farms: n=13); BW = Belgium Wallonia (n=21); FB = France Brittany (n=11); FL = France Pays de la Loire (n=9); FN = France Nord Pas de Calais (n=7); GE = Germany Baden-Wuerttemberg (n=14); IR = Ireland (n=21); IN = UK Northern Ireland (n=9); LU = Luxembourg (n=6); NL = the Netherlands (n=16); Box plots are explained in the text.
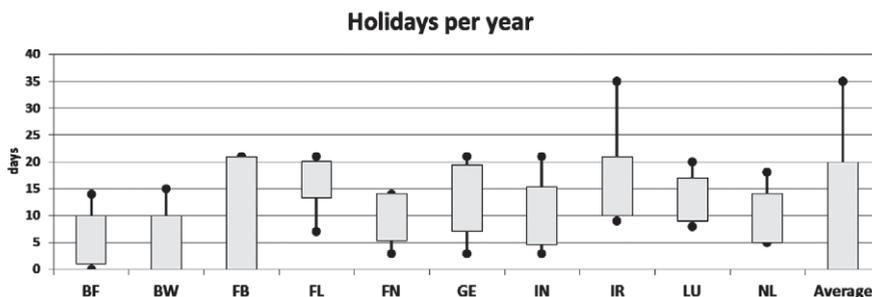
Figure 3. Example of a social parameter of the Dairyman sustainability index – Holidays per year (d) (2010).

BF = Belgium Flanders (Number of pilot farms: n=13); BW = Belgium Wallonia (n=21); FB = France Brittany (n=11); FL = France Pays de la Loire (n=9); FN = France Nord Pas de Calais (n=7); GE = Germany Baden-Wuerttemberg (n=14); IR = Ireland (n=21); IN = UK Northern Ireland (n=9); LU = Luxembourg (n=6); NL = the Netherlands (n=16); Box plots are explained in the text.

Indicator	Farm value	Scoring	Max. points	Points per farm	Scale points
Income € 100 kg milk[-1]	9.5	0.32	16	5.2	
Income € familiy worker[-1]	123,038	1	34	34	
Farm income € family labour unit[-1]	174,537	1	22	22	
Dependency on subsidies %	0.4	0.85	10	8.5	
Exposure to price fluctuations %	0.7	0.58	18	10.4	
Total economy		0.8	100	80.1	
N balance kg ha^{-1}	146	0.66	15	9.8	
N balance kg 1000 kg milk[-1]	20.1	0.55	11	6	
N efficiency %	22.6	0.13	13	1.7	
P balance kg ha^{-1}	20	0.01	11	0.1	
P balance kg 1000 kg milk[-1]	3	0	8	0	
P efficiency %	25.8	0	10	0	
Agroenvironmental payments € ha[-1]	74.4	0.61	10	6.1	
Greenhouse gas emissions 1000 kg CO_2-eq t milk[-1]	973	0.92	22	20.2	
Total ecology		0.44	100	43.9	
Education		0.75	20	15	
Working conditions		0.67	39	26.3	
Continousity of farm		1	14	14	
Social role and image		0.63	18	11.3	
Employment		0.6	9	5.4	
Total social aspects		0.72	100	71.9	

Figure 4. Detailed analysis of results of an exemplary German pilot farm with individual scoring for one year (bars in graph for 'scale points' are 'scoring' as proportion of the maximum).
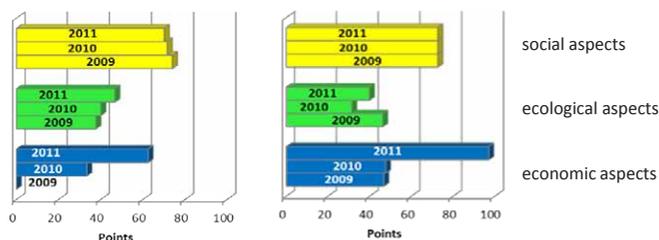
Figure 5. Development of two exemplary German Dairyman pilot farms during the project time assessed with the Dairyman sustainability index.

Opportunities and limits of Dairyman sustainability index

Several sustainability assessment systems have been developed over the last decade. Comparing, for example, the systems developed by Doluschitz and Hoffmann (2013) and by Schader *et al.* (2014) while they differ in a wide range of criteria, the overall target of both is similar, i.e. to assess sustainability as a whole and comprehensive item.

Weaknesses of the system

The DSI has not yet been completed. It was designed for the special situation in the DAIRYMAN project and relied on the data that were collected from the pilot farms within the scope of the project. For example, the assessment of biodiversity, soil quality and erosion, pesticide-use or data on animal welfare are missing. Moreover, the weighting was subjective and dependent on farm objectives. This was further complicated by the fact that different regions were involved, with differences in, for instance, legislative requirements or the main environmental issues. In addition the different indicators have been scored exclusively with information from the 127 pilot farms. These farmers have been selected as frontrunners in developing their farms. For this reason a calculation of the DSI on a pool of other dairy farms would need a new definition of scores, especially when the data used do not cover our reference year (2010).

Strengths of the Dairyman sustainability index

The discussion process in the project team was strongly stimulated by establishing the DSI. The process allowed a systematic investigation of production processes, and it stimulated the common discussions between project members and stakeholders, who were asked to evaluate and weight single indicators. Questions in the Group still remain such as whether the whole farm situation can be portrayed in this way and how missing data, e.g. biodiversity or efficiency of energy use, can be handled. An important advantage is that combined data are less sensitive to, for example, milk price fluctuations. The summarization of single indicators in combined indexes has offered new perspectives on sustainability and confirmed previous Dairyman results. It can be shown that highly autonomous farms (more extensive) are more resilient to milk price than more intensive farms (Boonen *et al.* 2013b; Grignard *et al.*, 2013). The data have also shown that farm size was not a main criterion for dairy farm sustainability.

While it seems to be unreasonable to express sustainability in one number, the German Agricultural Society (DLG) has adopted this approach based on more than twenty single indicators (DLG, 2015) for the sustainability of agriculture in Germany. Variation in the total DSI scores between years and regions will be used to offer a quick view on the consequence of changes made on farms to overall sustainability. This has potential for extension services and for farmers to monitor progress towards improving farm performance

Conclusion

The DSI index system was found to be well suited for monitoring the impact of management plans on the development of sustainability on farms or a group of farms in a defined region. Validation of the output of such a tool will always be problematic as there is no definitive quantifiable yardstick. However, in order to minimize bias exerted by specific single influences, we based the system on the arguments of several experts from different regions and the conclusions of an intensive discussion process within the Dairyman team. The development of indicators and their evaluation stimulated discussion among project participants resulting in better understanding of complex farming systems. Sometimes wide differences exist between regions, so these comparisons are of interest. Therefore differences and special situations between regions should be taken into account. However, as the reference scores for sustainability indicators were collected from pilot farms and hence unlikely to be representative of these regions, we have deliberately not presented regional comparisons of DSI as conclusions may be misleading and could be inappropriately used.

It was our common objective to develop a management tool which is suitable for all partners in order to evaluate dairy farm sustainability as a combination of single indicators. Moreover this tool should visualize individual farm development and show differences in milk production systems. The DSI is a first approach, exploiting the large data set of Dairyman. It is not the 'one and only' solution, but it can be a first step in the right direction to simplify and to understand complex systems like dairy farms and to evaluate and visualize the efforts of farmers. The farm situation can be described more comprehensively by factor aggregation instead of only single indicators. The DSI is a first step in scoring the farm success. It is not yet finished but it is worth further development.

Acknowledgements

References

Aarts H.F.M. (2013) Dairyman for a more efficient use of resources by dairy farms. *Grassland Science in Europe* 17, 753-755.

Arnould V., Reding R., Bormann J., Gengler N. and Soyeurt H. (2013) Review: milk composition as management tool of sustainability. *Biotechnologie Agronomie Societe et Environnement* 17, 613-621.

Bélanger V., Vanasse A., Parent D., Allard G. and Pellerin D. (2012) Development of agri-environmental indicators to assess dairy farm sustainability in Quebec, Eastern Canada. *Ecological indicators* 23, 421-430.

Bockstaller C., Girardin P. and van der Werf H.M.G. (1997) Use of agro-ecological indicators for the evaluation of farming systems. *European Journal of Agronomy* 7, 261-270.

Boonen J., Kohnen H., Hennaert S., Humphries J., Jilg T. and Oenema J. (2013a) *Data set of the Dairyman project. A practical manual to assess and improve farm performances*. Dairyman Report Nr. 2.

Boonen J., Kohnen H., Grignard A., Planchon V., Stilmant D., Hennart S. and Beguin E. (2013b) Analyse de la diversité de systèmes laitiers en Europe du Nord-Ouest sur base de leurs performances économiques et environnementales. *Carrefour des Productions Animales* 18, 1-14.

Briemle G., Elsaesser M., Jilg T., Mueller W. and Nussbaum H.J. (1996) Nachhaltige Gruenlandbewirtschaftung in Baden-Wuerttemberg. In: Linckh G., Sprich H., Flaig H. and Mohr H., (eds.) *Nachhaltige Land- und Forstwirtschaft – Expertisen*. Springer-Verlag, Heidelberg, Germany, pp. 215-263.

Breitschuh G., Eckert H. and Heissenhuber A. (2001) Ökonomische, ökologische und soziale Kriterien zur Beurteilung einer nachhaltigen Landwirtschaft. *KTBL-Schrift* 400, 7-21.

Breitschuh G., Eckert H., Matthes E. and Struempfel J. (2008) Kriteriensystem nachhaltige Landwirtschaft (KSNL). *KTBL-Schrift* 466.

Brundtland G.H. (1987) *Our common future*. World Commission on Environment and Development, 383, Oxford University Press, Oxford, UK.

Christen O., Hoevelmann L., Huelsbergen K.J., Packeiser M., Rimpau J. and Wagner B. (2009) *Nachhaltige landwirtschaftliche Produktion in der Wertschoepfungskette Lebensmittel*. Erich Schmidt Verlag, Berlin, Germany.

Coutey L. (2014) Development of a sustainability assessment methodology for European dairy farms using automatic milking systems and grazing. MSc thesis, ESA Angers, France.

De Mey K., D´Haene K., Marchand F., Meul M. and Lauwers L. (2011) Learning through stakeholder involvement in the implementation of MOTIFS: an integrated assessment model for sustainable farming in Flanders. *International Journal of Agricultural Sustainability* 9, 350-363.

DLG (2015) *Nachhaltigkeitsbericht*. Deutsche Landwirtschaftsgesellschaft, Frankfurt (a.M.), Germany.

Dubois D. (2002) Gedanken zur Forschung für eine nachhaltige Landwirtschaft. *Agrarforschung* 9, 188-193.

Doluschitz R. and Hoffmann C. (2013) Überblick und Einordnung von Bewertungssystemen zur Nachhaltigkeitsmessung in Landwirtschaft und Agribusiness. *KTBL-Schrift* 500, 34-47.

Elsaesser M., Herrmann K. and Jilg T. (2013) *The Dairyman-Sustainability-Index (DSI) as a possible tool for the evaluation of sustainability of dairy farms in Northwest-Europe*. Dairyman Report Nr. 3, Technical report LAZBW Aulendorf, 20 p.

Foray S., Beguin E., Ferrand M., Perrot C., Dolle J.B., Bechu T., Hennart S., Boonen J., Tirard S., Morin C. and Castellan E. (2013) Sustainability assessment of dairy farms in north-west Europe. *Rencontres autour des Recherches Ruminants* 20, 217-220.

Gaudino S., Goia I., Grignani C., Monaco S. and Sacco D. (2014) Assessing agro-environmental performance of dairy farms in northwest Italy based on aggregated results from indicators. *Journal of Environmental Management* 140, 120-134.

Gasparatos A., El-Haram M., and Horner M. (2008) A critical review of reductionist approaches for assessing the progress towards sustainability. *Environmental Impact Assessment Review* 28, 286-311.

Grignard A., Bailey J.S., Boonen J., Stilmant D. and Hennart S. (2013) The potential for improving the economic and environmental sustainability of dairy farming via farm diversification. *Grassland Science in Europe* 18, 96-98.

Grignard A., Bailey J.S., Bijttebier J., Boonen J., Castellan E., Tirard S., Lorinquer E., Jilg T., De Haan M., Mihailescu E., Stilmant D. and Hennart S. (2012) The farm management plan: a tool to support dairy farmers in their strategic decisions and to guide research centers in the definition of their research thematic. *Rencontres autour des Recherches Ruminants* 19, 269-272.

Girardin P. (2001) Französische Verfahren zur Bewertung von Umweltwirkungen landwirtschaftlicher Betriebe. In: *ITADA – Forum 'Nachhaltige Landwirtschaft'*, Sissach (CH), IfuL Müllheim, pp. 31-38.

Grenz J., Thalmann C., Staempfli A., Studer C. and Haeni F. (2009) RISE – a method for assessing the sustainability of agricultural production at farm level. *Rural Development News* 1, 5-9.

Guillaumin A., Hopquin J.P., Desvignes P. and Vinatier J.M. (2007) *Caractériser la participation des exploitations agricoles d'un territoire au développement durable*. Dictionnaire des indicateurs. Institut de l'Elevage, France.

Huelsbergen K.-J. (2003) *Entwicklung und Anwendung eines Bilanzierungsmodells zur Bewertung der Nachhaltigkeit landwirtschaflicher Systeme*. Shaker-Verlag, Aachen, Germany.

Kopfmueller J., Brandl V., Joerissen J., Paetau M., Banse G., Coenen R. and Grundwald A. (2001) *Nachhaltige Entwicklung integrativ betrachtet. Konstitutive Elemente, Regeln, Indikatoren*. Global zukunftsfaehige Entwicklung – Perspektiven für Deutschland, Bd. 1. Edition Sigma, Berlin, Germany.

Larochelle D.L., Parent D.P., Allard G.A. and Pellerin D.P. (2007) Dairy farm sustainability: The economic component indicators. *Journal of Animal Science* 85, Suppl. 1, 330-331.

Lebacq T., Baret P.V. and Stilmant D. (2012) Sustainability indicators for live-stock farming. A review. *Agronomy for Sustainable Development* 33(2), 311-327.

Marchand F., Debruyne L., Triste L., Gerrard C., Padel S. and Lauwers L. (2014) Key characteristics for tool choice in indicator based sustainability assessment at farm level. *Ecology and Society* 19(3), 46.

Meul M., Van Passel S., Nevens F., Dessein J., Rogge E., Mulier A. and Van Hauwermeiren A. (2008) MOTIFS: a monitoring tool for integrated farm sustainability. *Agronomy for Sustain. Development* 28, 321-332.

Schader C., Grenz J., Meier M.S. and Stolze M. (2014) Scope and precision of sustainability assessment approaches to food systems. *Ecology and Society* 19(3), 42.

Schroeder D. (2003) Nachhaltigkeitsindikatoren für die Landwirtschaft und EU-Agrarpolitik. *Schule und Beratung* 2, II-1 bis II-5.

Triste L., Marchand F., Debruyne L., Meul M. and Lauwers L. (2014) Reflection on the development process of a sustainability assessment tool: learning from a Flemish case. *Ecology and Society* 19(3), 47.

Vavra M. (1996) Sustainability of animal production systems: an ecological perspective. *Journal of Animal Science* 74, 1418-1423.

Von Wiren-Lehr S. (2001) Sustainability in agriculture – an evaluation of principal goal-oriented concepts to close the gap between theory and practice. *Agriculture, Ecosystems and Environment* 84, 115-129.

Zahm F., Viaux P., Vilain L., Girardin P. and Mouchet C. (2008) Assessing farm sustainability with the idea method – from the concept of agriculture sustainability to case studies on farms. *Sustainable Development* 16, 271-281.

Quantifying the environmental performance of individual dairy farms – the annual nutrient cycling assessment

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Abstract

Dairy farming is characterised by extensive fluxes of nitrogen (N) and phosphorus (P): large amounts of these elements cycle via feed, manure, soils and crops. Losses and exports in the form of milk, meat and manure are compensated for by purchased feeds and fertilisers. At this moment, farmers lack accurate insight into the impact of their management on the functioning of these cycles. We therefore developed the model ANCA, based on the results of the pilot farm network 'cows & opportunities' and the experimental farm 'De Marke'. The ANCA model quantifies the main performance indicator related to the nutrient cycles. The ANCA model is based on verifiable input data that can be collected with little effort, as the model is to be used by commercial farmers whilst being fraud resistant. The model outcomes help dairy farmers to demonstrate towards authorities and the dairy industry that they have produced their milk in accordance with sustainability standards. From 2015 onwards, ANCA will serve as a licence to produce for any dairy farm in the Netherlands with a manure surplus (about 70% of the number of farms).

Keywords: ANCA, nutrient cycling assessment, dairy farming, sustainability standards

Background and objectives

Dairy farms in the Netherlands are around 70% reliant on home-grown feed. In turn, feed crops receive nearby 65% of their nitrogen (N) and 100% of their phosphorus (P) requirements from the dung and urine excreted by the dairy herd (Aarts *et al.*, 2008). Therefore, dairy farming system are characterised by cycling of N and P. Losses from the cycles to the environment and exports in the form of milk, meat and manure are compensated for by purchasing feeds and fertilisers. A more efficient use of nutrients in home produced and purchased feeds and fertilisers reduces losses and the need for purchases and manure export, and it thus approaches even further the idea of cycling. Efficiency is partly governed by conditions that cannot be affected by the dairy farmer, such as weather conditions. However, management generally is the most dominant factor. Improving nutrient management starts with awareness of the actual farm performance. To find out where exactly the adjustment of management leads to improved use efficiency, the analysis must take due account of the extensive internal flows of home-produced forages and manures.

The flow model ANCA (annual nutrient cycle assessment) was constructed to provide indicator values for the utilisation of feeds and fertilisers, including manures, and for losses of harmful products. Reference and normative values are presented as comparisons. Reference values are the average values, as achieved by a group of farms under more or less similar conditions. Normative values are limits given by national legislation. With the farm specific values of the performance indicators, dairy farmers can justify their farm management towards authorities and the milk processing industry. Therefore, ANCA has to be fraud resistant, implying that input data have to be easily collectable and verifiable.

Construction of ANCA and generated indicators values

Since 1992, nutrient flows into, inside and from dairy farms have been extensively studied on the experimental farm De Marke and, since 1999, on commercial pilot farms in the project 'cows & opportunities' (Oenema, 2013; Verloop, 2013). Both projects are directed to a better understanding of processes involved and the identification of opportunities for improvement. Their results provided the basic information needed to design and test the ANCA model. Information from other sources was added. The attendant equations and their interrelationships, as implemented in the ANCA model, are reported by Schröder *et al.* (2014).

The ANCA model starts with the livestock component, in which the energy requirements of the dairy herd, including young stock, are estimated on the basis of normative values for each of the animal categories. The ration has to achieve these requirements. The composition of the ration is calculated from purchased feed (mainly concentrates) and consumed conserved forages, calculated from periodic inventories of changes of amounts of forages in stock, made by an accredited company. Fresh grass intake, by grazing, is estimated by subtracting consumed conserved feed (concentrates and forages) from energy requirements. The N- and P-consumption is estimated by chemical analyses of the components of the ration. From there, the excretion of N and P is calculated as feed intake minus the production of milk and meat.

Subsequently, ANCA models the soil-crop component. First, the production of home-grown feed is calculated by subtracting the amounts of purchased feed from the total feed consumption, taking due account of the pertinent normative losses associated with grazing, harvesting and conservation. These losses are specific for energy, N and P. Finally, the N and P yields are divided by the total input of N and P onto and into the soil (i.e. manures, fertilisers, deposition and estimated N-fixation by clover) to arrive at the use efficiency of the soil-crop subsystem. Inputs of mineral fertilisers are known from purchases. Inputs of slurry, urine and dung are calculated from total excretion, intensity of grazing, normative gaseous losses of N from housing and storages, and from exports of manure, if the latter is applicable. Ammonia losses from applied fertilisers and manures are calculated using standard emission factors depending on the method of application, the composition of the manure and the type of mineral fertiliser. Nitrate leaching is calculated from the N-soil surplus, with crop- and soil-type specific normative values for denitrification (Schröder *et al.*, 2014).

The major output of ANCA consists of the farm-specific indicator values as presented in Table 1. Values are presented for successive years, allowing the user to discern the development over time. The required input can almost entirely be derived from data that are digitally recorded and stored by suppliers, purchasers, authorities and other organisations related to the dairy farm. Therefore, most of the indicator values can be generated without requiring input from the farmers themselves, which makes the system easy to use and fraud resistant (Holster *et al.*, 2013).

The underlying normative parameters now apply to the 80% conventional specialised Dutch dairy farms only. The remaining 20% of farms are mixed with other agricultural activities or managed in an atypical way (e.g. by producing solid manures instead of the common slurries). ANCA will be improved to apply also to these farms.

How ANCA is implemented and utilised

Almost all organisations that are involved in Dutch dairy farming cooperate in the implementation of ANCA. A common structure is being developed for data collection and storage. Farm specific input data that are already recorded by suppliers, purchasers, authorities and other parties are sent to a central database, governed by the dairy industry. Calculated values for the performance indicators (Table 1)

Table 1. Indicators quantified by the annual nutrient cycle assessment model.

1	Excretion	N and P excretion of cattle (kg ha^{-1})
2	Use efficiency of feed by the herd	Conversion of N and P from feed into milk and meat (%)
3	Ammonia losses	Divided over housing, manure storage, grazing, manure spreading and mineral fertiliser application (kg ha^{-1})
4	Crop yields	Grassland and maize land: dry matter, N, and P (kg ha^{-1}) and energy (kVEM ha^{-1})
5	Use efficiency of fertilizers by the crops	Conversion of N and P from chemical fertilisers and organic manures into crop yield (%)
6	Soil surpluses	Amounts of N and P as inputs minus outputs at crop level (kg ha^{-1})
7	Nitrate leaching	NO_3 content of upper groundwater (mg l^{-1})
8	Losses of GHG	Emission of the gases methane (CH_4) and nitrous oxide (N_2O)
9	Farm surpluses	Amounts of N and P as inputs minus outputs at farm level (kg ha^{-1})
10	Use efficiency of farm as a whole	Conversion of N and P from purchased product (mainly feeds and fertilisers) into sold milk and animals (%)

will be stored in this database, checked and made available to the farmer, milk processing industry and authorities.

Milk processors want to provide buyers with a certificate showing that the processed milk has been produced in a sustainable way. This includes efforts to minimize harmful emissions and an efficient use of scarce resources. From the beginning of 2015 onwards, the use of ANCA is mandatory for all Dutch dairy farms that produce more manure than they are permitted to apply on their own fields; this is a licence to deliver milk to the processing industry. For the remaining 30% less intensive farms, the use of ANCA will probably become mandatory in the near future.

The ANCA model offers possibilities to differentiate generic environmental legislation to specific farm conditions and performances. National excretion standards, as prescribed by the Nitrates Directive, are based on average farm data. The ANCA model serves as a verifiable tool to calculate farm-specific N or P excretions. If its outcome is below the national standard, authorities accept the farm-specific outcome, allowing the farmer to reduce the amount of manure he is expected to export. The Dutch generic application standards for manures and fertilisers are based on average soil conditions and crop yields. The ANCA model can be used as a tool providing an underpinned differentiation between farms doing more justice to what crops need or the environment requires. In view of the above, a pilot has been set up investigating the possibilities for farm-specific fertilisation standards.

References

Aarts H.F.M., Daatselaar C.H.G. and Holshof G. (2008) *Bemesting, meststofbenutting en opbrengst van productiegrasland en snijmaïs op melkveebedrijven.* Rapport 208 Wageningen-UR Plant Research International, Wageningen, the Netherlands.

Holster H.C., de Haan M.H.A., Plomp M., Timmerman M. and Vrolijk M. (2013) *KringloopWijzer, goed geborgd!* Report 676 Wageningen-UR Livestock Research, Wageningen, the Netherlands.

Oenema J. (2013) *Transitions in nutrient management on commercial pilot farms in the Netherlands.* PhD thesis, Wageningen University, Wageningen, the Netherlands.

Schröder J.J., Sebek L.B., Reijs J.W., Oenema J., Goselink R.M.A., Conijn J.G. and de Boer J. (2014) *Rekenregels van de KringloopWijzer.* Rapport 553 Plant Research International, Wageningen, the Netherlands.

Verloop K. (2013) *Limits of effective nutrient management in dairy farming: analyses of experimental farm De Marke.* PhD thesis, Wageningen University, Wageningen, the Netherlands.

Eco-efficiency of grass-based dairy systems in Switzerland

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Abstract

Grassland covers 70% of the Swiss agricultural area, resulting in a large proportion of grass in the diet of Swiss dairy cows. In recent years, an increase in milk yield has been achieved, which has led to an increasing use of concentrates. The Federal Office for Agriculture has started to subsidize the inclusion of a large proportion of grass in the ration of ruminants. In two studies we assessed the environmental performance of dairy systems with different proportions of grass in the ration, by life cycle analysis according to SALCA. The comparison of the Swiss dairy system, with low use of concentrates, with systems in France, Germany and Italy showed that despite the lower milk yield and concentrate input, the Swiss system performed equally or better in all environmental impacts analysed, with the exception of land use. In the comparison of an intensive and a pasture-based dairy system within Switzerland the pasture herd performed equally or better for most environmental impacts with the exception of global warming, ozone formation and land occupation. This shows that despite the lower milk yield, grass-based systems can be eco-efficient.

Keywords: LCA, environmental performance, pasture-based milk production, Switzerland

Introduction

Grass is an important resource for Swiss agriculture. Over 70% of Swiss agricultural area are covered by grassland (BFS, 2014) and grass still constitutes the main ingredient in the diet of Swiss dairy cows. Depending on the type of farm, grass accounts for 62 to 85% of their total dry matter intake (Schmid and Lanz, 2013). In recent years, an acceleration in the trend towards higher milk yield and a higher proportion of concentrates in the ration of dairy cows was observed (Erdin and Giuliani, 2011). To alter this trend, the Swiss Federal Office for Agriculture (FOAG) started to promote grass based ruminant systems for a variety of reasons (preservation of landscape, efficient use of domestic resources, presumed advantages for the environment) and subsidizes a high proportion of grass in the diet of ruminants. Therefore, analyses of the eco-efficiency of grass based dairy systems are of high relevance.

Materials and methods

In two studies (Sutter *et al.*, 2013; Bystricky *et al.*, 2014) we assessed the environmental performance of dairy systems with different proportions of grass in the ration by life cycle assessment (LCA) according to SALCA (Nemecek *et al.*, 2010), developed by Agroscope for agricultural systems. The following environmental impacts were examined: non-renewable energy demand, global warming potential, ozone formation potential, demand for phosphorus and potassium resources, land competition, deforestation, eutrophication potential, acidification potential, terrestrial ecotoxicity potential, aquatic ecotoxicity potential and human toxicity potential, as well as water use (water stress index, taking account of water scarcity in the different countries) for the international comparison. System boundaries were set at the farm gate, and all results were expressed per kg milk produced. A rating system was used to assess the differences in individual results.

In the first study (Bystricky *et al.*, 2014), dairy systems in four countries with different proportions of grass in the ration were compared: a Swiss system with relatively low use of concentrates (877 kg cow[-1] a[-1])

and a moderate milk yield of 6,800 kg cow^{-1} a^{-1} and systems with higher use of concentrates (2,000-2,500 kg cow^{-1} a^{-1}) and higher milk yields (8,000-9,450 kg cow^{-1} a^{-1}) in Germany, France and Italy. For each country, a typical system was modelled based on literature data and expert opinion.

In the second study (Sutter *et al.*, 2013) two different milk production systems on an experimental farm were assessed: a pasture-based system with synchronized calving and barn feeding based on maize and grass silage and relatively high use of concentrates. Data were assessed directly on farm over three years.

Results and discussion

In the international comparison, Swiss milk production generally scored more favourably or was within the same range as milk production abroad (Figure 1). The energy required to produce 1 kg of milk increased with the milk yield per cow due to the purchase of extra feed and the use of energy carriers on the farm, both of which were higher in the foreign systems than in Switzerland. Similarly, the use of arable land was higher in the foreign systems. Deforestation for soybean cultivation was higher abroad, due to higher soybean meal consumption, as was water requirement and aquatic eutrophication by phosphorus.

Though the methane emissions from enteric fermentation per kg milk produced were higher for the Swiss system as a result of the lower milk yield per cow, there was no difference in total global warming potential. The higher CO_2 emissions through the higher energy demand and from land transformation from the use of soybeans outweighed the lower methane emissions of the foreign systems. In the comparison of the two Swiss systems, the pasture-based system showed lower impacts than the barn-feeding system for most categories analysed (Figure 2). A weakness of the pasture-based system was the higher methane emissions (+41%) and the higher land use (+50%) per kg milk produced. The most important disadvantages of the barn-feeding system were the higher deforestation, higher use of phosphorus and potassium resources and the higher ecotoxicity, mostly due to more maize and soybean meal in the ration.

An important reason for the good performance of the Swiss and Swiss pasture based systems could be the grassland in Switzerland producing high-quality fodder. Its utilisation for livestock production and the resultant reduced need for fodder concentrate in milk production bring benefits which may be emphasised. Also, other LCA-studies in regions with abundant precipitation and good grass growth, e.g. Arsenault *et al.* (2009) and O'Brien *et al.* (2012), indicate possible positive effects of grass-based dairy production on the environment.
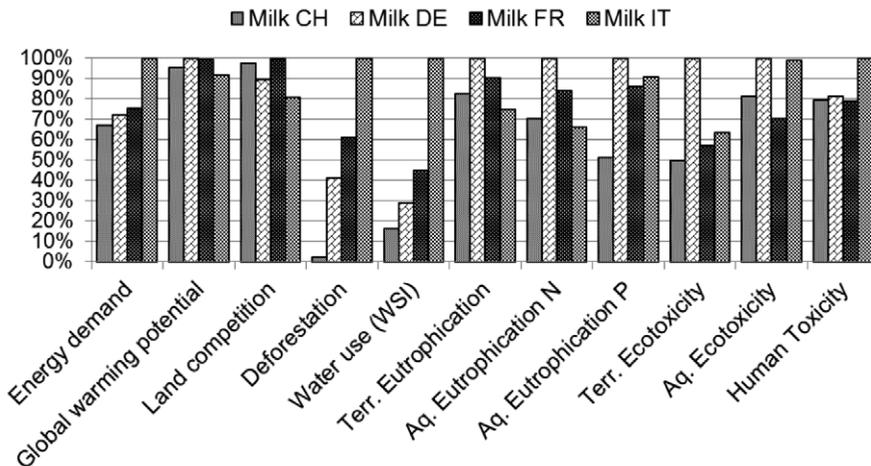
Figure 1. Relative environmental impacts per kg milk of the four systems analysed for selected impact categories. 100% = system with the highest impact.
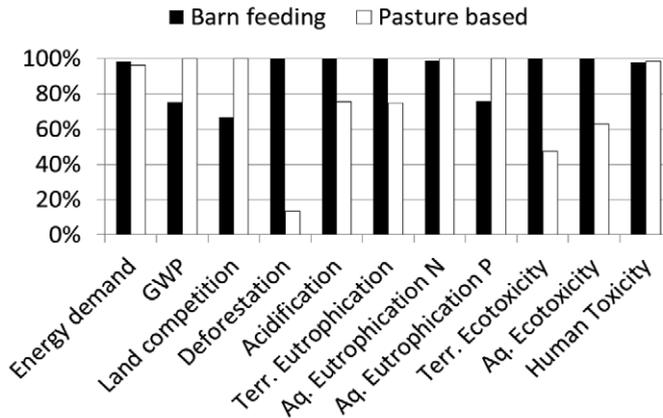
Figure 2. Relative environmental impacts of pasture-based milk compared to barn feeding for selected impact categories. 100% = system with the highest impact.

Conclusions

Despite the lower milk yield, the higher grass-based Swiss system performed equally or better for all environmental impacts analysed, compared to milk production systems in the neighbouring countries. Also within Switzerland, the environmental impacts of the pasture-based system were mostly lower than the impacts of the concentrate-based system. Grass-based milk production could make an important contribution to a more sustainable food production. To confirm these results, further studies with real farm data on a greater number of farms are needed.

References

Arsenault N., Tyedmers, P. and Fredeen, A. (2009) Comparing the environmental impacts of pasture-based and confinement-based dairy systems in Nova Scotia (Canada) using life cycle assessment. *International Journal of Agricultural Sustainability* 7(1), 19-41.

Bundesamt für Statistik BFS (2014) *Landwirtschaftliche Betriebsstrukturerhebung*. BFS, Neuchâtel, Switzerland.

Bystricky M., Alig M., Nemecek T. and Gaillard G. (2014). Ökobilanz ausgewählter Schweizer Landwirtschaftsprodukte im Vergleich zum Import. *Agroscope Science* 2, April 2014.

Erding D. and Giuliani S. (2011) Kraftfutterverbrauch der gemolkenen Kühe. *LMZ Aktuell* 5/2011: 4-6.

Nemecek T., Freiermuth Knuchel R., Alig M. and Gaillard G. (2010) The advantages of generic LCA tools for agriculture: examples SALCAcrop and SALCAfarm. In: Notarnicola B., Settanni E., Tassielli G. and Giungato P. (eds.) *Proceedings of the 7th int. conference on life cycle assessment in the agri-food sector*, Università degli studi di Bari Aldo Moro, Bari, Italy, pp. 433-438

O'Brien D., Shalloo L., Patton J., Buckley F., Grainger Ch. and Wallace M. (2012) A life cycle assessment of seasonal grass-based and confinement dairy farms. *Agricultural Systems* 107: 33-46

Schmid D. and Lanz S. (2013) Die Zusammensetzung der Futterration in der Milchviehhaltung der Schweiz. *Agrarforschung Schweiz* 4(4): 184-191.

Sutter M., Nemecek T. and Thomet P. (2013) Vergleich der Ökobilanzen von stall- und weidebasierter Milchproduktion. *Agrarforschung Schweiz* 4, 230-237.

Evaluation of dry matter yield of ryegrass varieties on Irish grassland farms

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Abstract

Increasing grass growth and utilisation on Irish dairy farms is shown to have a positive effect on farm profitability. This study was designed to establish the productivity of individual grass varieties under commercial conditions on-farms and compare this to their relative performance in recommended-list plot studies. The objective was to determine to what extent the plot tests are representative of on-farm performances. PastureBase Ireland (PBI) was established in Ireland as the national grassland database. 44 commercial dairy farms across different regions and soil types were selected to estimate grass yield using the PBI decision support tool. On these farms a number of grass varieties were sown as monocultures, each farm sowed the variety Tyrella (diploid 'D') (as a control), and a range of other varieties were also sown: AberGain (tetraploid 'T'), Kintyre (T), AberChoice (D), Twymax (T), Drumbo (D), and Astonenergy (T). The range between the highest and lowest yielding varieties in the first full growing season was 1.6 Mg dry matter (DM) ha^{-1}, but the level of variability of the on-farm recordings meant that no significant differences were recorded. When the relationship between varieties under simulated grazing plots and on-farm evaluations was examined it was found that every additional Mg of DM ha^{-1} in plot evaluations actually represented 0.64 Mg DM ha^{-1} on-farm.

Keywords: PastureBase Ireland, ryegrass, variety, evaluation, on-farm

Introduction

Grazed grass is the lowest cost feed available to ruminant production systems in Ireland (Finneran *et al.*, 2010). Irish producers enjoy a competitive advantage over counterparts who operate higher intensity confinement-based systems as a result of operating predominantly pasture-based production systems which are capable of sustaining high levels of physical and financial performance. There has been a surge in the level of interest in pasture-based systems in many temperate and subtropical regions of the world. This is a direct result of years of increased price volatility for both inputs and outputs (Dillon *et al.*, 2005). Central to the success of pastoral systems is the selection of the appropriate grass variety suited to localised environments.

The development of a comprehensive national grassland database such as PastureBaseIreland (PBI; http://www.pasturebase.teagasc.ie) has the potential to considerably increase grassland-related understanding. Generating phenotypic dry matter (DM) yield data for individual varieties on commercial farms is of particular interest in providing valuable information on individual variety performance across a range of different environments (e.g. soil type) and management systems. Routine on-farm evaluation of large numbers of grass varieties is prohibitively expensive and the internationally followed practice is to use small scale replicated field-plot trials under fixed protocols. The development of an on-farm DM yield phenotyping strategy would facilitate the quantification of variety DM yield across a much wider range of environmental conditions and management practices than can be achieved with traditional plot evaluation trials. Long-term experiments such as that described by Wilkins and Humphreys (2003) are necessary to evaluate varieties for persistence and stress tolerance. The objective of the present study was

to quantify the differences in grass DM yield of a number of recommended list grass varieties on a large number of Irish dairy farms and relate this performance to the yield of these varieties from plot studies within the recommended list evaluation scheme.

Materials and methods

The on-farm variety evaluation study began with the establishment of monocultures of several varieties on 44 different dairy farms. Each variety was sown at 34.5 kg ha^{-1} per paddock. The varieties used were: AberChoice (D), AberGain (T), Astonenergy (T), Drumbo (D), Kintyre (T), Twymax (T) and Tyrella (D). Where (D – diploid) and (T – tetraploid).

Tyrella was established on each of the 44 farms as a standard control variety. Varieties had been reseeded into the swards in either 2011 or 2012. DM yield was determined on 228 paddocks from 1 January 2013 until 10 December 2013. Grazing and silage yields (assessed prior to grazing or at the conservation harvest date) were measured separately and where necessary combined to generate total DM yield. The herbage mass of each paddock was estimated on a regular basis by visual assessment (calibrated by cutting and weighing) (O'Donovan *et al.*, 2002) or by measurement with rising plate meter (Castle, 1976). Growth rate of varieties was only calculated when the time between grass measurements did not exceed 16 days; all the farms in the study achieved this standard throughout the year. Farms were provided with guidelines to estimate DM percentage based on prevailing weather conditions.

Least squares means for the different varieties were estimated using mixed models; paddock nested within farm was included as a random effect with a compound symmetry covariance structure assumed among paddocks within farm. Only monocultures of known varieties were retained. The dependent variable was total paddock yield (kg DM ha^{-1}). Fixed effects considered in the mixed model were sowing rate, number of years since reseeding, and variety. An additional analysis replaced the variety (class effect) with the continuous fixed effect of DM yield from the 2013 recommended list plots for the same varieties used on farms; the regression coefficient from this analysis is the expected change in paddock DM yield (on the commercial farms) per unit change in DM yield from the recommended list plot studies.

Results and discussion

The range in DM yield between the highest and lowest yielding variety on-farm was 1.6 Mg DM ha^{-1}. For the on-farm trials (Figure 1), the Least squares means DM yield (Mg DM ha^{-1}) per variety were AberChoice (12.7; standard error (se) =0.878), AberGain (T) (13.6; se=0.858), Astonenergy (T) (11.97; se=0.540), Drumbo (12.4; se= 0.894), Kintyre (T) (13.5; se=0.590), Twymax (T) (12.6;
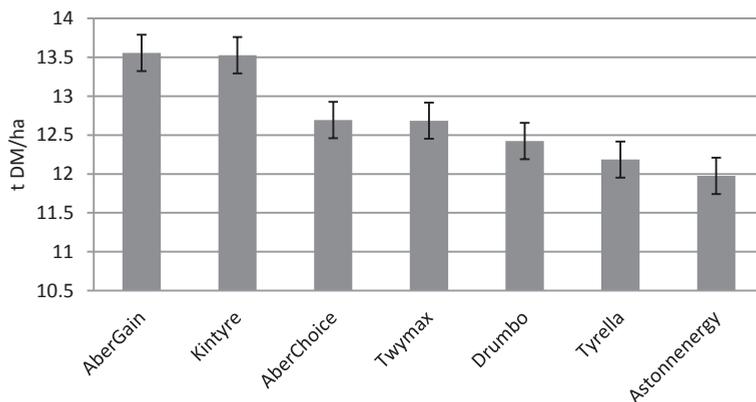
Figure 1. On-farm variety evaluation dry matter yield (Mg dry matter (DM) ha^{-1}) nationally in 2013

se=0.742) and Tyrella (12.2; se=0.412). The overall conversion factor between the farm generated yields and the RL plots simulated grazing yields was an increase of +0.67 Mg (se=0.71) on-farm per Mg yielded from the plots which is non-significant (P=0.35). Despite these overall mean differences in yield no significant yield differences were recorded between varieties on-farm. Due to the high level of between-farm variability and what is currently the first year of a longer term study, it was concluded that the relatively low sample size currently available is likely to have generated type II errors. Over time with increased farm measurements and an increase in cumulative years data it is expected that this will be overcome and with increased precision, it will be possible to better determine if these varieties perform significantly differently between farms and compared to plot based evaluations.

Conclusions

On-farm grass variety evaluation is potentially an alternative means determining the true agronomic potential of ryegrass varieties. The current network of on-farm grass growth monitoring through the PBI national grassland database is becoming an important means of knowledge transfer on grassland performance potential to ruminant farmers in Ireland. This study has quantified the initial levels of variability encountered by farmer-generated yield data and the need for very large data sets to screen out the inherent variability. The continuation of this study will determine at what level of data collection that varietal differences in performance can be isolated from the background noise. By making assessments across a wide range in such factors as topography, fertilizer use, stock management and farm specific micro-climates, it will be possible to determine how robust and relevant the variety performance ranking from limited plot evaluation trials are to the spectrum of farms that rely on this information to optimise grass performance.

References

Castle M.E. (1976) A simple disc instrument for estimating herbage yield. *Journal of the British Grassland Society* 31, 37-40.

Dillon P., Roche J.R., Shalloo L. and Horan B. (2005) Optimising financial return from grazing in temperate pastures. In: Murphy J.J. (ed.) *Utilization of grazed grass in temperate animal systems, Proceedings of a satellite workshop of the XXth International Grassland Congress,* Cork, Ireland. Wageningen Academic Publishers, Wageningen, the Netherlands, pp. 131-148.

Finneran E., Crossan P., Shaloo., Forristal D., O'Kiely P. and Wallace M. (2010) Simulation modelling of the costs of producing and utilising feeds for ruminants on Irish farms. *Journal of Farm Management* 14, 95-116.

O'Donovan M., Connolly J., Dillon P., Rath M. and Stakelum G. (2002) Visual assessment of herbage mass. *Irish Journal of Agricultural and Food Research* 41, 201-211.

Wilkins P.W. and Humphreys M.O. (2003) Progress in breeding perennial forage grasses for temperate agriculture. *Journal of Agricultural Science* 140, 129-150.

Benefits of × *Festulolium* varieties in European agriculture

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Abstract

Festulolium (× *Festulolium*) has been listed as a grass genus on the European list of Plant Varieties since 2004. DLF-Trifolium has made many trials with Festulolium varieties under different managements and climatic conditions across Europe. Results of these trials show the benefits of Festulolium and give a basis for recommendations on how to use varieties either as pure crops or in mixtures in various European regions.

Keywords: × *Festulolium*, yield, mixtures, feeding quality, persistence, variety

Introduction

Festulolium varieties have the potential to combine positive traits from both parental genera: fast development, high yield and high feeding quality from ryegrass (*Lolium*) and persistence and tolerance to stressful conditions (drought, frost) from fescue (*Festuca*). An extensive breeding programme in DLF-Trifolium has resulted in the successful registration of Festulolium varieties of various types. These varieties have been thoroughly tested under different managements and climatic conditions in field trials across Europe. The aim was to investigate yield, feeding quality, resistance to biotic and abiotic stress conditions and its utilization in grass-legume mixtures. All results were compared with top ryegrass or fescue varieties. This paper presents some of these results.

Materials and methods

Performance of Festulolium varieties under oceanic conditions was tested in two field trials established in autumn 2012 in Moerstraten, the Netherlands. Each trial included 18 entries in two replicates, plot size 10 m^2. Trials were harvested with a Haldrup F-55 in 2013 (4 cuts) and 2014 (5 cuts). Dry matter yield was calculated from moisture measured by a spectrometer (Corona Plus 45 NIR) on the machine. All yield results and scores were calculated by analysis of variance (ANOVA) using SAS/STAT® Software.

A long-term mixture trial was established in a flooded area near Odra river in Hladke Zivotice, Czech Republic in 1988. Mixtures were tested in plots of 100 m^2 (10×10 m) in two replicates. The trial was harvested with a Hege 212, with 3 cuts per year in each of 7 consecutive years. Composition of the original mixture was: *Festuca pratensis* 33%, *Poa palustris* 1%, *Dactylis glomerata* 9%, *Festuca rubra* 12%, *Agrostis gigantea* 3%, *Poa pratensis* 5%, *Lolium perenne* 17% and *Phleum pratense* 20%. In the tested mixture *F. pratensis* was replaced by the tall fescue-type Festulolium cv. Felina.

Festulolium krasanii cv. Fojtan was tested in comparison with *F. arundinacea* cv. Jordane and a mixture of two diploid and two tetraploid varieties of *L. perenne* at four different locations in Denmark in 2008 and 2009. Trials were cut 4-5 times per year and samples from each cut and location were analysed by near-infrared spectrometry.

Results and discussion

Ryegrass-type Festulolium cv. Perseus and two breeding lines were compared with *L. perenne*, *Lolium multiflorum* and *L. hybridum* in the Netherlands (Figure 1). The highest yields were harvested for all varieties in the first two cuts in the first harvest year. The yield decreased from the first to the second
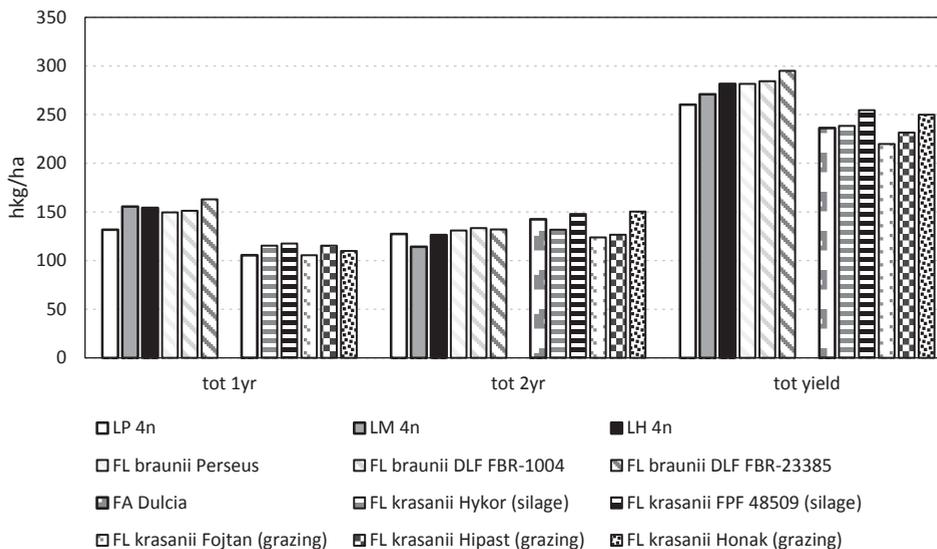
Figure 1. Yield comparison of Festulolium (FL) varieties, and original ryegrass (LP, LM, LH) and tall fescue (FA) species.

harvest year for *L. multiflorum* and, to a less extent, for *L. hybridum*, whereas the yield of *L. perenne* was similar in both harvest years. All Festulolium varieties of the ryegrass type yielded similar to *L. multiflorum* in the first harvest year and at the level of *L. perenne* in the second year. The total yield of these Festulolium varieties exceeded *L. hybridum* by 1-5%, *L. multiflorum* by 5-9%, and *L. perenne* by 9-13%.

Tall fescue-type Festulolium varieties Hykor, Fojtan, Honak, Hipast and two breeding lines were compared with *F. arundinacea* cv. Dulcia in the Netherlands (Figure 1). Compared with the ryegrass trial, the yield was distributed more evenly over the growing season and yields were higher in the second year than in the first year. The individual Festulolium varieties of the tall fescue type reached dry matter yields that were 95% to 108% that of cv. Dulcia.

In a standard mixture for permanent meadows in the Czech Republic, replacement of *F. pratensis* (33% in the mixture) by *Festulolium krasanii* cv. Felina resulted in an increase in hay yield of 1-2 Mg per year from from the 2nd to the 7th harvest year (Figure 2).
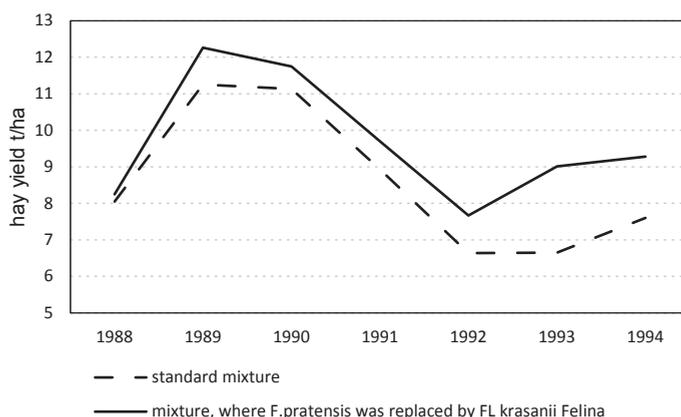
Figure 2. Replacing meadow fescue with Festulolium of tall fescue type in permanent mixture.

Table 1. Feeding quality of *Festulolium krasanii* (Fk) variety Fojtan compared to *Lolium perenne* (Lp) and *Festuca arundinacea* (Fa) (Nielsen K.A., 2008, 2009).[1]

	% crude protein in DM	% sugar in DM	% NDF in DM	D-NDF	DOM	NELp20 MJ kg^{-1} DM
1st year (2008)						
Lp	12.9	15.7	45.4	67.1	74.6	6.28
Fa Jordane	14.0	10.4	50.6	64.3	71.0	6.00
Fk Fojtan	14.5	10.5	49.6	66.5	72.6	6.16
2nd year (2009)						
Lp	15.6	16.2	42.0	71.6	78.2	6.31
Fa Jordane	15.5	7.8	51.7	64.1	71.4	5.76
Fk Fojtan	15.9	7.5	51.3	65.7	72.5	5.87

[1] DM = dry matter; NDF = neutral detergent fibre; D-NDF = digestible NDF; DOM = digestible organic matter.

Trials in Denmark (Table 1) showed that the tall fescue-type Festulolium variety Fojtan has a digestibility of neutral detergent fibre and organic matter between that of its two parent components, tall fescue and perennial ryegrass. Likewise, the energy concentration NEL20, MJ kg^{-1} dry matter, is higher than pure tall fescue but lower than perennial ryegrass.

Conclusions

Festulolium braunii = L. multiflorum × F. pratensis (4×) is currently the Festulolium species with the most registered varieties. Morphology, yield and feed quality is similar to Italian ryegrass (*L. multiflorum*) but persistence, winter hardiness and drought tolerance is better. Varieties from this group are suited for silage production as pure crop or in mixture with other grasses, clover or alfalfa.

Festulolium loliaceum = L. perenne × F. pratensis (2×, 4×) is similar to perennial ryegrass (*L. perenne*) or hybrid ryegrass (*L. boucheanum*). These types can replace perennial or hybrid ryegrass in different mixtures, resulting in higher yield and improved persistence.

Festulolium krasanii = L. multiflorum × F. arundinacea backcrossing into *F. arundinacea* (6×) varieties are similar to tall fescue (*F. arundinacea*) as far as yield and persistency is concerned, but late varieties like Fojtan have a better feeding quality.

References

Nielsen K.A. (2008) Græsmarksplanter, sortsforsøg. In: Pedersen J.B. (ed.) *Oversigt over Landsforsøgene 2008*, Dansk Landbrugsrådgivning, pp. 330-332.

Nielsen K.A. (2009) Græsmarksplanter, sortsforsøg. In: Pedersen J.B (ed.) *Oversigt over Landsforsøgene 2009*, Dansk Landbrugsrådgivning, pp. 335-337.

Estimation of methane emissions by dairy cows feeding on diets based on Italian ryegrass or legume silages in two grazing seasons

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Abstract

The dairy sector plays an important role in the emission of greenhouse gases (GHG). Dairy cows are a significant contributor to total livestock GHG emissions, being the main sources carbon loss from land use change, methane emissions from enteric fermentation, soil nitrous oxide emissions and manure management. For this reason, the objective of this study was to estimate methane emissions using the IPCC model in lactating Holstein cows with feeding rations based on Italian ryegrass silage grown conventionally or fava bean-rapeseed silage fertilized with manure and slurry in two grazing seasons, and to compare the results obtained with other models tested. Two trials were carried out in spring and autumn 2013, each with ten lactating Holstein cows. Both trials were performed using a crossover design. Considering the IPCC Tier 2 as an international reference to estimate enteric methane emissions, the estimations were similar considering both seasons and diets. When the IPCC predictions were compared to other models, the results showed the same variation of methane production, but with higher values for Mills and Yates models and lower estimations based on Ellis equations.

Keywords: methane emission estimation, organic fertilization, Italian ryegrass, fava bean-rapeseed

Introduction

The dairy sector plays a major role in livestock production, however, it is a source of greenhouse gases (GHGs) and contributes 3% of the total anthropogenic emissions. In addition, the feedstuffs industry accounts about 10% of emissions, and storage of animal manure can reach up to 9% (Gerber *et al.*, 2010). The highest percentage of methane emissions in livestock is due to enteric fermentation in ruminants, which has increased by about 11% from 2001 to 2011 (Tubiello *et al.*, 2014). Different equations have been proposed to estimate the production of GHGs that are based on the type of feed, the amount of dry matter intake (Kebreab *et al.*, 2008) and also in the animal itself (Yan *et al.*, 2002). The objective of this study was to estimate methane emissions using the IPCC model in lactating Holstein cows with feeding rations based on Italian ryegrass silage grown conventionally (conventional) or fava bean-rapeseed silage fertilized with manure and slurry (organic) in two grazing seasons, and to compare the results with other models tested.

Materials and methods

Two trials, each with ten lactating Holstein cows, were conducted during the spring and autumn of 2013 in the SERIDA experimental farm. The animals, at the beginning of the trials, were 100 ± 8.2 days in milk (average $\pm$ standard error), 2.3 ± 0.22 lactations, 614 ± 16.5 kg live weight and a production of 28.0 ± 1.26 l d^{-1}. The animals were randomly divided into 2 groups and in both trials were fed with two total mixed rations (TMR) using a crossover design. The details of all TMR are shown in Table 1. The TMRs were supplemented by grazing in meadows for 12 hours daily in spring and 8 hours in autumn. The TMR intakes of each cow were daily and automatically recorded by an electric weighing system integrated to the scale pens using a computerized system. The grass intake at grazing was estimated by the animal performance method suggested by Macoon *et al.* (2003).

Table 1. Composition and nutritional value of the total mixed rations in spring and autumn.

	Spring		Autumn	
	Organic	Conventional	Organic	Conventional
Ingredient (%dry matter)				
Maize silage	32.56	35.30	-	-
Ryegrass silage	-	36.85	-	32.38
Fava bean-rapeseed silage	43.53	-	37.92	-
Alfalfa hay	-	-	23.35	25.44
Cereal straw	15.62	16.16	6.58	7.16
Concentrate	8.29	11.69	32.15	35.02
Nutritional value (g kg^{-1} dry matter)				
Dry matter	387.9	329.5	408.1	416.0
Crude protein	103.8	971.0	133.3	127.4

The IPCC Tier 2 equation (IPCC, 2006) was used as reference model to estimate the methane production for each cow. This model incorporates CH_4 conversion factors for milking cows, animal production and gross energy intake without considering the forage proportion in the diet. The results of the IPCC methane emission estimations, as MJ d^{-1}, were compared using a paired t-test with different models based on many factors such as dry matter intake (DMI) and forage proportion (Yates *et al.,* 2000; Mills *et al.,* 2003 and Ellis *et al.,* 2007). The dry matter intake, the forage proportion and CH_4 emissions were analysed using a lineal model considering the type of TMR and season as main factors (R Core team, 2014).

Results and discussion

Based on the IPCC model as reference, the enteric methane emissions did not show any significant difference, either for seasons or for the TMR used (Table 2). Nevertheless, according to the results obtained the ryegrass diet (conventional) presented higher methane emissions than the fava bean-rapeseed diet (organic) (28.71 vs 22.56 MJ d^{-1}, respectively, *P*>0.05). In comparison with IPCC prediction, both Ellis' models underestimated the CH_4 emissions (24.80 vs 22.14 and 19.36 MJ d^{-1} for IPCC; Ellis based on DMI and Ellis based on forage proportion, respectively, *P*<0.001). However, when the Mills' models based on DMI and forage proportion were used, the CH_4 emissions estimated were

Table 2. Methane emissions estimated as MJ d^{-1} according to season (S) and type of total mixed ration (TMR).

	Season		TMR		RSD	Significance[1]		
	Spring	Autumn	Conventional	Organic		S	TMR	S × TMR
IPCC	24.25	25.33	28.71	22.56	10.240	NS	NS	NS
Mills 1[2]	27.76	28.27	29.38	25.65	8.742	NS	NS	NS
Mills 2[3]	29.50	29.43	31.22	27.72	9.165	NS	NS	NS
Ellis 1[4]	21.55	22.73	23.58	20.70	7.688	NS	NS	NS
Ellis 2[5]	20.39	18.34	19.32	19.14	1.460	***	NS	NS
Yates[6]	33.06	31.38	34.30	30.14	11.830	NS	NS	NS

[1] Statistical significance *** *P*<0.001. RSD = relative standard deviation. NS = not significant.

[2] CH_4 (MJ d^{-1}) = 5.93 + 0.920 dry matter intake (DMI) (kg d^{-1}).

[3] CH_4 (MJ d^{-1}) = 1.06 + 10.27 forage proportion + 0.87 DMI (kg d^{-1}).

[4] CH_4 (MJ d^{-1}) = 3.23 + 0.809 DMI (kg d^{-1}).

[5] CH_4 (MJ d^{-1}) = 8.56 + 0.139 forage proportion.

[6] CH_4 (MJ d^{-1}) = 1.36 + 1.21 DMI (kg d^{-1}) − 0.825 × g concentrate + 12.8 × g neutral detergent fibre.

higher than the estimated values by IPCC equations (24.80 vs 27.51 and 29.47 MJ d^{-1} for IPCC, Mills based on DMI and Mills based on forage proportion, respectively, $P<0.001$). In the same vein, the Yates' model, including both DMI and forage proportion estimated higher values than IPCC model (24.80 vs 32.22 MJ d^{-1} for IPCC and Yates models, respectively, $P<0.001$).

It should be noted that, whatever the model used, there were no significant differences between TMR for enteric methane, although the values were higher with the diet based on ryegrass silage. No differences were observed between seasons, except in the Ellis' model that includes the forage proportion ($P<0.001$), due to the higher forage proportion in spring than autumn (85 vs 71% of forage proportion, respectively).

Conclusions

If the IPCC model is considered as an international reference to estimate enteric methane emissions, these estimations were similar considering both seasons and diets. In comparison with the IPCC predictions, the other models showed the same variation of methane production, but with higher values for Mills and Yates models and lower estimations based on Ellis equations.

Acknowledgements

References

Ellis J.L., Kebreab E., Odongo N.E., McBride B.W., Okine E.K. and France J. (2007) Prediction of methane production from dairy and beef cattle. *Journal of Dairy Science* 90, 3456-3467.

Gerber P., Vellinga T., Opio C., Henderson B. and Steinfeld H. (2010) *Greenhouse gas emissions from the dairy sector – a life cycle assessment.* Food and Agriculture Organisation of the United Nations, Animal Production and Health Division, Rome, Italy.

IPCC (2006) *IPCC guidelines for national greenhouse gas inventories. Vol. 4: Agricultural, forestry and other land use*. IGES, Kanaggawa, Japan.

Kebreab E., Johnson K.A., Archibeque S.L., Pape D. and Wirth T. (2008) Model for estimating enteric methane from United States dairy and feedlot cattle. *Journal of Animal Science* 86, 2738-2748.

Macoon B., Sollenberger L.E., Moore J.E., Staples C.R., Fike J.H. and Portier K.M. (2003) Comparison of three techniques for estimating the forage intake of lactating dairy cows on pasture. *Journal of Animal Science* 81, 2357-2366.

Mills J.A.N., Kebreab E., Yates C.M., Crompton L.A., Cammell S.B., Dhanoa M.S., Agnew R.E. and France J. (2003) Alternative approaches to predicting methane emissions from dairy cows. *Journal of Animal Science* 81, 3141-3150.

R Core Team (2014) *R: A language and environment for statistical computing*. R foundation for Statistical Computing, Vienna, Austria.

Tubiello F.N., Salvatore M., Cóndor Golec R.D., Ferrara A., Rossi S., Biancalani R., Federici S., Jacobs H. and Flammini A. (2014) *Agriculture, forestry and other land use emissions by sources and removals by sinks*. ESS Working Paper No. 2, Rome, Italy.

Yan T., Agnew R.E. and Gordon F.J. (2002) The combined effects of animal species (sheep versus cattle) and level of feeding on digestible and metabolisable energy concentrations in grass silage based diets of cattle. *Animal Science* 75, 141-151.

Yates C.M., Cammel S.B., France J. and Beever D.E. (2000) Prediction of methane emissions from dairy cows using multiple regression analysis. *Proceedings of the British Society of Animal Science* 2000, 94.

Trace elements supply and requirements in Dutch dairy farming

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Abstract

Well-supplied trace elements are necessary for production and animal health. The Water Framework Directive requires a reduction of the output of heavy metals. The tool 'Spoorwijzer' (Trace element guide) is used to calculate the supply of Zn, Se, Cu and Co of different groups of dairy cattle. Zn and Cu are necessary for animal health. Zn is amply supplied on most conventional Dutch dairy farms. Young stock, dry cows and end-lactation cows receive little or no concentrate feed, causing low supply of Se, Cu or Co. Using tailor-made mineral mixtures on a number of farms did not have a negative effect on production and animal health. The surplus per ha on these farms was decreased by 52% for Zn, 28% for Cu, 22% for Se and 56% for Co. It is concluded that Zn is not necessary in mineral mixtures on Dutch conventional dairy farms. Considerable cost reduction is possible by using tailor-made mineral mixtures. In conclusion, the studies found that using tailor-made mineral mixtures is positive for high-output dairy farming and eco-efficient farming.

Keywords: animal health, cattle feeding, surplus per ha, trace elements

Introduction

Intensive dairy farming with high production of grassland and fodder crops requires sufficient nutrients for crop growth. Crop-fertilisation with trace elements, e.g. zinc (Zn), selenium (Se), copper (Cu) and cobalt (Co), is often not given sufficient attention. Dairy cattle need sufficient trace elements for good production animal health. Supplementing the ration with trace elements takes place by feeding compounds and mineral mixtures. Shortage and excess is detrimental for production and animal health. Trace elements, not utilised for growth of milk production are secreted in the manure, which is applied to the field. Römkens and Rietra (2008) showed that the Cu and Zn content in the cattle slurry in 2008 was significantly higher than in 1996. Cu and Zn are not only essential nutrients but also heavy metals. The Water Framework Directive requires a reduction of surplus heavy metals. Optimising trace element balances is necessary for high-output dairy farming and eco-efficient farming.

In a number of projects the trace element supply of dairy cattle and young stock with Zn, Se, Cu and Co is calculated. In the province Noord Brabant two pilots were carried out: pilot 'De Beerze' with 8 dairy farms (Den Boer *et al.*, 2007) and pilot 'Hooge Raam' with 7 dairy farms (Den Boer en Van der Draai, 2008). Both studies were commissioned by ZLTO (Southern Agriculture and Horticulture Organization). The province of Drenthe commissioned two province-wide studies on trace element supply: on 25 dairy farms (Den Boer en Van der Draai, 2007) and 8 dairy farms (Den Boer *et al.*, 2011) respectively. The first three projects were aimed to ascertain the problem, create awareness among the dairy farmers, feed suppliers and veterinarians and resolve bottlenecks in reducing the supplementation of trace elements. Recommendations were drawn up to improve trace element balances. Several participants were hesitant to reduce the trace element supply because of animal health issues. To convince these participants that feeding in accordance with recommendations is possible, while also maintaining animal health and production, tailor-made mineral mixtures were fed on 8 farms during one year (grazing period and housing period). The health status was verified through the analysis of the trace element content of blood samples.

Material and methods

The supply of dairy cattle with trace elements Zn, Se, Cu and Co during lactation and dry period and of young stock is calculated using NMI's 'Spoorwijzer' (Trace element guide), a software tool commissioned by the Dutch Dairy Board. The recommended levels of trace elements are based on the Dutch COMV (2005). The calculations are carried out for different groups: calves (0.5-1 year), young heifers (1-2 years),

dry cows, new-lactating, mid-lactating, and end-lactating cows. Ration compositions were provided by the participating farmers. The trace element content in silage (grass and maize) was analysed. The trace element composition of the compounds and mineral mixtures were provided by the suppliers.

On 5 dairy farms using tailor-made mineral mixtures, blood samples were analysed at the beginning and halfway of the grazing period and at the beginning and end of the housing period. On each sampling date per farm 12 blood samples (two samples per aforementioned group) were analysed giving in total 240 blood samples. The analyses were carried out by GD Animal Health. Per trace element a one-way Anova was conducted to compare the sampling dates and a post hoc Tukey HSD test was used to differentiate between the sampling dates.

The reduction of the surplus of trace elements per ha is evaluated. The output of trace elements through milk and meat is deducted from the cattle uptake (uptake year^{-1} × stocking density). Trace element deposition and manure content are totalled into the supply per ha. The surplus is calculated as the supply minus the crop uptake per ha.

Results and discussion

Zinc

In all four projects the studies showed ample Zn supply, often more than twice the recommended level (ranging from 1.5 in lactating cows to 5 times in dry cows). Calculations on the supply showed that addition of Zn to mineral mixtures was not necessary, with the exception of an organic dairy farm growing their own concentrates. Dutch mineral mixtures often contain 1000-7,500 mg Zn kg^{-1} dry matter (DM). It is highly desirable that producers decide not to add any or only small amounts of Zn to mineral mixtures (<500 mg kg^{-1} dm).

Selenium

Se (and Zn, Cu, Co) is normally added to compounds. Studies showed ample Se supply at the beginning of the experimental period, and where Se fertilisation was carried out and Se-containing mineral mixtures are fed, the combination was not necessary. On farms without Se fertilisation, supplementation with a small amount of Se-containing mineral mixture is necessary for animals not receiving compounds (young heifers, dry cows, end-of-lactation cows. The Se content of mineral mixtures was adapted to the group requirements.

Copper

The Cu supply varied strongly between farms. On farms where animals were not fed mineral mixtures, a deficiency occurred with young stock, end-lactation cows and dry cows. Supplementation of dry cows and young stock with a Cu-containing mineral mixture is almost always necessary. Supplementation of cows at end of lactation is not necessary because of mobilisation of the body reserve which can be replenished when compounds are being fed.

Cobalt

The Co supply varied strongly, from deficiency to an excess of 10 times recommended level. For young stock, end-lactation cows and dry cows not receiving compounds, supplementation with an appropriate Co-containing mineral mixture was necessary.

Health status

The 8 dairy farms with tailor-made mineral mixtures were supervised by the farmers' veterinarian. Feeding tailor-made mineral mixtures did not lead to lower production, extra hoof disorders or mastitis. Table 1 shows the average blood levels of Zn, Se and Cu for the four sampling periods (Co in blood is an unreliable health status indicator). Table 2 shows the effect of feeding tailor made mineral mixtures on the surplus per ha.

Table 1. Average Zn and Cu (µmol l^{-1}) and Se content (GSH-Px in U g^{-1} Hb) in blood and corresponding recommended levels of 5 dairy farms on 4 moments of measurement.[1]

Trace element	Recommended level	Grazing period		Housing period	
		May 2010	August 2010	November 2010	April 2011
Zinc	12-23	14.9 ab	14.3 a	15.2 ab	15.9 b
Copper	7.5-18	11.4 a	11.7 a	11.4 a	11.6 a
Selenium	120-600	387 b	307 a	293 a	311 a

[1] Per trace element, means with same letter are not significant different from each other at P=0.05.

Table 2. Calculated surplus of Zn, Cu, Se and Co (g ha^{-1} year^{-1}) of 8 dairy farms in Drenthe without and with feeding tailor made mineral mixtures and calculated decrease (%).

Trace element	Without tailor made mineral mixture	With tailor made mineral mixture	Calculated decrease %
Zinc	511	247	52
Copper	245	177	28
Selenium	5.4	4.2	22
Cobalt	8.4	3.7	56

Feeding of mineral mixtures without Zn did not result in lower blood levels. At the start of the project 8 sampled animals had Zn levels below and 2 above the recommended level. At the end of the project only one animal was below the recommended level. The Cu blood content remained stable during the entire period. At the beginning three sampled animals were above and one animal below the recommended level. At the end all animals were within the recommended level. The Se-content in blood dropped during the grazing period; however, they were well within the recommended levels. During the housing period more compounds are fed, increasing the Se-content slightly compared to end of the grazing period.

Using tailor-made mineral mixtures without Zn reduced the surplus (g ha^{-1}) by more than 50%. Adjusting the Cu, Se and Co to the requirements reduces the surplus by 28, 22 and 56% respectively. Five dairy farms used copper sulphate in the footbaths, which is not included in the results of Table 2. If included in the calculations the surplus increases two-fold.

On conventional dairy farms feeding according to recommended levels the cost of mineral mixtures is about €500 year^{-1} (80 cattle; cost mineral mixture €50 per 100 kg). On dairy farms with a high supply of mineral mixtures the cost amounts to about €2000 year^{-1}.

Conclusions

The studies found that the optimization of trace element balances is positive and of importance for high-output dairy farming and eco-efficient farming.

References

COMV (2005) *Handleiding mineralenvoorziening rundvee, schapen, geiten*. Centraal Veevoederbureau, 6[e] druk, 228 pp.

Den Boer D.J., Moolenaar S.W. en Bakker R.F. (2007) *Verminderen aanvoer zware metalen via het rantsoen met de Spoorwijzer*. NMI-rapport 1216.N.06, 70 pp.

Den Boer D.J. en Van der Draai H. (2007) *Verminderen aanvoer spoorelementen (zware metalen) op melkveebedrijven*. NMI-rapport 1237.N.06, 96 pp.

Den Boer D.J. en Van der Draai H. (2008) *Verminderen aanvoer zware metalen via de voeding op melkveebedrijven in de Hooge Raam*. NMI-rapport 1294.N.08, 59 pp.

Den Boer D.J., De Haas M.J.G. en Van der Draai H. (2011) *Verbeteren voorziening spoorelementen op melkveebedrijven in Drenthe*. NNI-rapport 1314.502, 80 pp.

Römkens P.F.A.M. and Rietra R.P.J.J. (2008) *Zware metalen en nutriënten in dierlijke mest*. Alterra-rapport 1729, 37 pp.

No trade-off between root biomass and aboveground production in *Lolium perenne*

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Abstract

Grasses have dense rooting systems, but nutrient uptake and drought resistance can be increased, and N-leaching reduced, if rooting is further improved. Improved rooting of grasses in agricultural systems should, however, not be a trade-off with aboveground biomass allocation and yield. In two field experiments on sandy soil in the Netherlands, we measured the variation in grass yield of sixteen varieties of *Lolium perenne* (Lp) during three years, and the root dry matter (RDM) at the end of the experiments. The Lp-varieties differed in aboveground and genetic characteristics such as productivity (classified according to the measured yields in the actual experiments), grass cover and ploidy. Results of the experiments show that RDM of perennial ryegrass differed significantly between varieties, and that these differences were not linked to grass yield. Our results indicate that it is possible to select perennial ryegrass varieties that combine high aboveground productivity with high RDM. Considering challenges in the areas of climate change, pollution and soil degradation, high yielding grass varieties with improved root systems could contribute to an efficient use of nutrients and water, and to erosion control, soil improvement and carbon sequestration.

Keywords: root mass, grass yield, *Lolium perenne* varieties

Introduction

Grasses have dense rooting systems, compared with other agricultural crops, but there are indications that further increased rooting can enable additional increased uptake of nutrients, improve drought resistance and reduce N-leaching (Van Loo *et al.*, 2003). Improved rooting of grasses in agricultural systems should, however, not be a trade-off with aboveground biomass allocation and yield. Therefore, it is important to explore which management practices promote deeper rooting of grassland plants, and also to investigate the relation with yield. One management practice is the use of genetic variation among different grass varieties (Crush *et al.*, 2007). In this paper, we describe the relation between root biomass and grass yield of sixteen *Lolium perenne* (Lp) varieties in two field experiments.

Material and methods

In Experiment I, eight Lp varieties were selected from a field experiment that is part of the VCU (value for cultivation and use) testing programme for the Dutch variety list. This trial was sown in 2005 with 50 Lp varieties on a sandy soil in four replicates. The Lp-varieties differed in characteristics of productivity class, earliness class, and ploidy (diploid versus tetraploid) in an orthogonal way. Grass dry matter (GDM) yield was measured in 2006-2008. In October 2010, root samples were taken in three soil layers: 0-8, 8-16 and 16-24 cm. Per plot and per layer, three soil cores (8.5 cm diameter, 8 cm depth) were taken and pooled to one sample. The fresh samples were washed through a sieve (mesh size 2 mm) and non-root particles were removed. The root dry matter (RDM) was determined after drying, first at 70 and then at 105 °C. During the VCU testing and the following years, the experiment was managed according to a cutting regime with five cuts per year.

In Experiment II, eight other Lp varieties were selected in a second experiment, also part of the VCU testing programme and also on a sandy soil. Here, 80 Lp varieties had been sown in 2009 in four replicates. The varieties differed in their characteristics of productivity class, soil cover class and ploidy, also in an orthogonal way. GDM was measured in 2010-2012. Root sampling was done in September 2013 following the method of Experiment I. This trial was managed as a cutting/grazing pasture (two cuttings/four grazings per year). More details on the experiments are given in Deru *et al.* (2014).

Variety effect on RDM was analysed for each experiment separately using the ANOVA procedure in Genstat 13.3. RDM effect on GDM was calculated with linear regression analysis. Regression was carried out on the whole dataset with and without discerning different groups (experiments, ploidy, production). RDM was expressed as the total over the three soil layers or separately, and GDM as average of the three measured years.

Results and discussion

The grand mean RDM in the 0-24 cm soil layer in Experiment II (2,663 kg ha^{-1}) was lower than in Experiment I (3,286 kg ha^{-1}). Total nitrogen applied, including slurry manure, artificial fertilizer and the estimated extra N input from dung and urine during grazing (Experiment II) was comparable in both experiments. Besides differences in abiotic conditions and sampling year between the experiments, the more intensive cutting/grazing regime in Experiment II may have contributed to reduced RDM. Ennik and Baan Hofman (1983) measured a lower RDM with higher harvesting frequencies.

RDM in the sampled soil layers for the sixteen varieties are shown in Figure 1. In Experiment I, there was a significant variety effect on RDM$_{0-24cm}$ (P=0.004). In Experiment II the variety effect was close to significant on RDM$_{0-24cm}$ (P=0.053) and significant on RDM$_{8-16cm}$ (P=0.008).

Regression analysis showed that no significant relation existed between GDM and RDM in any soil layer, either in the whole dataset or with separated groups (Experiment I and II; high or low production category; diploid or tetraploid). This lack of negative relation, as measured in our experiments, does not exclude the possibility that varieties with high RDM would be less vulnerable to stress conditions (e.g. drought) and give higher aboveground yield compared with varieties with low RDM. Further, this indicates that it is possible to select perennial ryegrass varieties that combine high aboveground productivity with high root mass. The potential for improvement is certainly there, considering that Crush *et al.* (2006) reported a narrow-sense heritability value of 0.35 for perennial ryegrass, and Bonos *et al.* (2004) increased root mass in the deeper soil layer of forage type perennial ryegrass in test tubes by 367% after only two breeding cycles.
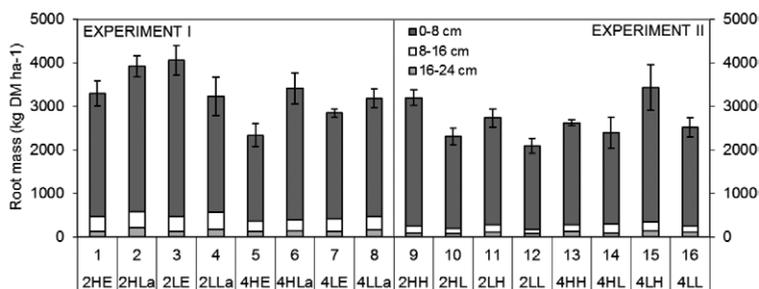
Figure 1. Cumulated root mass (kg dry matter (DM) ha^{-1}) of sixteen *Lolium perenne* varieties (Experiments I and II) with different genetic and aboveground characteristics. Abbreviations: 2 or 4: diploid or tetraploid; H or L: high or low productive; La or E: late or early; H or L (second character in experiment II): high or low soil cover). Error bars represent + and − the standard error of root DM across the 0-24 cm soil layer.

In this field experiment it is possible that differences in root morphology between genotypes (e.g. proportion of fine roots) influenced the results, as the washing method does not extract all roots from the soil. Another possible bias is that part of RDM can include dead roots, and that genotypes differ in their proportion of dead roots (or root decomposition rate). For breeding purposes other techniques could be used to quantify rooting characteristics of genetic material.

Conclusions

Based on the results of these two experiments, it can be concluded that root mass of *Lolium perenne* differs between varieties under field conditions and that there is no trade-off between root mass and grass yield.

Acknowledgements

References

Bonos S.A., Rush D., Hignight K. and Meyer W.A. (2004) Selection for deep root production in tall fescue and perennial Ryegrass. *Crop Science* 44, 1770-1775.

Crush J.R., Easton H.S. and Waller J.E. (2006) Genetic variation in perennial ryegrass for root profile characteristics. In: Mercer C.F. (ed.) *New Zealand Grassland Association Research and Practice* Series No. 12, Dunedin, New Zealand: New Zealand Grassland Association, pp. 63-65.

Crush J.R., Easton H.S., Waller J.E., Hume D.E. and Faville M.J. (2007) Genotypic variation in patterns of root distribution, nitrate interception and response to moisture stress of a perennial ryegrass (*Lolium perenne* L.) mapping population. *Grass and Forage Science* 62, 265-273.

Deru J., Schilder H., Van der Schoot J.R. and Van Eekeren N. (2014) Genetic differences in root mass of *Lolium perenne* varieties under field conditions. *Euphytica* 199, 223-232.

Ennik G.C. and Baan Hofman T. (1983) Variation in the root mass of ryegrass types and its ecological consequences. *Netherlands Journal of Agricultural Science* 31, 325-334.

Van Loo E.N., Dolstra O., Humphreys M.O., Wolters L., Luessink W., De Riek J. and Bark N. (2003) Lower nitrogen losses through marker assisted selection for nitrogen use efficiency and feeding value in ryegrass (Nimgrass). *Vortrage fur Pflanzenzuchtung* 59, 270-279.

Reduced tillage for silage maize on sand and clay soils: effect on yield and soil organic matter

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Abstract

Maize (*Zea mays*) cultivation for silage has negative impacts on soil and water quality: reduced soil organic matter, nitrate leaching, soil-biota decline, etc. These problems can be caused partly by intensive soil tillage, like ploughing. The suitability of less-intensive tillage alternatives for farmers, in terms of effects on yield and soil quality, is unknown. On three field experiments, two on sandy soils and one on marine clay soil, we compared 'full-field inversion tillage' with two reduced tillage systems: 'full-field non-inversion tillage' and 'strip-cutter'. Reducing tillage intensity in silage maize cropping influenced both yields and soil quality: at two locations yields tended to be reduced, and at two locations soil organic matter content was lower in inversion tillage compared to reduced tillage. The possible implications of reduced soil organic matter mineralisation for nitrogen dynamics are discussed.

Keywords: *Zea mays,* reduced tillage, yield, soil organic matter

Introduction

Traditional continuous cultivation of silage maize is known to have negative impacts on soil and water quality: reduced soil organic matter, nitrate leaching, soil-biota decline, soil degradation and compaction (Van Eekeren *et al.*, 2008). Part of the problems are linked to the intensity of traditional soil tillage (ploughing, spading) and, therefore, less-intensive tillage systems have been developed. In the Netherlands, an increasing number of farmers and contractors are adopting these new practices. Drivers for this adoption are conservation of soil organic matter and soil biota, better harvest conditions (load-bearing capacity) and lower fuel consumption. Reduced tillage systems for silage maize include non-inversion tillage (full-field) and strip-till or strip-cutter (cultivation of the maize row only). The strip-cutter can be used in grassland or another closed crop, the cutter preparing a seedbed for the maize row (10-15 cm width) (www.maisteeltinstroken.nl). In the Netherlands little experimental research has been done to test the suitability of these alternative systems in terms of their effects on yield and soil quality. At three locations, one on marine clay and two on sandy soil, we set up field experiments to compare a number of tillage strategies in silage maize cropping.

Materials and methods

Three experiments were established after grassland in 2009 (Lelystad) and 2012 (Rolde and De Moer) with treatments combining silage maize crops with different tillage and green manure strategies. Key information is given in Table 1. In this paper, we report the results of treatments related to soil tillage: full-field inversion tillage (IT; ploughing in Lelystad and De Moer, and spading in Rolde), full-field non-inversion tillage (NIT) and strip-cutter (SC). Silage yield was measured each year with an experimental plot maize harvester. Dry matter (DM) content was determined to calculate DM yield. Soil samples were taken in December 2014 in the soil layers 0-15 cm and 15-30 cm and soil organic matter (SOM) content was determined by loss-on-ignition (Ball, 1964). Statistical analysis was done for each experiment separately using ANOVA, randomized block design in Genstat 13.3 and a significance level of 5%. For Lelystad, data from 2010-2014 are reported.

Table 1. Overview of the experiments in Lelystad, Rolde and De Moer, the Netherlands.

| | Location | | |
	Lelystad	Rolde	De Moer
Province	Flevoland	Drenthe	Noord-Brabant
Soil type	Young marine clay	Sand	Sand
Year of establishment	2009	2012	2012
Previous crop	Grassland	Grassland	Grass-clover
Replicates	3	3	4

Results and discussion

In Lelystad, silage maize yields were significantly lower in NIT and SC compared to IT. Furthermore, yields tended to increase in the later experimental years, with high figures in 2014 (Table 2). This tendency was biased by the low yields in 2011 caused by heavy *Kabatiella zeae* infection. Later on, *Kabatiella*-tolerant varieties were used. A change of tillage system brings changes in infection type, and varieties have to be adapted. In Rolde and De Moer, the effect of experiment year interacted with tillage (Table 2). In De Moer for example, the yield of SC was greater than that of IT in the first experiment year, but in the last two years no significant differences were found.

Soil organic matter (SOM) was significantly influenced by soil tillage at both Lelystad and De Moer. In both experiments, SOM was greater in the reduced tillage (NIT or SC) compared to the IT treatment at the 0-15 cm layer, but not in 15-30 cm (Table 3). In contrast to the reduced tillage, no difference in SOM distribution between soil layers was found for the IT treatment. This is clearly an inversion and mixing effect of IT over the 0-30 cm layer. In Rolde, however, where in the IT treatment a spader was used instead of a plough, the SOM mixing was less pronounced. In contrast to Lelystad and Rolde, the treatment effect on SOM in De Moer was still significant over the whole 0-30 cm layer (P=0.031; Lelystad: 0.315; Rolde: 0.507) and represented a difference of 12.4 Mg SOM ha^{-1} when comparing IT with SC. This difference

Table 2. Silage maize yield for inversion tillage (IT), non-inversion tillage (NIT) and strip-cutter (SC), per location and year.[1]

| Location | Year | Maize yield (Mg DM ha^{-1}) | | | |
		IT	NIT	SC	Mean
Lelystad	2010	16.6	18.1	16.3	17.0 b
	2011	14.6	10.4	11.4	12.1 a
	2012	23.4	20.8	16.9	20.3 c
	2013	17.9	17.1	13.6	16.2 b
	2014	24.2	21.3	20.5	22.0 c
	Mean	19.3 c	17.5 b	15.7 a	17.5
Rolde	2012	17.5 e	16.3 cde	13.1 a	15.6
	2013	16.4 cde	15.0 bc	17.4 de	16.3
	2014	17.1 de	15.5 bcd	14.2 ab	15.6
	Mean	17.0	15.6	14.9	15.8
De Moer	2012	15.3 a	15.4 ab	17.2 bc	16.0
	2013	15.3 a	13.9	13.8 a	14.4
	2014	19.7 d	20.3	18.8 cd	19.6
	Mean	16.8	16.6	16.6	16.6

[1] Where an effect (tillage, year or interaction) is significant, different letters indicate significant difference between numbers within a location.

Table 3. Soil organic matter content for inversion tillage (IT), non-inversion tillage (NIT) and strip-cutter (SC), per location and soil layer.[1]

Location	Layer (cm)	Soil organic matter (g kg⁻¹)			
		IT	NIT	SC	Mean
Lelystad	0-15	4.4 b	5.6 c	5.4 c	5.2
	15-30	4.3 ab	4.1 ab	3.7 a	4.0
	Mean	4.4	4.9	4.5	4.6
Rolde	0-15	5.1	5.9	5.4	5.5 b
	15-30	4.3	4.9	5.0	4.7 a
	Mean	4.7	5.4	5.2	5.1
De Moer	0-15	3.6 a	n.d.	4.2 b	3.9
	15-30	3.6 a	n.d.	3.6 a	3.6
	Mean[2]	3.6		3.9	3.8

[1] Where an effect (tillage, layer or interaction) is significant, different letters indicate significant difference between numbers within a location. n.d. = not determined.

[2] The difference between IT and SC in De Moer in 0-30 cm was significant.

over three growing seasons equals ca. 150 kg N ha⁻¹ per year from mineralization (N SOM⁻¹ ratio of 0.037; Van Eekeren *et al.*, 2008), which is probably lost to the environment under IT as no difference was found in harvested yield (Table 2) or in soil mineral N at the end of the season (data not shown).

Conclusions

Reducing tillage intensity in silage maize cropping can influence both yields and soil quality. Yields tend to be reduced, but the net mineralization of soil organic matter is also reduced.

References

Ball D.F. (1964) Loss-on-ignition as estimate of organic matter + organic carbon in non-calcareous soils. *Journal of Soil Science* 15, 84.

Van Eekeren N., Bommelé L., Bloem J., Schouten T., Rutgers M., De Goede R., Reheul D. and Brussaard L. (2008) Soil biological quality after 36 years of ley-arable cropping, permanent grassland and permanent arable cropping. *Applied Soil Ecology* 40, 432-446.

Productivity and herbage quality in two-species grass-legume mixtures under cutting

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Abstract

Inclusion of legumes in grasslands could enhance N-use efficiency of forage production. Performance of 7 binary grass-legume mixtures was studied to examine companion species with contrasting attributes. Perennial ryegrass (PR) was sown alone and with each of four forage legumes: red clover (RC), birdsfoot trefoil (BT), lucerne (LU) and white clover (WC); WC was sown with each of four companion grasses: PR, hybrid ryegrass (HR), meadow fescue (MF) and timothy (TI). Mixtures were studied in a small-plot (1.5×8 m) cutting trial with 4 replications in Denmark to test the effect of species composition on herbage yield, contents of nitrogen (N) and neutral detergent fibre (NDF), and *in vitro* organic matter digestibility (IVOMD). Plots were fertilised with 300 kg N ha^{-1} from cattle slurry and harvested five times from May to October in year 1 and four times in year 2. With different companion grasses, the WC proportion was similar in mixtures with HR and MF, which had a lower WC content than with PR and TI. Annual herbage yield was highest for PR/RC (15.6 Mg DM ha^{-1}) which had, on average, the highest legume proportion of DM, the highest N content (33 g N kg^{-1} DM) and the highest N yield (505 kg N ha^{-1}) across both years. The mixture with the lowest values was PR/BT (9.6 Mg DM ha^{-1}; 25 g N kg^{-1} DM; 243 kg N ha^{1}). PR/RC had the lowest concentration of NDF (375 g kg^{-1} DM) and pure PR the highest (437 g kg^{-1} DM). IVOMD ranged from 730 g kg^{-1} organic matter (OM) in PR/LU to 774 g kg^{-1} OM in WC/HR. Choice of companion grass had less effects than that of companion legume in the examined mixtures. Red clover contributed most to N yield.

Keywords: companion species, functional group, fibre, grass-legume mixture, nitrogen, protein, yield

Introduction

Herbage is an important natural source of protein and fibre in ruminant diets. Inclusion of legumes in grass swards contributes to sustainable intensification as symbiotically fixed N$_2$ may replace fertilizer-N.

An optimal combination of suitable grass and legume companion species is needed to obtain high N-use efficiency, high herbage yield, a desirable seasonal production pattern and high contents of nutritive compounds in grass-legume mixtures. The impact of different grass-legume mixtures on the N contribution and effects of companion species have rarely been investigated under comparable soil and climatic conditions. Therefore a field experiment was conducted on a sandy soil with 7 two-species forage mixtures. N$_2$ fixation and residual N effects were reported earlier (Rasmussen *et al.*, 2012). The aim of this experiment was to study the effects of companion grasses and legumes in mixtures on annual and seasonal herbage yield, N production, and forage quality. We hypothesised in line with data of Smit *et al.* (2008) that red clover and lucerne would be most productive in terms of dry matter (DM) and N yield. As competition from the companion grass affects the growth of the forage legume we also hypothesised that under a silage cut regime, perennial ryegrass would allow a higher white clover proportion than other grass species.

Materials and methods

Perennial ryegrass (*Lolium perenne* L.; 'PR') was sown alone and with each of four forage legumes: red clover (*Trifolium pratense* L.; 'RC'), lucerne (*Medicago sativa* L.; 'LU'), and birdsfoot trefoil (*Lotus corniculatus* L.; 'BT'), and white clover was sown with each of four companion grasses: perennial ryegrass, hybrid ryegrass (*Lolium boucheanum* Kunth; 'HR'), meadow fescue (*Festuca pratensis* Huds.; 'MF') and timothy (*Phleum pratense* L.; 'TI'). Grass and mixtures were sown in 2006 in a small-plot (1.5×8 m) cutting trial with 4 replications in Denmark. Mixtures are abbreviated as PR/RC, PR/BT, PR/LU, PR/WC, MF/WC, TI/WC and HR/WC, respectively. Plots were fertilised with 300 kg N ha^{-1} from cattle slurry divided into four applications during the growing season of 100, 80, 60 and 60 kg and harvested five times in 2007 and four times in 2008 with a Haldrup forage harvester at a residual stubble height of 7 cm. Herbage yield, contents of N and neutral detergent fibre (NDF), acid detergent fibre (ADF) and lignin, and *in vitro* organic matter digestibility (IVOMD) were determined in mixtures as reported by Rasmussen *et al.* (2012). Species composition was measured in May and August 2007 and in all harvests in 2008.

Results

In all mixtures, grass production was higher in the first harvest than in later harvests. MF and HR were the highest yielding grass species in the first harvest. MF/WC and HR/WC had similar high annual yields, and similar clover proportions that were slightly lower than in PR/WC as illustrated for 2008 in Figure 1. Regardless of companion grass species the seasonal WC production pattern was similar, the second harvest being most productive. The mean clover proportion in May and August was similar in MF/WC, TI/WC and HR/WC (Table 1). In contrast, legume proportions in mixture with PR differed (*P*<0.001): RC>LU>WC>BT, as did legume yields and seasonal production patterns (Figure 1).

Annual herbage yield was highest for PR/RC that had the highest legume proportion of DM, the highest N content and the highest N yield averaged across both years (Table 1). The mixture with the lowest values was PR/BT. PR/RC had the lowest concentration of NDF and pure PR the highest. IVOMD ranged from 730 g kg^{-1} organic matter (OM) in PR/LU to 774 g kg^{-1} OM in in HR/WC.
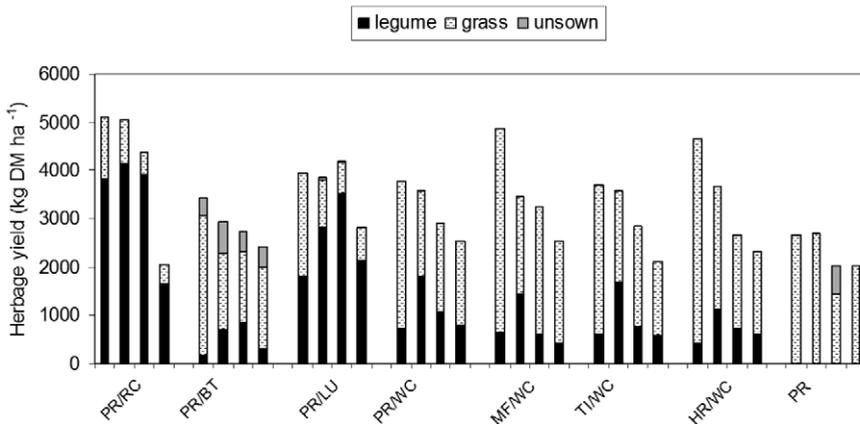
Figure 1. Seasonal dry matter (DM) production (harvests: 21 May, 2 July, 12 August and 9 October) from seven binary grass-legume mixtures and a pure-sown perennial ryegrass sward for 2008 (mean of four replicates). Mixture species abbreviations: perennial ryegrass (PR), red clover (RC), birdsfoot trefoil (BT), lucerne (LU), meadow fescue (MF), timothy (TI) and hybrid ryegrass (HR). Sown grass and legume species and unsown species are shown.

Table 1. Annual dry matter yield (DMY) and nitrogen (N) yield, *in vitro* organic matter digestibility (IVOMD), neutral detergent fibre (NDF), N content, and legume proportion of dry matter (DM).[1,2] Average values of 4 replicate plots during 9 harvests in 2 years (n=72).

Mixture	DMY (kg ha⁻¹)	N yield (kg ha⁻¹)	IVOMD (g kg⁻¹ OM)	NDF (g kg⁻¹ DM)	N (g kg⁻¹ DM)	Legume[3] (%)
PR/RC	15,581 a	505 a	737 f	375 g	32.5 a	81 a
PR/BT	9,571 e	243 d	758 d	421 c	25.3 g	18 e
PR/LU	13,374 b	396 b	730 g	421 c	29.7 d	69 b
PR/WC	12,635 c	388 b	763 c	386 f	30.7 c	34 c
MF/WC	13,303 b	378 b	752 e	430 b	28.5 e	22 de
TI/WC	11,835 d	380 bc	758 d	393 e	32.2 b	30 cd
HR/WC	13,073 b	365 c	774 a	394 d	27.8 f	22 de
PR	7,572 f	170 e	773 b	437 a	21.9 h	-
SE	229	6.8	0.7	0.6	0.07	4.2

[1] Abbreviations: perennial ryegrass (PR), red clover (RC), birdsfoot trefoil (BT), lucerne (LU), meadow fescue (MF), timothy (TI) and hybrid ryegrass (HR). SE = standard error. - = not applicable.

[2] Within a column, values without a common superscript are significantly different (*P*<0.001).

[3] Legume proportion of DM in 2008.

Discussion

Our hypothesis that perennial ryegrass would allow a higher clover proportion than other grass species was not confirmed: PR/WC and TI/WC had similar clover proportions and N yields, but N content was lower and annual yield higher in PR/WC. MF/WC and HR/WC had similar annual yields and clover proportions while N content and N yield were slightly higher in MF/WC. White clover had a high proportion of N derived from atmosphere for all companion grasses despite significant differences in clover proportion (Rasmussen *et al.*, 2012). Frame and Harkess (1987) studied white clover, red clover and lucerne with each of five companion grasses: diploid and tetraploid perennial ryegrass, timothy, meadow fescue and sweet brome (*Bromus carinatus* Hook & Arn.). Companion grass species did not affect annual DM production levels or N production in any of the three harvest years.

Choice of companion legume had major effects. As hypothesised, red clover and lucerne were more productive in terms of DM and N yield than birdsfoot trefoil which is in line with data of Smit *et al.* (2008). Even with slurry application of 300 kg N ha⁻¹, red clover and lucerne fixed >300 kg N ha⁻¹ (Rasmussen *et al.*, 2012). Frame and Harkess (1987) highlighted the high production levels achievable from red clover in the short term. This study showed that during the first two harvest years, red clover contributed most to N yield in forage mixtures under a silage cut regime.

References

Frame J. and Harkess R.D. (1987) The productivity of four forage legumes sown alone and with each of five companion grasses. *Grass and Forage Science* 42, 213-223.

Rasmussen J., Søegaard K., Pirhofer-Walzl K. and Eriksen J. (2012) N₂-fixation and residual N effects of four legume species and four companion grass species. *European Journal of Agronomy* 36, 66-74.

Smit H.J., Nepal S., Van Vilsteren D., Witkowska I.M. and Elgersma A. (2008) Seasonality of apparent nitrogen fixation, nitrogen transfer, and productivity of four forage legume-grass mixtures under cutting. *Grassland Science in Europe* 13, 628-630.

Herbage production in grazed grass-white clover plots: effect of N fertilizer application

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Abstract

The objective of the experiment was to evaluate herbage removed (HR) and sward clover content in grass-only (GO) and grass-white clover (GW) swards under frequent tight grazing conditions. A series of grazing plots (8×8 m) were established as a 2-sward (GO and GW) × 5-fertilizer N rate (0, 60, 120, 196, 240 kg N ha^{-1}) experiment. Measurements were taken from 2010 to 2013. Dairy cows grazed swards 8-10 times yr^{-1} to a target post-grazing sward height of 4 cm. GW swards had 14-46% greater ($P<0.05$) HR than GO swards receiving the same N rate (0GO: 9.1; 60GO: 9.2; 120GO: 11.0; 196GO: 11.3; 240GO: 12.6; 0GW: 13.3; 60GW: 13.1; 120GW: 13.1; 196GW: 13.8 and 240GW: 14.4; standard error of the mean (SEM): 0.55 Mg dry matter (DM) ha^{-1}). Clover content was reduced ($P<0.01$) as N rate increased (0GW: 33.3; 60GW: 30.6; 120GW: 27.0; 196GW: 21.7 and 240GW: 19.6; SEM: 2.31 DM%). Regardless of N rate, the GW swards were able to, at least, match the HR of 240GO swards. Every percentage point increase in clover content corresponded with an increase of 0.2 Mg DM ha^{-1}. It is concluded that under frequent tight grazing conditions clover inclusion can increase overall HR regardless of N rate applied.

Keywords: *Trifolium repens*, mixed sward, yield, herbage, fertilizer, nitrogen

Introduction

There is interest in the inclusion of white clover (*Trifolium repens* L.; clover) in grazed grass swards due to the potential of grass-clover (GW) swards to improve the sustainability of grazing systems as it can increase nitrogen (N) availability for herbage production. However, the amount of N fixed is influenced by a range of factors, including N fertilizer application (Andrews *et al.*, 2007). Nitrogen fertilizer application can reduce sward clover content (Ledgard *et al.*, 1995) as the clover can be out-competed in terms of growth rate and nutrient uptake by the grass, and shading reduces the persistency of the clover. The objective of this experiment was to identify an appropriate N-fertilizer application rate to maximize annual herbage removed (HR) in grass-only (GO) and GW swards on a free draining soil subjected to frequent and tight grazing without compromising sward clover content.

Materials and methods

A series of grazing plots (8×8 m) were established as a 2-sward (GO and GW) × 5-fertilizer N rates (0, 60, 120, 196, 240 kg N ha^{-1}) factorial arrangement with 3 replicates according to a split plot design. Both swards were sown with a perennial ryegrass (*Lolium perenne* L.) mixture (50% Dunluce and 50% Tyrella cultivars; 37 kg ha^{-1}) and the GW swards had an even mixture of Chieftan and Crusader clover cultivars (5 kg ha^{-1}). Measurements were taken from 2010 to 2013. Dairy cows grazed swards 8-10 times yr^{-1} during the grazing season (from February until October) to a target post-grazing sward height of 4 cm. The dry matter (DM) harvested herbage (HR) was estimated by cutting a strip with an Etesia lawn mower (Etesia UK Ltd., Warwick, UK). Sward clover content was estimated by removing a herbage sample (approx. 70 g) and separating into grass and clover components. Annual values were calculated from the values taken before each grazing. Data were analysed using the Mixed procedure in SAS (SAS,

2005) including sward type, N rate, year and the interactions in the model as fixed effects; the sward type × block interaction as a random factor and the year was used as a repeated measure.

Results and discussion

There was an effect of sward type, N rate and their interaction on HR ($P<0.01$ for all), but the three-way interaction was not significant. The HR increased from 2010 until 2012 but was lower in 2013 due to a severe summer drought. However, despite the year-to-year variation, the GW swards had 14 to 37% greater HR than the GO swards across years (Table 1; $P<0.05$). There was no significant year×N rate interaction for clover content, but while clover content was high in the first two years of the experiment, the mild and wet grazing season of 2012 and the drought in late summer and autumn of 2013 favoured clover growth at the expenses of grass growth across all treatments (Table 1). Increasing the N rate increased HR on GO swards, but had little effect on HR from GW swards (Table 2). The GW swards had between 14 to 46% greater HR than GO swards receiving the same N rate (Table 2). However, the annual clover content was reduced from 8 to 41% ($P<0.01$) as N rate increased from 60 to 240 kg N ha^{-1} (Table 2) and the strongest effect was observed during the warmest months (Figure 1), which is in agreement with previous findings (Harris *et al.*, 1998; Ledgard *et al.*, 1995). As the N rate increased the clover-content plateau observed during the July to September period was smaller, but less so up to 120 kg N ha^{-1}. Frame and Boyd (1987) reported a 48 and 81% reduction in clover content when 120 and 240 kg N ha^{-1}, respectively, were applied to GW swards. Thus, it seems that the frequent and tight grazing management used in this experiment alleviated the suppression effect of N fertilizer on clover, most markedly up to 120 kg N. Regardless of N rate, the GW swards were able to, at least, match the HR of GO swards receiving 240 kg N ha^{-1}. Every percentage point increase in clover content corresponded with an increase of 0.2 Mg DM ha^{-1}. Although the clover contribution to HR should not be dismissed, and the overyielding of GW compared to GO swards receiving up to 450 kg N ha^{-1} has previously been

Table 1. Effect of sward type (sward) and year of the experiment on annual herbage removed (Mg dry matter (DM) ha^{-1}) and white clover content (DM %).

| | Year | | | | SEM | *P*-value | | |
	2010	2011	2012	2013		Sward	Year	Sward × Year
Herbage removed yield								
Grass only	8.6[a]	11.5[bc]	13.9[d]	8.5[a]	4.9	<0.01	<0.01	<0.01
Grass white clover	11.8[c]	15.6[e]	15.9[e]	11.0[b]				
White clover content	30.7[c]	32.1[c]	19.2[a]	23.8[b]	1.5	-	<0.01	-

[1] Values with different superscript letters are significantly different ($P<0.05$). SEM = standard error of the mean.

Table 2. Effect of sward type (sward) and nitrogen (N) application rate on annual herbage removed (Mg dry matter (DM) ha^{-1}) and white clover content (DM %) across the four experimental years.

| | N application rate (kg N ha^{-1}yr^{-1}) | | | | | SEM | *P*-value | | |
	0	60	120	196	240		Sward	N	Sward × N
Herbage removed yield									
Grass only	9.1[a]	9.2[a]	11.0[b]	11.3[b]	12.6[c]	5.5	<0.01	<0.01	<0.01
Grass white clover	13.3[cd]	13[c]	13.1[c]	14.0[cd]	14.4[d]				
White clover content	33.3[c]	30.6[c]	27.0[bc]	21.7[b]	19.6[a]	2.31	-	<0.01	-

[1] Values with different superscript letters are significantly different ($P<0.05$). SEM = standard error of the mean.
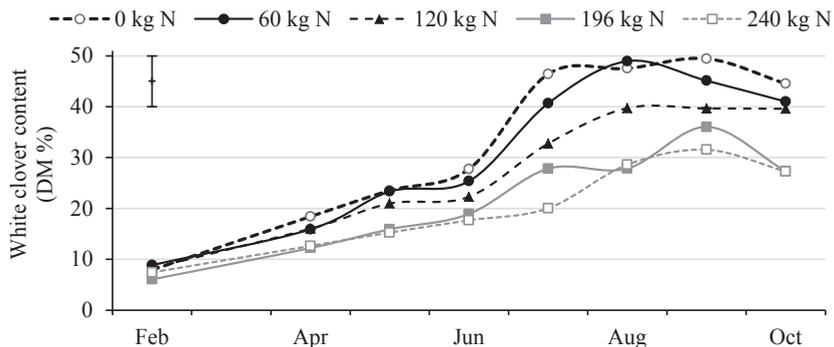
Figure 1. Effect of nitrogen (N) application rate (kg N ha^{-1}) on sward white clover content (% dry matter (DM)) of the grazing seasons across the four experimental years.

reported (Nyfeler *et al.*, 2009), it is possible that the outstanding GW sward performance could be related to the poor response of the GO swards to N application (average 18.5 kg DM ha^{-1} per kg N applied).

Conclusions

Under frequent and tight grazing management white clover inclusion increased overall herbage removed regardless of the N rate applied. The management strategy applied in this experiment may be capable of alleviating the detrimental N fertilizer effect on clover to a point between 60 and 120 kg N ha^{-1}.

Acknowledgements

References

Andrews M., Scholefield D., Abberton M.T., McKenzie B.A., Hodge S. and Raven J.A. (2007) Use of white clover as an alternative to nitrogen fertiliser for dairy pastures in nitrate vulnerable zones in the UK: productivity, environmental impact and economic considerations. *Annals of Applied Biology* 151, 11-23.

Frame J. and Boyd A.G. (1987) The effect of fertilizer nitrogen rate, white clover variety and closeness of cutting on herbage productivity from perennial ryegrass/white clover swards. *Grass and Forage Science* 42, 85-96.

Harris S.L., Auldist M.J., Clark D.A. and Jansen E.B.L. (1998) Effects of white clover content in the diet on herbage intake, milk production and milk composition of New Zealand dairy cows housed indoors. *Journal of Dairy Research* 65, 389-400.

Ledgard S.F., Sprosen M.S., Steele K.W. and West C.P. (1995) Productivity of white clover cultivars under intensive grazing, as affected by high nitrogen fertiliser application. *New Zealand Journal of Agricultural Research* 38, 473-482.

Nyfeler D., Huguenin-Elie O., Suter M, Frossard E., Connolly J. and Lüscher A. (2009) Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding. *Journal of Applied Ecology* 46, 683-691.

SAS (2005) *SAS User's Guide Statistics*. SAS Inst. Inc., Cary, NC, USA.

Lucerne as an alternative protein source in southwest England: a Demo Farm perspective

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Abstract

Lucerne (*Medicago sativa*) remains a widely grown forage crop globally. In Great Britain however, its use has been restricted by crop establishment challenges. With global demand for protein continuing to rise, the European dairy sector is tasked with increasing the use of home-grown protein forages. In 2013 the British Grassland Society and DairyCo embarked on the three-year-long Demo Farms project, whereby selected findings from the DairyCo-funded Grass, Forage and Soils research partnership involving a number of UK universities could be transferred to farmers via a network of trials and events on commercial farms. In 2014 a high-output dairy farm in southwest England in its second year of growing lucerne joined the project, providing knowledge exchange opportunities around the use of home-grown lucerne to reduce purchased protein costs and improve farm business scale efficiency. This paper explores the strategies employed at the demo farm growing and feeding the crop to date, and the farm's use as a knowledge exchange mechanism.

Keywords: knowledge transfer, lucerne, on-farm practice

Introduction

Lucerne (*Medicago sativa*) remains a minority crop in Great Britain despite its proven high yields, protein content, palatability and zero nitrogen fertiliser requirement. It is estimated that as much as 404,680 hectares (ha) are suitable for growing lucerne in Great Britain. The main barrier has been the establishment phase. A number of trials undertaken at universities within the Grass, Forage and Soils research partnership (RP) have provided insight into strategies to maximise establishment, including investigations into the potential of a cover crop (spring barley) to reduce weed burden and whether spring or autumn sowing is preferential for lucerne production in Great Britain.

Additionally, there is a knowledge gap regarding optimum strategies to maximise the value of lucerne in dairy cow diets. Alternative feeding strategies are also being explored, including: the optimum rate of inclusion of lucerne in dairy cow diets when combined with maize and/or grass silage, the effect of plant maturity at harvest for silage on forage quality and cow performance, and the effect of chop length of lucerne on ensilability, digestibility and cow performance.

The aim of the demo farm is to provide a suitable context in which to relay relevant messages from the RP to farmers.

The demo farm case study

The farm is located in mid-Cornwall, southwest Great Britain. The soil type is a clay loam to loam over slaty mudstones, with naturally high groundwater in places. Average rainfall is 1000 mm per annum and the farm is at an altitude of 100 m. The herd comprises 230 Holstein cows, one third of which are milked by robot. Average production is 10,000 litres with an all year-round calving pattern. Grass (61 ha), forage maize (44 ha) and lucerne (24 ha) are now the predominant crops grown on the farm. Winter wheat (15 ha) is also produced.

Lucerne was established for the first time in May 2013 when 17 ha (cv. Marshall) was sown as a pure stand at a seed rate of 25 kg ha^{-1} (seed costs £170 ha^{-1}). The land was previously used for wheat, grass and potato production, and the soil nutrient status was good (Table 1).

The crop was harvested twice in 2013 with an estimated yield of 17.5 Mg ha^{-1} (fresh weight, cut), equating to dry matter (DM) yield of 4.25 Mg DM ha^{-1}. Slurry was applied after each cut with a dribble bar at a rate of 27.5 Mg ha^{-1}. A further 7 ha of the crop were sown in April 2014. Weed burden in the newly sown crop was controlled early in the growing season with a weed wiper.

The first harvest of 2014 (11 June) was taken from the 17 ha in second-year production only, again followed by 27.5 m^3 ha^{-1} slurry. Yields were estimated from quadrat clips, projecting a yield difference of more than 3.29 Mg ha^{-1} between north- and south-facing fields (Table 2). The yield at second harvest was estimated by the farmer to be 7.59 Mg ha^{-1} fresh weight, based on the weight capacity and number of trailer loads carried off the fields (transportation to the nearest weigh bridge was not feasible as contractors were used for silaging).

Clamp silage was made, with fructan biological additive at a rate of 2 l Mg^{-1} (Table 3). The growing season was generally drier in 2014 than the previous year, receiving an average 59 mm rainfall per month between March and September compared to an average 66.4 mm in 2013 (Camborne Weather Station, Met Office 2015).

Table 1. Soil nutrient status prior to lucerne cultivation.

pH	7.25
Phosphorous mg l^{-1}(index)	34 (3)
Potassium mg l^{-1}(index)	283.5 (3)
Magnesium mg l^{-1}(index)	98 (2)
Organic matter % loss on ignition	8.5

Table 2. Difference in crop performance in adjacent north- and south-facing fields prior to the first cut of second-year lucerne in June 2014.

	North-facing	South-facing
Plant size (mean g plant^{-1})	326.4	490.8
Plant density (number of plants m^{-2})	50	67
Estimated yield (fresh weight Mg ha^{-1})	6.53	9.82

Table 3. First and second harvest lucerne silage analysis from the demo farm, 2013 and 2014.

	First harvest		Second harvest	
	2013	2014	2013	2014
Dry matter (DM) (g kg^{-1})	243	409	255	52.6
Crude protein (g kg^{-1} DM)	168	166.5	168	201.5
D-value (digestible organic matter g kg^{-1} DM)	640	665	630	-
Metabolisable energy (MJ kg DM^{-1})	10.2	10.6	10.1	-
pH	4.7	4.05*	4.7	4.79

* Value significantly different.

Lucerne is provided in the diet of both the robotically milked and conventionally milked cows at a rate of approximately 1.5 kg dry matter per cow per day (5-6 kg fresh weight per cow per day). This equates to 15% of the dry matter intake from forage. It is fed as part of a total mixed ration which includes (amongst other ingredients): chopped fodder beet, whole crop wheat, haylage and first cut silage. The lucerne is chopped to approximately 5 cm.

This commercial farm, and the story of its experience with this little-used crop, provides a platform for knowledge exchange activity that breaks down barriers around learning styles and the perceived impractical nature of university-based trials. Farmer-facing events were held at the farm in July and November 2014. The first focused on growing and feeding lucerne, whilst the second related to the use of lucerne in potential lower crude protein diets for dairy cows. Researchers from the RP led presentations at each event, providing a rare opportunity for direct interaction with farmers in a farmer-centric setting. Through the data generated from the demo farm, researchers were able to compare and contrast their findings with on-farm practice, providing stimulus for comment at the events. Attendance figures at each event were encouraging, with a total number of 90 participants. Attendance was dominated by, but not restricted to farmers, and included representatives from associated trades such as farm advisers, agronomists and merchants.

Both the popularity of the events and feedback collected indicate that the target audience is engaged with the topic area and that the demo farm is a suitably located and a credible host. The demo farmers view their involvement in the project as a new and valuable learning experience and particularly welcome the opportunity to hear from primary researchers.

The demo farm project is ongoing until 2016, allowing further data collection and evaluation during 2015. Existing issues remain with the quality of data collected, which can also be addressed as the project progresses. A cost-benefit analysis (planned to take place in 2015) may help elucidate the influence of including lucerne in the dairy ration compared to other simultaneous on-farm actions in this commercial farming situation. A further 10 ha lucerne will be sown in 2010, reflecting the farmers' satisfaction with its performance and the impact of greening requirements under the 2015 Common Agricultural Policy reforms.

Conclusions

Conducting demonstrational investigations within the context of a commercial farm presents challenges in terms of collecting significant sample sizes of comparable data, applying controls and obtaining precise data without overtly impacting on farming activities. Accounting for other influencing factors is problematic as the project is not research led in the same way as trials at university-based sites. Nevertheless, the demo-farm format for knowledge exchange presents enhanced opportunities for researchers and intermediaries such as the British Grassland Society and DairyCo to work with active farmers to address practical challenges collaboratively.

References

Met Office (2015) Camborne meteorological data set. Available at: http://tinyurl.com/p9ktzct.

Concentrate supplementation and milking frequency in automated milking with grazing

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Abstract

Voluntary movement of cows from paddock to milking yard is an inherent aspect of an automatic milking system (AMS) integrated with grazing. The motivation for the cow to present at the milking yard, during the main grass-growing period, is the trained knowledge that they will be rewarded with fresh grass in a new paddock. In late-lactation concentrate supplementation assists in ensuring the cow receives adequate nutrition. Although the cow decides to present at the milking yard, AMS settings determine when the cow is milked based on milk yield and time since last milking. The aim of this study was to investigate the influence of milking permission and concentrate supplementation on milk production and cow traffic. There were 4 treatments with combinations of milking permissions, 3.2 or 1.8 times per day and concentrate supplementation allowance of either 3 kg or 0.84 kg per day. This study has highlighted strategies to maintain consistent milk production and cow traffic in the latter stages of lactation, through adjusting AMS settings for concentration supplementation and milking permission.

Keywords: milking permission, concentrate supplementation, automatic milking, grazing

Introduction

In Ireland the integration of automatic milking systems (AMS) is relatively new and this is the first study in an Irish context to attempt to define best animal, grass and concentrate supplementation management practices during the latter stages of the grazing season. The successful integration of an AMS with grazing is reliant upon voluntary movement of cows around the farm system and achieving an even distribution of milkings over 24 hours. Lyons *et al.* (2013) compared the use of supplementary feed pre- and post-milking in a grazing system and observed a reduced voluntary return time of cows from the paddock with pre-milking supplementation. Reduced pre-milking waiting time enhances animal welfare and was achieved by providing concentrate at the milking unit in a voluntary robotic rotary system (Scott *et al.,* 2014). In a spring-calving, pasture-based system of farming the availability of grass is a key factor in a farmer's management decisions relating to grass budgeting and concentrate supplementation. During a period when there is a grass deficit, for example as a result of reduced grass growth and quality in the latter end of the year, the dairy system needs to be sufficiently flexible to react to and compensate for the shortage of grass without dramatically impacting on milk production and, in the case of an AMS, on cow traffic. The current study assesses the effects of milking permission and concentrate supplementation in late lactation on milk yield and cow traffic.

Materials and methods

An AMS was located on a 25.2 ha milking platform divided into 3 grazing sections; A, B and C. Cows moved voluntarily to and from the paddock, passing through the milking yard, between the grazing sections. The experiment was divided into a lead-in period of 2 weeks (04/08/14 to 17/08/14) and an 11-week trial period (18/08/14 to 02/11/14). The herd had access to new pasture from 00:00 in A, 08:00 in B and 16:00 in C. Prior to each grazing the herbage mass (HM) (available grass kg dry matter (DM) ha^{-1} above 4 cm) was either estimated visually or by weighing grass DM in a 0.25 m^2 quadrat. The density of grass dry matter (kg m^{-3}), pre- and post grass heights in the area allocated to the herd for grazing were used to determine the grass DM intake for the herd after each grazing. The grazing area was allocated based on the pre-herbage mass and a demand of 18 kg grass DM cow^{-1} day^{-1} which was distributed over

the 3 grazing sections in a 24 h period. Pasture management involved strip grazing and only back grazing a grazing area for 1 day if the post grass height was greater than 6 cm from the previous grazing. Pre- and post-grazing heights were measured prior to and after each grazing using a Jenquip rising plate meter (NZ Agriworks Ltd t/a Jenquip, New Zealand). The grass DM removed for each grazing was calculated to estimate the herd daily grass intake. The dairy featured one Fullwood Merlin 225 AMS unit. During the lead-in period all cows received 0.5 kg of concentrate with a milking permission of 2.5 times per day. 65 out of 68 cows milking on the system were randomly allotted to four groups and balanced for breed, lactation, days in milk, previous milk yield and milking frequency. The average days in milk, for the 65 cows on the experiment, was 175 days, ranging between 134 and 214 days in milk. The experimental design was a 2×2 factorial with 2 concentrate levels (3 kg, 0.84 kg) and 2 milking permissions (3.2, 1.8 times per day). The groups consisted of high concentrate (3 kg) with high milking permission (3.2) (HCHP) and low milking permission (1.8) (HCLP) and low concentrate (0.84 kg) with high milking permission (3.2) (LCHP) and low milking permission (1.8) (LCLP). Milking-permission treatments were selected based on previous work carried out in Teagasc Moorepark in a grazing based system with an AMS. Dependent variables included milk production and cow traffic. The statistical model used was a repeated measures ANOVA in SAS with PROC MIXED and Tukey's post-hoc analysis.

Results and discussion

During the trial period, grass budgeting decisions based on a deficit of grass availability resulted in supplementation of silage in a shed instead of 8 hours grazing in B for 9 days and in C for 5 different days. The average pre-grazing available herbage mass across all sections was 1,538±295 kg DM ha^{-1} (A – 1,587±324 kg, B – 1,410±416 kg and C – 1584±333 kg DM ha^{-1}). Of the days where there was a full set of data for A, B and C the total daily grass DM allowance per cow was 20.7±6.2 kg (A – 7.2±3.4 kg, B – 7.1±2.6 kg and C – 6.5±2.3 kg) and daily estimated grass DM intake per cow was 18.1±6.2 kg (A – 6.4±3.4 kg, B – 6.0±2.3 kg and C – 5.8±2.1 kg). The average post-grazing height was 4.9 cm (A – 5.0±1.0 cm, B – 4.9±0.9 cm and C – 4.8±0.9 cm). The results indicated that for the dependent variables of milk production (milk yield per visit and per day) and cow traffic (milking frequency, milking interval per visit, milking duration per day and waiting time per visit) the interaction between milking permission and concentrate was not significant. The main effects of milking permission and concentrate were significant for each dependent variable, except for wait time per day under the concentrate-supplementation treatments. Cows on the high milking permission (HP) and low milking permission (LP) had a milking frequency of 1.9 and 1.3 per day, respectively. Cows on high concentrate (HC) and low concentrate (LC) had an allowance of 3 and 0.84 kg per day, respectively. Cows with lower milking permission (HCLP and LCLP) compared to cows with a higher milking permission (HCHP and LCHP) had a significantly lower milking frequency ($P<0.01$), longer milking interval per visit ($P<0.01$), higher milk yield per visit ($P<0.01$) lower milk yield per day ($P<0.01$), shorter milking duration per day ($P<0.01$) and less time waiting to be milked per day ($P<0.01$) (Table 1). Cows with the lower concentrate level (LCHP and LCLP) compared to cows with the higher concentrate level (HCHP and HCLP) had a significantly lower milking frequency ($P<0.05$), longer milking interval per visit ($P<0.05$), lower yield per visit ($P<0.01$), lower milk yield per day ($P<0.01$) and a shorter milking duration per day ($P<0.01$) (Table 2). Decreasing milking permission had a positive impact on cow traffic as cows spent significantly less time waiting to be milked. This effect was not observed by increasing concentrate supplementation; instead an increase in milk yield per visit and per day was achieved.

Conclusions

Reducing milking frequency reduced time spent waiting to be milked, which may benefit lower ranking cows providing them with increased opportunities to access the AMS and also reduce time spent standing on hard surfaces, thereby enhancing cow welfare. This study demonstrated that by implementing appropriate settings on an AMS it is possible to achieve a milk yield response to concentrate

Table 1. Effect of milking permission on milk yield (MY), milking frequency (MF), milking interval (MI), milking duration (MD) and waiting time (WT) per day and per visit.[1,2]

	Milking permission per day								
	3.2				1.8				P-value
	HCHP	LCHP	Group		HCLP	LCLP	Group		
	LS Means	LS Means	LS Means	SE	LS Means	LS Means	LS Means	SE	
MY day^{-1} (kg)	16.6	14.9	15.7	0.2	16.0	14.1	15.0	0.2	0.002
MY visit[-1] (kg)	8.4	7.8	8.1	0.2	11.5	10.7	11.1	0.2	<0.0001
MF day^{-1}	2.0	1.9	1.9	0.0	1.4	1.3	1.3	0.0	<0.0001
MI visit[-1] (hrs)	10.9	12.4	11.6	0.3	16.2	16.9	16.6	0.3	<0.0001
MD day^{-1} (min)	10.9	10.2	10.5	0.1	8.9	8.2	8.6	0.1	<0.0001
WT day[-1] (hrs)	1.9	2.4	2.1	0.1	1.5	1.6	1.6	0.1	0.003

[1] Least squares (LS) means and standard error (SE) are represented. Group denotes the combination of two treatments with respect to milking permission and concentrate supplementation.

[2] HCHP = high concentrate/high milking permission; LCHP = low concentrate/high milking permission; LCHP = low concentrate/high milking permission; LCLP = low concentrate/low milking permission.

Table 2. Effect of concentrate supplementation on milk yield (MY), milking frequency (MF), milking interval (MI), milking duration (MD) and waiting time (WT) per day and per visit.[1,2]

	Concentrate per day (kg)								
	3				0.84				P-value
	HCHP	HCLP	Group		LCHP	LCLP	Group		
	LS Means	LS Means	LS Means	SE	LS Means	LS Means	LS Means	SE	
MY day^{-1} (kg)	16.6	16.0	16.3	0.2	14.9	14.1	14.5	0.2	<0.0001
MY visit[-1] (kg)	8.4	11.5	10.0	0.2	7.8	10.7	9.3	0.2	0.008
MF day^{-1}	2.0	1.4	1.7	0.0	1.9	1.3	1.6	0.0	0.022
MI visit[-1] (hrs)	10.9	16.2	13.6	0.3	12.4	16.9	14.6	0.3	0.012
MD day^{-1} (min)	10.9	8.9	9.9	0.1	10.2	8.2	9.2	0.1	0.001
WT day[-1] (hrs)	1.9	1.5	1.7	0.1	2.4	1.6	2.0	0.1	0.230

[1] Least squares (LS) means and standard error (SE) are represented. Group denotes the combination of two treatments with respect to milking permission and concentrate supplementation.

[2] HCHP = high concentrate/high milking permission; LCHP = low concentrate/high milking permission; LCHP = low concentrate/high milking permission; LCLP = low concentrate/low milking permission.

supplementation in the latter stages of lactation. This research suggests management strategies involving reduced milking frequency and increased concentration supplementation towards the latter stages of lactation, in an effort to maintain milk yield and reduce pre-milking waiting time.

References

Lyons N.A., Kerrisk K.L. and Garcia S.C. (2013) Comparison of 2 systems of pasture allocation on milking intervals and total daily milk yield of dairy cows in a pasture-based automatic milking system. *Journal of Dairy Science* 96, 4397-4405.

Scott V.E., Thomson P.C., Kerrisk K.L. and Garcia S.C. (2014) Influence of provision of concentrate at milking on voluntary cow traffic in a pasture-based automatic milking system. *Journal of Dairy Science* 97, 1481-1490.

Regional animal feed centre as an intermediary between fodder farming and milk production

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Abstract

A regional feed centre buys crops from grassland farmers and arable farmers. These crops can provide roughage or concentrates for dairy cows. It processes these fodders into balanced total mixed rations (TMR) and delivers them to dairy farmers. A feed centre makes it possible to optimize fodder production at the regional level rather than at the farm level. It also stimulates arable farmers to grow fodder, like they produce concentrates, for the dairy sector. Calculations of another exploratory study (Walsum et al., 2014) showed that optimization of fodder production at regional level reduces nutrient losses to surface water by 10-20%. The advantage of a regional feed centre for dairy farmers is that they can outsource the storage of fodder and feeding of the cows. On the other hand, the feed centres provide an additional service that costs money and give more traffic. The cost of a feed centre depends on its size and its distance to fodder farmers and dairy farmers. A large feed centre creates less overhead costs, but more traffic. Therefore a model calculation (Waterwijs) has been made for the region 'The Peel' in the Province Brabant. In this study arable farmers grow 60% of the concentrates requirement of the dairy cows. This model optimizes the number and locations of the feed centres by minimizing the total overhead costs of the feed centres and the total transport cost of fodder (roughage and concentrates) to the feed centre and of TMR to the dairy farmers. When 10% of the total number of 150,000 dairy farmers participate in 'The Peel' the optimum is two feed centres. In this optimal situation the total cost of the service of a feed centre and transport is € 2 per 100 kg milk.

Keywords: dairy, feed centre, minimize cost, regional collaboration, spatial optimization

Introduction

In the current situation each dairy farmer and arable farmer optimizes his land use at the farm level. Dairy farmers also buy their concentrates from the compound feed factory. Consequently, dairy farming in the Netherlands partly relies on the import of foreign feed concentrates. This causes an extra burden on the environment due to the import of nutrients that end up leaching into surface water and groundwater. A regional feed centre makes it possible to optimize land use at a regional level. It is intermediate between fodder farming and milk production. It buys crops (fodder) from grassland farmers and arable farmers, makes a total mixed ration (TMR) and delivers it to dairy farmers. This service and the transport of the crops (fodder) and TMR cost money. The aim of another exploratory study (Walsum et al., 2014) was to calculate the environmental impact of optimization of crop production at a regional level rather than at farm level and by using more regionally grown concentrates. The aim of the study reported here is to minimize the total cost of the feed centre and transport. A few large feed centres will give more traffic, but provide less overhead costs. The main question is: How many feed centres and at what location will provide the lowest total cost?

Materials and methods

To minimize the total costs for a feed centre and traffic we used the model 'Waterwijs'. This model optimizes the number and locations of the regional feed centres (Van Walsum et al., 2014). It has been applied for two scenarios. One scenario where all dairy farmers with a total of 150,000 dairy cows in the region 'The Peel' make use of a regional feed centre and one scenario where 10% of the farmers participate.

In another exploratory study (Van Walsum *et al.*, 2014) the model 'Waterwijs' is used to calculate the environmental impact of optimization of land use at a regional level rather than at the farm level.

Results and discussion

The exploratory study on the impact of land use change in the region 'De Peel' in the Province Brabant of the Netherlands has shown that spatial optimization of land use conversion resulted in 10 to 20% reduction in nitrogen and phosphorus leaching (Van Walsum *et al.*, 2014). In this case 60% of the foreign feed concentrates were replaced by regionally grown crops.

The results of the impact of a feed centre on all the different costs for the situation with a total of 150,000 cows in the region, of which 10% (15,000 cows) are fed by a regional feed centre are shown in Table 1.

The number of feed centres varies from 1 to 10. If all the cows are fed by a feed centre there is a wide range for the optimal number of feed centres, namely 5 to 10. In the situation with fewer than 5 centres the traffic costs will increase too much.

But it is not realistic that all farmers will join the feed centre. Therefore a situation has been simulated in which 10% of the cows are fed by a feed centre. In that situation the optimum is two feed centres. The total of overhead costs of the feed centre (labour, machinery, storage, location) and traffic (supply of feed stuffs from arable and dairy farmers to the feed centres and delivery of TMR to dairy farmers) are lowest with these two centres. The optimal locations are shown in Figure 1, with traffic of crops and total mixed ration (TMR).

The total costs for a regional feed centre, for the optimal situation, are €2.5 million for 15,000 cows. Based on this, the total costs of the feed centre and transport will increase by almost 2 € per 100 kg milk. For some farmers this would still be profitable. Calculations in another study have shown that the cost for the dairy farmer can be €1.80 to €3.30 per 100 kg milk lower, due to less labour and machinery for feeding and less feed storage (Galama *et al.*, 2012).

Table 1. Cost for a feed centre and traffic with an increasing number of feed centres for two scenarios: 150,000 cows (all farms) and 15,000 cows (10%).

Number of feed centres	Capacity (M ton year^{-1})		Average distance (km)		Costs (M€ year^{-1})			
	Supply crops	Deliver TMR[1]	Supply crops	Deliver TMR	Feed centre	Supply crops	Deliver TMR	Total costs
Feed centre for 150,000 cows								
1	2.7	2.5	29.1	27.4	14.2	6.1	7.4	27.7
2	2.7	2.5	20.7	19.6	14.5	4.3	5.3	24.1
3	2.7	2.5	17.2	15.6	14.7	3.6	4.2	22.6
4	2.7	2.5	14.0	12.7	14.	3.0	3.4	21.3
5	2.7	2.5	12.7	11.4	15.1	2.7	3.1	20.9
6	2.7	2.5	11.4	10.2	15.4	2.4	2.8	20.6
7	2.7	2.5	10.8	9.7	15.7	2.3	2.6	20.6
8	2.7	2.5	10.0	9.0	15.9	2.1	2.4	20.5
9	2.7	2.5	9.7	8.3	16.1	2.1	2.3	20.5
10	2.7	2.5	9.2	8.2	16.4	2.0	2.2	20.6
Optimized feed centre for 15,000 dairy cows (10% of region)								
2	0.27	0.25	4.5	19.6	1.88	0.09	0.53	2.5

[1] TMR = total mixed ration.
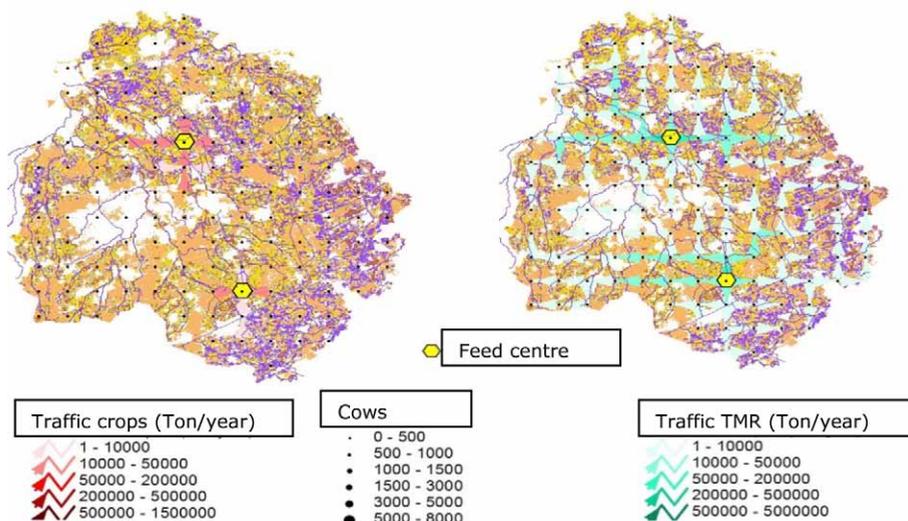
Figure 1. Optimal location for two feed centres in region 'The Peel', for 10% of dairy cows.

Conclusions

Regional feed centres can play an important role in optimizing the growing of crops at a regional level and stimulate collaboration between arable and dairy farmers. For the situation in 'The Peel', if 10% of the dairy farmers were to participate in a feed centre the lowest total overhead costs of the feed centre and transport would be achieved with two feed centres. The extra total costs are in that situation would be €2 per 100 kg milk. This can still be profitable for dairy farmers, because they save costs on labour and machinery for feeding and feed storage. This study and another study with the model 'Waterwijs' have shown that a regional feed centre, as an intermediate stage for optimizing crop rotation and feeding at regional level instead of at farm level, can be promising from an economic and environmental point of view.

Acknowledgements

References

Galama P. and Van den Pol-van Dasselaar A. (2012) Sustainability of a regional feed centre. *Grassland Science in Europe* 17, 768-770.

Van Walsum, P.E.V., Galama P., Roelsma J., Cormont A. and Hack-ten Broeke M.J.D. (2014) *Ruimtelijke optimalisatie van voederstromen in de Peel, Nieuwe landgebruiksvormen en clustering ten behoeve van regionale productie van veevoer*. Alterra Report, Wageningen, the Netherlands.

Comparing the *in vivo* dry matter digestibility of perennial ryegrass in sheep and dairy cows

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Abstract

Pre-grazing herbage mass (PGHM) affects grass quality and intake. Higher PGHM swards usually have lower dry matter intake (DMI) and *in vitro* dry matter digestibility (DMD) than lower PGHM swards, leading to reduced performance in lactating dairy cows. *In vivo* digestibility experiments involving cows are often laborious and expensive and, as a result, sheep are often used instead. The objective of this experiment was to compare the *in vivo* DMD of perennial ryegrass (*Lolium perenne* L.) at high and low PGHM in lactating dairy cows and wether sheep. A Latin-square design experiment was repeated twice (TS1 (April-May) and TS2 (July-August)) using eight wether sheep and eight spring-calving lactating dairy cows to determine the *in vivo* DMD of two different PGHM swards (1,700 kg dry matter (DM) ha^{-1} (low mass; LM) and 4,000 kg DM ha^{-1} (high mass; HM)). There were no interactions between PGHM, animal species and TS. The *in vivo* DMD of perennial ryegrass reduced from LM to HM and from TS1 to TS2. There was a tendency for cows to have lower *in vivo* DMD of perennial ryegrass than sheep. The greater *in vivo* DMD of LM compared to HM may be due to the greater proportion of leaf and lower true stem proportion in LM. As there were no interaction effects on *in vivo* DMD, sheep DMD and cow DMD are similar to each other across all PGHM and all seasons.

Keywords: digestibility, cows, sheep, perennial ryegrass

Introduction

Grass is a cheap and nutritious feed and Shalloo (2009) identified grass quality and grass utilisation as key components of profitability in grass-based dairy production systems. Dry matter digestibility (DMD) is a common measurement of grass quality. High sward DMD is essential to the delivery of good nutrition to dairy cows. In order to provide high DMD grass to dairy cows it is essential to measure factors that affect sward quality. A major factor is pre-grazing herbage mass (PGHM), which has a substantial effect on the DMD of a sward (Wims *et al.*, 2010). There is further need to quantify the effects of PGHM on DMD, including sward morphology measurements in order to understand these effects more clearly. Also, as sheep are routinely used as the model animal for *in vivo* digestibility evaluation, the suitability of using sheep as a model animal for predicting digestibility in dairy cows must be evaluated.

Materials and methods

Eight wether sheep and eight spring-calving lactating dairy cows were used to determine the *in vivo* DMD of two treatments; namely, two different PGHM (1,700 kg dry matter (DM) ha^{-1} – low mass (LM) and 4,000 kg DM ha^{-1} – high mass (HM)). A Latin square design experiment (2 (treatments) × 2 (periods)) was repeated twice (time stage (TS) 1: April-May 2014, TS2: July-August 2014). Each TS had two periods of 12 days per period: six days adaptation phase and six days measurement phase (MP). The sheep and cows were housed in individual stalls to allow for individual feeding and for total faecal collection. Sheep were blocked on body weight (TS1 51±2.0 kg, TS2 67±3.9 kg), while cows were blocked on body weight (TS1 547±29.2 kg, TS2 509±34.7 kg), milk yield (TS1 26.2±3.16 litres day^{-1}, TS2 24.4±1.99 litres day^{-1}) and milk solids yield (TS1 2.2±0.51 kg day^{-1}, TS2 1.86±0.10 kg day^{-1}) at the start of each TS.

Fresh grass was cut daily using a Pottinger mower and silage wagon (Pottinger M. GmbH, Grieskirchen, Germany). Sheep and cows were fed grass *ad libitum* (110% of DMI) and grass DMI was recorded daily. Pre-grazing herbage mass was measured using a Gardena hand shears (Accu 60, Gardena Int. GmbH, Ulm, Germany) and a 0.25 m^2 quadrat four times during each period. On day 8 of each period a 40 g sample of each PGHM was separated into leaf, pseudostem, true stem and dead proportions >4 cm. During the MP, a representative sample of the grass offered to, and faeces voided by, each sheep and cow was collected daily. The daily grass and faeces samples were dried and then bulked to give one sample of each per PGHM per MP for each species. Dry matter digestibility was calculated as (kg DM ingested – kg DM output in faeces) kg^{-1} DM ingested. The DMD data were analysed using PROC MIXED in SAS (2002). Pre-grazing herbage mass, period within TS, TS, species and the interactions between TS, species and PGHM were included as fixed effects. Animal was included as the random effect. The sward morphology data were analysed using PROC MIXED in SAS (2002). Fixed effects included PGHM, period within TS, TS, and the interaction between TS and PGHM.

Results and discussion

No significant interaction effects between animal species, TS and PGHM were found on *in vivo* DMD (Table 1). This was an important finding as it indicated that the species effect on DMD was consistent across the different times of the year evaluated, and across different PGHM. There was a tendency (P=0.09) for sheep to have greater *in vivo* DMD than dairy cows. Average sheep DMD was +13 g kg^{-1} compared to average cow DMD (739 g kg^{-1}). The similarity of the two species is in contrast to the findings of Reid *et al.* (1990) who found that cows have greater DMD than sheep. However in that study, non-lactating dairy cows were used and grass was fed as hay. The lower DMD in cows in this study may be due to the greater level of intake by the cows (the cows consumed 2.93% of bodyweight, compared to 2.17% of bodyweight consumed by sheep). The greater intake could result in faster passage rate of feed through the lactating cows, resulting in decreased feed digestibility, as found by Shaver *et al.* (1986). There was an effect of PGHM on *in vivo* DMD as LM swards had greater DMD than HM swards (P<0.01). This is similar to the findings of Curran *et al.* (2010) who found that high PGHM swards (2,400 kg

Table 1. The effect of pre-grazing herbage mass (PGHM) on grass *in vivo* dry matter digestibility (DMD) in wether sheep and spring-calving lactating dairy cows in two time stages (TS).

	PGHM	Species	DMD (g kg^{-1})
TS1 (April-May)	High	Sheep	756
		Cow	745
	Low	Sheep	783
		Cow	774
TS2 (July-August)	High	Sheep	730
		Cow	697
	Low	Sheep	740
		Cow	739
Significance[1]		SED	15.0
		PGHM	**
		TS	***
		Species	†
		PGHM × TS	ns
		PGHM × Species	ns
		TS × Species	ns
		PGHM × TS ×Species	ns

[1] SED = standard error of difference; ** *P*<0.01; *** *P*<0.001; †<0.1; ns = not significant.

Table 2. The effect of pre-grazing herbage mass (PGHM) on sward leaf, stem and dead proportions in two time stages (TS).[1]

	TS1 (Apr-May)		TS 2 (Jul-Aug)		SED	Significance[2]		
	High PGHM	Low PGHM	High PGHM	Low PGHM		PGHM	TS	PGHM × TS
Leaf %	43.5	59.5	45.8	69.8	4.0	***	†	ns
Pseudostem %	24.3[a]	26.3[a]	19.5[ab]	12.5[b]	2.3	ns	**	*
True stem %	22.3	8.5	23.8	3.3	4.3	**	ns	ns
Dead %	9.5[ab]	6.0[a]	11.5[ab]	14.3[b]	2.2	ns	**	†

[1] SED = standard error of difference. Values in rows with different superscript letters are significantly different.

[2] * $P<0.05$; ** $P<0.01$; *** $P<0.001$; †<0.1; ns = not significant.

DM ha^{-1} >4 cm) had lower *in vitro* organic matter digestibility than low PGHM swards (1,600 kg DM ha^{-1} >4 cm). This result was explained by the fact that the LM swards had a greater leaf proportion and lower true stem proportion than the HM swards ($P<0.01$) (Table 2). The TS also had an effect on *in vivo* DMD with greater DMD in TS1 swards than in TS2 swards ($P<0.01$). The dead proportion of swards was greater in TS2 than in TS1, which may have contributed to the reduction in DMD. Garry *et al.* (2014) found similar effects of PGHM and sward morphology on *in vivo* DMD when evaluated with sheep alone.

Conclusions

There were no effects of the interaction between PGHM, TS and animal species on *in vivo* DMD, despite a tendency for animal species to differ for DMD. Calculations relating to organic matter digestibility are pending and will allow definitive conclusions to be made regarding the relationship between cow and sheep digestibility. Both PGHM and time of year have significant effects on sward digestibility. *in vivo* DMD was greater in low PGHM swards with greater leaf proportion and in swards in spring.

References

Curran J., Delaby L., Kennedy E., Murphy J.P., Boland T.M. and O'Donovan M. (2010) Sward characteristics, grass dry matter intake and milk production performance are affected by pre-grazing herbage mass and pasture allowance. *Livestock Science* 127(2/3), 144-154.

Garry B., O'Donovan M., Boland T.M. and Lewis E. (2014) Effect of pre-grazing herbage mass on *in vivo* digestibility and dry matter intake of perennial ryegrass in sheep. In: *Proceedings of the 30th biennial conference of the Australian Society of Animal Production*, 8-12 September 2014, Canberra, Australia, pp. 248.

Reid R.L., Jung G.A., Cox-Ganser J.M., Rybeck B.F. and Townsend E.C. (1990) Comparative utilization of warm- and cool-season forages by cattle, sheep and goats. *Journal of Animal Science* 68(9), 2986-2994.

Shalloo, L. 2009. Milk production costs – Can we compete? In: *Proceedings of the Teagasc National Dairy Conference*, 18 November 2009, Mullingar, Ireland, pp. 19-38.

Shaver R.D., Nytes A.J., Satter L.D. and Jorgensen N.A. (1986) Influence of amount of feed intake and forage physical form on digestion and passage of prebloom alfalfa hay in dairy cows. *Journal of Dairy Science* 69(6), 1545-1559.

Wims C.M., Deighton M.H., Lewis E., O'Loughlin B., Delaby L., Boland T.M. and O'Donovan M. (2010) Effect of pregrazing herbage mass on methane production, dry matter intake, and milk production of grazing dairy cows during the mid-season period. *Journal of Dairy Science* 93(10), 4976-4985.

The use of radar images for detecting when grass is harvested and thereby improve grassland yield estimates

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Abstract

Cutting date and frequency are important parameters which, together with weather, soil conditions, botanical composition and fertilizer, determine grassland yields. However, cost- and time-efficient methods for recording cutting dates of grassland are currently lacking. Therefore, we developed a method for detecting cutting dates using changes in radar images of the sward surface. The combination of this method with a grassland yield model will result in more reliable and region-wide data on grassland yield estimates. For determining when grassland has been cut, robust amplitude-change detection techniques were used evaluating the amplitude or backscatter statistics before and after the cutting events in a test area in Germany. All detected cuts were verified according to *in situ* measurements and recorded in a GIS database. This method will be further adjusted to Sentinel-1 data which will then enable an area-wide and cost-efficient cutting-date detection service. The cutting frequency and yield data gained by this method are essential for optimising the use of grassland, for yield adjusted fertilisation, and the assessment of unused potential of grassland for alternative energies (e.g. biogas, solid fuel).

Keywords: radar, change detection, Sentinel-1, grassland, cutting date, forage yield model

Introduction

Although grasslands are essential for the livelihood of millions of people, accurate and area-wide data on grassland yields are generally not available. Cutting date and frequency are important parameters which can determine grassland yield, in addition to the effects on yield of climate, soil, plant composition and fertilisation. Thus, these parameters are required for yield modelling (Herrmann *et al.*, 2005). In the absence of yield data, cutting frequency is also currently used to calculate amounts of fertiliser for managed grassland (Wendland *et al.*, 2012). Therefore, a method to record dates when grass is harvested over large areas would not only improve estimations of grassland yields and sustainable use of fertiliser, but could also be relevant for questions of nature conservation. For example, moderately extensively used grassland can be detected, and the designation and linking of protected areas might therefore be improved (Herben and Huber-Sannwald, 2002). Thus, it is necessary to find a cost- and time-efficient method to detect cutting dates for whole regions or countries. Remote sensing techniques are useful to monitor surface changes (e.g. structure, height) for large areas. So far, it has been very expensive to get the necessary satellite images with high time resolutions for wide areas. The new European earth observation programme Copernicus has developed a set of satellites (called Sentinel) which will cover the entire world's land masses at least on a bi-weekly basis. The European Space Agency and the European Commission provide the data obtained with Sentinels on an open and free basis. The first Copernicus satellite, Sentinel-1A, carrying a radar system, was launched in April 2014 and radar images are now available routinely every 12 days and systematically for land monitoring (ESA, 2014). Together with the identically constructed Sentinel-1B (launch 2016) the revisit time of each point will be shortened to 6 days. This study aims to investigate the applicability of Sentinel-1 radar data for the derivation of agricultural information. It focusses on the detection of cutting dates in grassland as changes in the radar backscatter. Cutting of grass significantly affects the surface or vegetation structure of the grassland (height, density, shape) and therefore results in changes of the backscatter intensity of the radar signals. By comparing the reflection signals over a set of radar images acquired at a high temporal sampling frequency

or with short time interval, cuts are expected to be detectable using change detection techniques and finally temporally classified. The application of change detection methods is therefore promising since the cuts and harvest events are temporally sampled in an adequate way.

Materials and methods

For the first phase of the project a series of radar images acquired by the COSMO-SkyMed Constellation was used, as the Sentinel-1A data were not yet available. Images of the 3, 7 and 15 October 2014 were evaluated. All images were HH polarized X-band full-resolution single-look complex slant data acquired in HImage mode. The radar images were georeferenced using a digital terrain model (Range Doppler Terrain Correction, SRTM) and reprojected to the coordination system 3-degree-Gauss-Krüger zone 4. For analysis and comparison the radar images were radiometrically calibrated. The corrected amplitude data was resampled to 3 m and transformed to the logarithmic scale (dB). Two kinds of filters were tested to reduce speckle and to improve the image quality: a multitemporal filter (window size 5×5) and an adaptive Frost filter (window size 7×7). All image processing was performed with SARscape (ENVI) and ERDAS Imagine. Radar data were exported as GeoTIFF (unsigned 8-bit) to visualize and analyse data in a GIS environment. Radar data were overlaid with a shapefile including a map of grassland plots with cutting dates from *in situ* measurements. The grey values of each image represent the strength of the radar return. For a qualitative comparison grey level statistics were calculated for each grassland plot illustrating the backscatter or intensity change before and after an area of grassland had been harvested.

Results and discussion

Alterations in the grey values of radar images showed modified radar backscatter signals due to surfaces changes in the test area (Figure 1). These changes were caused by grassland cuttings, which could be verified by *in situ* measurements. In order to estimate the separability of cut and uncut grassland, mean grey values of each image were extracted and compared. Differences in means and therefore detection of the grassland cut were usually more pronounced when an image was filtered with an adaptive Frost filter (AFF) compared to the multitemporal filter (MTF, Figure 1). Of 191 tested plots (covering in total 510 ha) 171 and 135 cuts were detected using AFF and MTF, respectively. In using AFF on radar images, cuts on plots were also detected, where MTF images revealed only small (Table 1, plot 6) or no changes (plot 3 and 5) in the means of grey values. For the comparison of the plots cut between 3 and 7 October, the MTF filter showed higher differences in the grey values corresponding to approx. 3 dB. The decreased separability was caused by an ineffective filtering using the MTF, resulting in a higher remaining noise level that corresponds to a standard deviation of up to 3.5 dB (which is in the range of the mean differences). In this case the number of images was limited and minimal. By increasing the

Figure 1. Alteration in radar backscatter signal/grey value (images: 3, 7 and 15 October 2014) by grassland cuts in a part of the test area; *in situ* measurements detected grassland cuts on all 6 plots during this time period (black frame: cut between 3-7 October; white: cut between 7-15 October).

Table 1. Comparison of grey values in filtered radar images of selected grassland plots; given are plot size (ha), mean grey value per plot and radar images (3, 7, 15 October 2014) filtered with multitemporal (MTF) and adaptive Frost (AFF) filter, as well as difference in means between dates.[1]

Plot	Area (ha)	Mean grey value						Differences in means between dates			
		MTF			AFF			MTF		AFF	
		3 Oct	7 Oct	15 Oct	3 Oct	7 Oct	15 Oct	3-7 Oct	7-15 Oct	3-7 Oct	7-15 Oct
1	2.6	126	153	135	123	149	135	-27	18	-26	14
2	1.4	133	151	144	133	147	146	-18	7	-14	1
3	1.5	118	113	108	115	101	104	5	5	14	-3
4	2.4	91	90	99	85	71	95	1	-9	14	-24
5	1.6	117	108	101	112	94	96	9	7	18	-2
6	2.2	126	125	128	122	115	127	1	-3	7	-12

[1] Negative values show detected cuts by mean grey value comparison, bold numbers mark *in situ* detected cuts (plot 1 and 2 were cut between 3-7 October, other plots between 7-15 October).

number of images (for MTF) in an operational real setting the filter effect will be improved. A statistically sound analysis of separability and temporal statistics of plots will be conducted based on an increased number of acquisitions.

Conclusions

This study shows that grassland cuts can be detected using radar images of chronologically close dates. A speckle reduction with an adaptive Frost filter seemed to be more suitable to prepare the radar images for cut detection by mean grey value comparison. In the next steps, this method will be adjusted to Sentinel-1 data. After the detection process is automated, regional-wide changes of grassland management (indicated by cutting frequency) can be efficiently assessed. This automatically gained data can be integrated into a yield model.

References

ESA (European Space Agency) (2014) *Observing the Earth – Copernicus – Sentinel 1 facts and figures*. Available at: http://tinyurl. com/noxycuk.

Herben T. and Huber-Sannwald E. (2002) Effect of management on species richness of grasslands sward-scale processes lead to large-scale patterns. *Grassland Science in Europe* 7, 635-643.

Herrmann A., Kelm M., Kornher A. and Taube F. (2005) Performance of grassland under different cutting regimes as affected by sward composition, nitrogen input, soil conditions and weather – a simulation study. *European Journal of Agronomy* 22, 141-158.

Wendland M., Diepolder M. and Capriel P. (2012) *Leitfaden für die Düngung von Acker- und Grünland (Gelbes Heft)*, 10th edition. Bayerische Landesanstalt für Landwirtschaft, Freising, Germany.

Effect of sulphur fertilization on the rate of photosynthesis and yield of *Lolium × boucheanum* Kunth cultivated in monoculture and mixture with *Trifolium repens* L.

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Abstract

The aim of this study was to determine the effect of sulphur fertilization on the rate of photosynthesis and yield of hybrid ryegrass (*Lolium × boucheanum*) grown in monoculture and mixture with white clover (*Trifolium repens*). The study was conducted in a split-plot design with four replications. Soil conditions were degraded chernozem formed from loess. The fertilization scheme was 50 and 100 kg N ha^{-1}, 35 kg P ha^{-1}, 83 kg K ha^{-1}, and sulphur at 5, 10 and 15 kg S ha^{-1}. The intensity of photosynthesis was measured in each regrowth at weekly intervals using a portable gas analyser (Li-Cor 6400). Plants were mown 3 times during the growing season. Both nitrogen and nitrogen-with-sulphur fertilization positively influenced the rate of photosynthesis in each regrowth. Sulphur fertilization compared to nitrogen fertilization increased the rate of photosynthesis in hybrid ryegrass grown in monoculture. Total dry matter yields of hybrid ryegrass grown in monoculture were lower than in mixture with white clover, irrespective of the amount of nitrogen or nitrogen-and-sulphur fertilization. The biggest difference in yields between the monoculture and the mixture was found with 100 kg N and 15 kg S ha^{-1}. The smallest difference was shown in treatments fertilized with 50 kg N and 5 kg S ha^{-1}.

Keywords: *Lolium*, sulphur, photosynthesis, yield

Introduction

Sulphur deficiency occurs especially in crop production with intensive nitrogen fertilization. There is concern that the traditionally used NPK fertilization is not balanced and the deficit of sulphur may limit the use of the other ingredients, mainly nitrogen (Morris, 2007). Currently, studies on the reduction and prevention of sulphur deficiency generally focus on species with high demand for this element (Lošak and Richter, 2003). Most studies have been carried out with rapeseed, some with cereals, and only a few studies relate to plants of the families *Fabaceae* and *Poaceae* (Richards, 1990; Sator *et al.*, 2002; Zhao *et al.*, 2006). Hence, the aim of this study was to determine the effect of sulphur fertilization on the rate of photosynthesis and yield of hybrid ryegrass (*Lolium × boucheanum*) grown in monoculture and mixture with white clover (*Trifolium repens*).

Material and methods

The study was conducted in 2007-2009 in a split-plot design with four replications, on plots of 12 m^2. The study included hybrid ryegrass (tetraploid variety Gala) grown in monoculture and in mixture (50% of seeding rate) with white clover (variety Romena). Total annual precipitation during the study period ranged from 581 to 700 mm, and during the vegetation period from 358 to 478 mm. Average annual temperature ranged from 7.9 and 8.6 °C and in the vegetation period from 15.2 to 16.0 °C. Long-term (1977-2013) mean total annual precipitation was 690 mm, and during the vegetation period 466 mm. Average long-term annual temperature was 8.4 °C and for the vegetation period 15.2 °C. Soil conditions were as follows: degraded chernozem formed from loess; pH$_{KCl}$ 6.5; organic carbon 24.7 g kg^{-1}; total nitrogen 1.8 g N kg^{-1}; total sulphur 321.5 mg S kg^{-1}; phosphorus 62.5 mg P kg^{-1}; potassium 136.7 mg K kg^{-1}; and magnesium 54.9 mg Mg kg^{-1}. Fertilization treatments included: nitrogen 50 and 100 kg N

ha^{-1}; phosphorus 35 kg P ha^{-1}; and potassium 83 kg K ha^{-1}. Foliar fertilization with sulphur was supplied at 5, 10 and 15 kg S ha^{-1}.

The intensity of photosynthesis was measured using a portable gas analyser Li-Cor 6400. The indicators were determined at 400 ppm CO_2 concentration and the light conditions 1000 μmol m^{-2} s^{-1}. Measurements were performed on the youngest, but fully developed leaves, which were selected randomly from each plot. In each regrowth four measurements were performed at weekly intervals. Plants were mowed 3 times during the growing season. The results were statistically analysed by performing an analysis of variance. The significance of differences was verified by Tukey test with a confidence level α=0.05.

Results and discussion

Both nitrogen and nitrogen-with-sulphur fertilization positively influenced the rate of photosynthesis in each regrowth. Extra sulphur fertilization compared to nitrogen fertilization increased the rate of photosynthesis in hybrid ryegrass grown in monoculture in treatments fertilized with 50 kg N and 100 kg N (Table 1). Additional sulphur fertilization of mixtures resulted in an increase in the intensity of photosynthesis in plants at fertilization rate 100 kg N and 15 kg S ha^{-1} only. Photosynthesis in plants proceeded more intensively in the second regrowth, which could be due to the favourable air temperatures. The intensity of photosynthesis depends on, amongst other things, the temperature at which the plants grow. For most plants a temperature of 26 °C is considered as optimal (Olszewska, 2003).

Total dry matter yields of hybrid ryegrass grown in monoculture were lower than in mixture with white clover irrespective of the amount of nitrogen or nitrogen-and-sulphur fertilization. The biggest difference in yield between monoculture and mixture was found with 100 kg N and 15 kg S ha^{-1} (Table 2). The smallest difference was shown in treatments fertilized with 50 kg N and 5 kg S ha^{-1}. The positive impact of nitrogen and sulphur on the amount of dry matter yield of plants was also shown by Zhao *et al.* (1999).

Conclusions

Both fertilization with nitrogen alone, and nitrogen-with-sulphur, positively influenced the rate of photosynthesis in the analysed plants. The cumulative dry matter yield of hybrid ryegrass grown in monoculture was lower than that of mixtures, regardless of the amount of nitrogen or nitrogen-and-sulphur applied. Practical recommendations of sulphur supply resulted from the highest yield of the crops, and this may be application of 100 kg N with 10 kg S ha^{-1}.

Table 1. Intensity of photosynthesis of the plants (μmol CO_2 m^{-2} s^{-1}).

Fertilization treatment[1]	*Lolium × boucheanum*			*Lolium × boucheanum + Trifolium repens*		
	Cuts			Cuts		
	1	2	3	1	2	3
Control	15.67	16.79	14.57	15.34	17.62	16.53
N_{50}	16.04	19.36	17.61	16.65	20.52	18.90
N_{100}	15.52	18.90	16.53	15.84	19.47	17.12
$N_{50}+S_5$	15.25	17.10	16.84	15.61	18.53	17.67
$N_{50}+S_{10}$	18.74	21.28	20.39	18.07	19.89	18.75
$N_{50}+S_{15}$	15.48	18.37	17.15	15.86	18.20	15.68
$N_{100}+S_5$	16.51	20.13	17.81	16.47	17.88	16.94
$N_{100}+S_{10}$	17.29	20.75	18.47	16.23	19.43	17.07
$N_{100}+S_{15}$	19.32	21.82	18.25	17.30	20.54	18.21
$LSD_{0.05}$	2.60	3.40	2.43	2.60	2.36	2.78

[1] Fertilization: N_{50} = 50 kg N ha^{-1}; N_{100} = 100 N kg ha^{-1}; S_5 = 5 kg S ha^{-1}; S_{10} =10 kg S ha^{-1}; S_{15} = 15 kg S ha^{-1}. LSD = least significant difference.

Table 2. Average dry matter yield (Mg ha^{-1}).

Fertilization treatment[1]	Lolium × boucheanum			Lolium × boucheanum + Trifolium repens		
	Cuts			Cuts		
	1	2	3	1	2	3
Control	1.65	0.85	0.52	2.02	1.10	0.77
N_{50}	4.15	1.79	0.85	5.21	2.49	1.07
N_{100}	7.97	3.57	1.51	7.89	4.63	2.19
$N_{50}+S_5$	6.14	2.18	1.04	6.52	2.62	1.47
$N_{50}+S_{10}$	5.98	2.47	1.32	7.16	2.95	1.27
$N_{50}+S_{15}$	5.73	2.27	0.96	6.89	2.79	1.36
$N_{100}+S_5$	8.35	4.21	2.03	9.15	4.30	2.16
$N_{100}+S_{10}$	8.53	4.37	2.17	9.53	4.27	2.41
$N_{100}+S_{15}$	7.61	4.45	1.96	9.34	4.52	2.19
$LSD_{0.05}$	1.24	0.88	0.53	1.14	0.70	0.55

[1] Fertilization: N_{50} = 50 kg N ha^{-1}; N_{100} = 100 N kg ha^{-1}; S_5 = 5 kg S ha^{-1}; S_{10} =10 kg S ha^{-1}; S_{15} = 15 kg S ha^{-1}. LSD = least significant difference.

References

Lošak T. and Richter R. (2003) The influence of nitrogen and sulphur on the yield and oils content of winter rape. *Fertilizers Fertilization* 4, 160-168.

Morris R.J. (2007) *Sulphur in agriculture*. *Global overview*. Fertilizer Focus 2007(1/2), 12-16.

Olszewska M. (2003) Influence of water stress on intensity of photosynthesis, chlorophyll content and yielding of *Dactylis glomerata* L. cultivars. *Biuletyn Instytutu Hodowli i Aklimatyzacji Roślin* 225, 229-237 (in Polish with English summary).

Richards I.R. (1990) Sulphur as a crop nutrient in the United Kingdom. *Sulphur in Agriculture* 14, 8-9.

Sator Ch., Rogasik J. and Schnug E. (2002) Influence of sulfur nutrition on yield and dietary quality of lupin seeds. In: *Proceedings of the 10th International Lupin Conference,* Laugarvatn, Iceland, pp. 1-4.

Zhao F.J., Wood A.P. and McGrath S.P. (1999) Sulphur nutrition of spring peas. *Annals of Applied Biology* 56, 189-194.

Zhao F.J., Fortune S., Barbosa V.L., McGrath S.P., Stobart R., Bilsborrow P.E., Booth E.J., Brown A. and Robson P. (2006) Effects of sulphur on yield and malting quality of barley. *Journal of Cereal Science* 43, 369-377.

Concentrations of micro-nutrients in forage legumes and grasses harvested at different sites

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Abstract

Forage is a major source of micronutrients for dairy cows. This study examined the concentrations of micronutrients in birdsfoot trefoil (Bf), red clover (Rc), timothy (Ti) and meadow fescue (Mf) at different sites, years and cutting dates. Mixtures of Bf+Ti, Rc+Ti and Rc+Mf were established at Skara (58°21'N; 13°08'E) and Umeå (63°45'N; 20°17'E) in Sweden. First-year leys (Umeå 2005, Skara 2005 and 2007) were cut on three occasions in spring relative to the maturity stage of timothy: one week before heading, at heading and one week after heading. Summer growth was cut six weeks after each of the three occasions in spring growth. The results show that there was a need for Cu supplementation in all treatments because of low Cu concentration. The relatively high Mo concentrations compared to the Cu concentration in both grasses at Skara, in Mf in second cut at Umeå, and in Bt in the second cut at Skara may further increase the demand for Cu supplementation in dairy cow rations because there is a risk that Cu can be bound to a sulphate-Mo-complex in the rumen. The Zn concentration was lower than required for dairy cows, except for the mixture with Ti and Rc in the second cut at Umeå. For Mn and Fe, concentration levels were appropriate for expected dairy cow requirements for all treatments.

Keywords: forages, grass, harvest time, legumes, micronutrients

Introduction

Micronutrients are important for health and production in dairy cattle systems (Suttle, 2010). Forage is a major source of micronutrients for dairy cows (Whitehead, 2000). The concentrations can be affected by different factors such as soil properties, especially pH (Lindström *et al.*, 2014), and harvest time and species (Høgh-Jensen and Søegaard, 2012). Despite the importance of micronutrients, it has not been common in practice to analyse their concentrations in forages. However, reduced costs for analysis and the objective of more sustainable production have increased interest in analysis, with the aim of reducing supplementation in cattle rations.

Materials and methods

Three field experiment was carried out at two sites in Sweden: (1) Lanna Research Station (58°21'N; 13°08'E; altitude 75 m.a.s.l.; silty clay loam; 3% organic matter (OM); pH: 7.2 (field for 2005) and 6.7 (field for 2007) at Skara and (2) Röbäcksdalen Research Centre (63°45'N; 20°17'E; altitude 5 m.a.s.l.; silty loam; 6% OM; pH: 6.4) at Umeå. Three mixtures: birdsfoot trefoil (*Lotus corniculatus* L.) + timothy (*Phleum pratense* L.) (Bt+Ti), red clover (*Trifolium pratense* L.) + timothy (Rc+Ti) and red clover + meadow fescue (*Festuca pratensis* Huds.) (Rc+Mf) were harvested as first-year leys (Umeå 2005, Skara 2005, Skara 2007). The cultivars were Bt (cv. Oberhaunstaedter), Ti (cv. Grindstad), Mf (cv. Kasper) and Rc (4n) (cv. Sara at Skara; cv. Betty at Umeå). The aim was to harvest at three different stages of maturity in the spring growth of timothy: one week before expected heading, at heading and one week after heading of timothy (Gustavsson, 2011). Samples from two blocks were sorted into sown legumes and grasses, dried and analysed for Fe, Zn, Cu, Mn and Mo with IPC-OES. A split-split-plot design was analysed using PROC MIXED (SAS, 2001). Grasses at spring growth, grasses in the second cut, legumes at spring growth and legumes in the second cut were analysed separately. The effects of site and

year (named YS) (n=3) was treated as main plot, mixture (n=3) as sub-plot and cutting date (n=3) as sub-sub-plot. Pair-wise comparisons between LSMEANS were analysed with Tukey's test at $P<0.05$.

Results and discussion

Mixtures at Skara contained more legumes than mixtures at Umeå, and mixtures with Rc had higher legume proportions than mixtures with Bt at both sites. Forages at Skara 2005 yielded more than at Umeå 2005 and Skara 2007 when averaged over mixture and cut in spring growth (5.7 vs 4.4 and 5.0 Mg DM ha^{-1}, respectively; $P<0.01$). In the second cut, the experiment at Umeå 2005 yielded more than the two Skara experiments (3.2 vs 2.3 and 2.6 Mg DM ha^{-1}, respectively; $P<0.0001$). Mixtures with Rc yielded more than mixtures with Bt, when averaged over YS and cut both in spring growth and in second cut (5.3 vs 4.5 Mg DM ha^{-1}; $P<0.0001$ and 2.9 vs 2.4 Mg DM ha^{-1}, respectively; $P=0.0008$). Averaged over YS and mixture, DM yield increased with later cutting date in spring growth (3.8, 5.1 and 6.2 Mg DM ha^{-1} for early, mid and late cut, respectively; $P<0.0001$). Second cut after early first cut resulted in higher DM yield than after later first cuts (3.0 vs 2.6 and 2.5 Mg DM ha^{-1}; $P<0.0001$). Despite a very fast increase in DM yield in spring growth, the effects of harvest time on micronutrient concentrations were small. This indicates that the crop uptake of micronutrients was as fast as the growth and that the concentrations were not diluted. The numerical differences between harvest times were small also in second cut. Therefore, the micronutrient concentrations averaged over harvest time are presented in this paper (Table 1).

In first cut the Cu concentration in grass was lower at Umeå than at Skara. In both cuts the Cu concentration was higher in Rc than in Bt. There is a relationship between Mo concentration and utilization of Cu because Mo and sulphate interact in the rumen and can form an insoluble complex with high affinity to Cu (NRC, 2001). The requirements of Cu for dairy cows are 10-12 mg kg^{-1} DM when the concentration of Mo is below 2 mg kg^{-1} DM (NRC, 2001). If the Mo concentration is higher the Cu requirement can also be higher. In this experiment the Cu concentration was lower than 10 mg kg^{-1} DM for all species except in Rc where the concentrations were close to the requirement. The Mo concentration was high compared to the Cu concentration in both grasses at Skara, in Mf in second cut at Umeå, and in Bt in second cut at Skara. The Zn concentration was lower than the requirements for dairy cows (40-60 mg kg^{-1} DM; NRC, 2001) in all treatments, except in Ti + Rc in second cut at Umeå. In grasses, Umeå had higher Mn concentration than Skara, and it was higher in Mf than in Ti. There were no differences between Rc and Bt, but both had lower concentrations than the grasses. The Fe concentrations in grasses were higher at Skara than at Umeå in both cuts, but in Rc the concentrations at Umeå were higher than at Skara in first cut. Bt had higher concentration than Rc in spring growth, at summer growth the differences were small.

Conclusions

For Mn and Fe, concentration levels were appropriate for expected dairy cow requirements. Cu concentration was normally low in grasses and in Bt, but in Rc were at the levels required for dairy cows, and in Rc-grass mixtures were too low because of the low concentrations in the grass. The results show that there was a need for Cu supplementation in all treatments because of low Cu concentration. The relatively high Mo concentrations may further increase the demand for Cu supplementation in dairy cow rations because there is a risk of Mo-induced Cu deficiency. The Zn concentration was lower than required for dairy cows, except for the mixture with Ti and Rc in second cut at Umeå.

Acknowledgements

Table 1. Concentrations of Cu, Mn, Mo, Zn and Fe (mg kg^{-1} DM) in first-year leys of timothy (Ti), meadow fescue (Mf), red clover (Rc) and birdsfoot trefoil (Bt) in mixtures from different sites and years.[1]

Harvest	Nu[4]	Umeå 2005			Skara 2005			Skara 2007			P-value
		Ti+Rc	Mf+Rc	Ti+Bt	Ti+Rc	Mf+Rc	Ti+Bt	Ti+Rc	Mf+Rc	Ti+Bt	YS×S[5]
Grasses		Ti	Mf	Ti	Ti	Mf	Ti	Ti	Mf	Ti	
Spring growth[2]	Cu	2.67e	2.83e	2.33e	5.17b	7.17a	4.00cd	4.83bc	5.33b	4.00d	<0.0001
2nd cut[3]	Cu	6.00ab	5.00ab	4.83ab	5.33ab	7.00ab	5.00ab	7.11a	7.83a	4.67b	0.02
Spring growth	Mn	62.0ab	70.7a	56.3bc	36.7de	54.0bc	24.2e	42.9cd	56.8abc	27.5e	0.06
2nd cut	Mn	94.7b	133a	87.0b	24.8e	37.2de	29.2de	37.7d	52.3c	59.3c	<0.0001
Spring growth	Mo	0.45c	1.33a	0.55c	4.05b	4.32b	5.62a	3.23b	3.13b	3.47b	0.006
2nd cut	Mo	1.42d	4.10a	1.55d	3.78c	5.58b	8.13a	3.55c	5.70ab	6.60a	<0.0001
Spring growth	Zn	18.0c	17.5c	18.7c	23.9a	22.5ab	19.0c	23.1a	19.5bc	17.5c	0.002
2nd cut	Zn	39.3a	25.5cd	33.2bc	22.3d	20.8d	28.2cd	24.3cd	19.8d	21.7d	0.04
Spring growth	Fe	30.7c	26.0c	30.5c	75.6b	102a	73.3b	69.9b	78.9b	64.2b	0.008
2nd cut	Fe	49.7	48.7	46.8	82.3	148	95.2	97.8	136	93.8	0.26
Legumes		Rc	Rc	Bt	Rc	Rc	Bt	Rc	Rc	Bt	
Spring growth	Cu	9.67a	8.00b	-	9.33a	9.33a	6.83c	10.2a	9.17ab	6.50c	0.11
2nd cut	Cu	13.3a	12.3a	8.33b	13.0a	13.0a	8.00b	13.7a	13.2a	7.33b	0.63
Spring growth	Mn	24.5	22.2	-	18.5	17.7	14.0	18.6	18.4	19.7	0.23
2nd cut	Mn	24.8	23.7	25.7	21.3	19.8	18.2	19.3	20.5	22.2	0.30
Spring growth	Mo	1.79b	1.82b	-	3.53a	2.80ab	3.00ab	2.49ab	2.32ab	2.92ab	0.36
2nd cut	Mo	0.72d	1.13d	1.53d	4.18a	3.60a	5.52a	3.60a	3.65a	5.08a	0.18
Spring growth	Zn	34.6a	29.5a	-	19.3b	19.3b	19.3b	19.2b	19.3b	19.3b	0.06
2nd cut	Zn	47.2	39.8	39.5	22.5	23.0	20.0	21.8	21.3	17.5	0.33
Spring growth	Fe	97.7a	73.2bcd	-	55.5e	61.2de	85.5ab	66.2cde	66.7cde	83.3abc	0.001
2nd cut	Fe	49.0b	49.0b	75.5a	66.0ab	65.8ab	85.8a	59.5ab	57.3ab	74.5ab	0.67

[1] Values with different letters within a row are significantly different.

[2] Mean value of three harvest occasions in first cut (one week before heading; at heading; one week after heading).

[3] Mean value of 2nd cut harvested 6 weeks after each harvest occasion in spring growth.

[4] Nu = micronutrient.

[5] YS = year site; S = species.

References

Gustavsson A-M. (2011) A developmental scale for perennial forage grasses based on the decimal code framework. *Grass and Forage Science* 66, 93-108.

Høgh-Jensen H. and Søegaard K. (2012) Robustness in the mineral supply from temporary grasslands. *Acta Agricultura Scandinavica, Section B – Soil Plant Science* 62, 79-90.

Lindström B.E.M, Frankow-Lindberg B.E., Dahlin A.S., Watson C.A. and Wivstad M. (2014) Red clover increases micronutrient concentrations in forage mixtures. *Field Crop Research* 169, 99-106.

National Reseach Council (2001) *Nutrient requirements of dairy cattle*, 7th revised ed. National Academies of Sciences, Washington, DC, USA.

Suttle N. (2010) *Mineral nutrition of livestock*, 4th ed. CABI, Wallingford, UK.

Whitehead D.C. (2000) *Nutrient elements in grassland: soil plant animal relationship*. CABI, Wallingford, UK.

Economic and environmental viability of regionally growing feed concentrate replacers

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Abstract

In an exploratory study on the impact of land use options on environment and farm income we considered closing nutrient cycles, clustering of agricultural activities and, as a combination of these two, the cooperation between dairy and arable farms. In the search for alternative feeds that can reduce the use of soybean from Brazil for feeding cattle, we investigated to what extent the growing of feed concentrate replacers by arable farmers within the region could be of interest economically. For this study our pilot area was part of the provinces of Brabant and Limburg (larger Peel region). We quantified the effect of growing up to 20, 40, 50, 60, 80 or 100% of the feed concentrate replacers within the region by replacing the least profitable arable crops by these crops (e.g. lupins, peas and beans). We found that the farm income would not be affected by replacement of up to 60% of the foreign feed concentrates by regionally grown feed concentrate replacers. However, replacement of more than 60% would reduce income. Cultivation of the new crops hardly affected nitrogen and phosphorus leaching to groundwater. But spatial optimization of land use conversion resulted in 10 to 20% reduction of nitrogen and phosphorus leaching. This means that cooperation between arable farmers growing feed concentrate replacers and dairy farmers using these products for feeding their livestock could be both economically and environmentally viable.

Keywords: land use, spatial optimization, dairy farming, regional cooperation, nutrient leaching

Introduction

Dairy farming in the Netherlands is facing many challenges, like the need to improve sustainability and of course maintain profitability. For an exploratory study on the impact of land use changes aimed at improving sustainability (for both environment and farm economy) we tried to define future land use scenarios. We decided to study the impact of land use change scenarios for a pilot area which is intensively used for agriculture. This pilot area is De Peel in the southeast of the Netherlands, covering parts of the provinces of Brabant and Limburg. We defined three scenarios: (1) business as usual; (2) closing nutrient cycles; and (3) clustering agricultural activities. The 'business as usual' scenario was characterized by larger but fewer farms with decreasing job opportunities. In the scenario 'closing nutrient cycles' all animal manure is applied within the region and this would result in less agricultural production and less employment (Cormont *et al.*, 2012). A more realistic option might be the 'clustering agricultural activities' scenario. As a combination of closing cycles and clustering we also considered cooperation between dairy and arable farms. Arable farms can use the manure produced by cattle and dairy farms can use fodder crops form arable farms. In the search for alternatives reducing the use of soybean from Brazil for feeding cattle, we then also investigated to what extent growing of feed concentrate replacers by arable farmers within the region could be of interest economically (Cormont *et al.*, 2013).

Materials and methods

For an analysis of land use change scenarios, data and tools are necessary. We used available regional data on land use, farms, cattle and grown crops from the Dutch geographical agricultural database GIAB, registered field data and data from the national statistics agency. From these data we generated information on cattle per farm, regional demand for fodder crops and feed concentrates, employment,

farm income etc. For assessing environmental impact we used the model STONE (Wolf *et al.*, 2003) and for spatial optimization we used the tool 'Waterwijs' (Van Walsum *et al.*, 2002).

The STONE-model can simulate leaching of N and P to groundwater and surface water, linked to a hydrological model which simulates water and nutrient flow within the soil and a model for deep groundwater flow. Fertilizer and manure supply are important input parameters together with meteorological data, soil characteristics, crop characteristics and regional hydrology.

Optimization within 'Waterwijs' is performed using meta models embedded in an algorithm for mathematical optimization, in this case 'Mixed Integer Linear Programming'. The meta model for our study was derived from the STONE results (Van Walsum *et al.*, 2014).

Based on the amount of cattle in the region we calculated the demand for fodder crops and feed concentrate replacers (Cormont *et al.*, 2013). From this demand the required area for these crops was determined. Considering the gross margins of currently grown crops in the region we decided for this scenario that the non-fodder crops with the lowest gross margins could be replaced by feed concentrate replacers, such as lupins, peas and beans.

The environmental and economic effects of replacing arable crops by feed concentrate replacers was quantified using the model STONE (environmental effect) and the data on gross margins within the agricultural regional database (economic effect). We varied the amount of feed concentrate replacers from 0 to 100% and thus quantified the effects of growing up to 20, 40, 60, 80 or 100% of the feed concentrate replacers within the region by replacing the least profitable arable crops by these crops.

Results and discussion

We found that the farm income for the region would not or hardly be affected by replacement of 20, 40 and even 60% of the foreign feed concentrates by regionally grown feed concentrate replacers (Cormont *et al.*, 2013). An increase to more than 60% would reduce income (Figure 1).

For the scenario where 60% of the required feed concentrates is replaced by regionally grown feed concentrate replacers, the simulated nitrate and phosphorus leaching to groundwater was only slightly affected. Only small increases of nutrient leaching were predicted. Spatial optimization of this land use
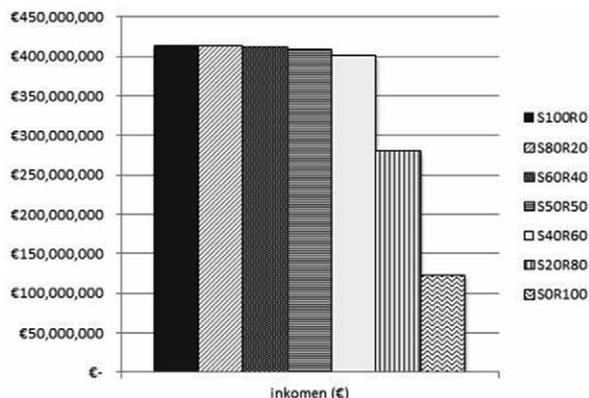
Figure 1. Regional total farm income (€) for different scenarios.
S100R0 = 100% 'standard' feed used and 0% regionally grown feed concentrate replacers; S80R20 = 80% 'standard' feed used and 20% using feed concentrate replacers (regionally grown), etc.

conversion resulted in a 10 to 20% reduction of nitrogen and phosphorus leaching (Van Walsum *et al.*, 2014). This is caused by the differences in hydrological conditions and soil characteristics.

Conclusions

The results of this exploratory study show that cooperation between arable farmers growing feed concentrate replacers and dairy farmers using these products for feeding their livestock could, potentially, be both economically and environmentally viable. The environmental benefits can be enhanced by carefully choosing where these new crops are grown. It is also worthwhile to investigate further the impact on the environmental global footprint. The footprint of feeding cattle might be reduced by regionally growing feed concentrate replacers, whilst maintaining economic profitability.

Acknowledgements

References

Cormont A., Van Diepen C.A., Hack-ten Broeke M.J.D., Jansen P.C., Janssen S.J.C., Roelsma J., Roest C.W.J., Smeets P.J.A.M. and Uiterwijk M. (2012) *Duurzaam landgebruik en prestatie-indicatoren; Een case studie voor de Peel.* Rapport 2335, Alterra, Wageningen, the Netherlands.

Cormont A., Van Diepen C.A., Galama P.J., Hack-ten Broeke M.J.D., Roelsma J., Uiterwijk M. and Zom R.L.G. (2013) *Clustering van voerstromen in de Peel; Case study duurzaam landgebruik en prestatie-indicatoren.* Rapport 2456, Alterra, Wageningen, the Netherlands.

Van Walsum P.E.V., Helming J.F.M., Schouwenberg E.P.A.G., Stuyt L.C.P.M., de Bont C.J.A.M., Vereijken P.H., Kwakernaak C., Van Bakel P.J.T., Van Staalduinen L.C., Groenendijk P. and Ypma K.W. (2002) *Waterwijs. Plannen met water op regionale schaal.* Rapport 433, Alterra, Wageningen, the Netherlands.

Van Walsum P.E.V., Galama P., Roelsma J., Cormont A. and Hack-ten Broeke M.J.D. (2014) *Ruimtelijke optimalisatie van voederstromen in de Peel, Nieuwe landgebruiksvormen en clustering ten behoeve van regionale productie van veevoer.* Rapport 2615, Alterra, Wageningen, the Netherlands.

Wolf J., Beusen A.H.W., Groenendijk P., Kroon T., Rötter R. and Van Zeijts H. (2003) The integrated modeling system STONE for calculating nutrient emissions from agriculture in the Netherlands. *Environmental Modelling and Software* 18, 597-617.

Increasing the resource efficiency of permanent grassland: outcomes of an EIP-AGRI Focus Group

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Abstract

This paper summarizes outcomes of a focus group that examined resource-use efficiency of permanent grassland in the context of profitable utilization, taking account of trade-offs needed to deliver other ecosystem services. Resource efficiency is considered at the levels of (1) improved herbage production and quality; (2) improved herbage utilization; (3) improved livestock utilization to deliver higher product value; and (4) resource efficiency to improve ecosystem services. A range of farm-scale and system-scale measures and innovative actions are identified that have potential for realizing improved resource-use efficiencies.

Keywords: grass, production, utilization, biodiversity, carbon sequestration

Introduction

Focus groups of EIP-AGRI are temporary groups of experts (researchers, farmers, advisers, non-governmental organisations) brought together to explore practical innovative solutions to problems (http://ec.europa.eu/eip/agriculture/en/content/focus-groups). The EIP-AGRI permanent grassland focus group was established in 2014. Its objective is to identify and exchange knowledge and practices that allow increased efficiency and profitability in grassland management consistent with maintaining or improving biodiversity and carbon sequestration. Maintaining the area of permanent grassland is an important element in the greening of the Common Agricultural Policy. Permanent grassland in Europe is in decline due to (1) abandonment of areas unsuited to crops and where socio-economic factors and environmental conditions limit the profitable use of grassland-based farming; and (2) conversion of grassland to maize or arable crops on land which can be easily cultivated. These two changes impact on other ecosystem-service provisions of permanent grassland: its roles in carbon (C) sequestration and supporting biodiversity, and its contribution to cultural heritage and local economies associated with landscapes, recreation or tourism. This short paper, based on contributions of the focus group, summarizes aspects of resource-use efficiency of permanent grassland in the context of profitable utilization, with further consideration of the trade-offs needed to deliver other ecosystem services. Opportunities for potential improvement of resource efficiency of permanent grassland are considered in terms of four main categories.

Improving herbage production and quality

Herbage production and quality are highly variable between sites, depending on environment, management and sward composition. Land with low levels of dry matter production, that is insufficient in amount and feed value for economically viable livestock production, is most vulnerable to abandonment. Optimum net herbage accumulation requires that limitations to growth and herbage accumulation are addressed, e.g. by improving the efficiency of use of water, light, nutrients and forage species, consistent with the farm situation and environmental objectives, notably C sequestration and biodiversity. Improved forage production may be incompatible with other ecosystem services, but loss of permanent grassland through abandonment or cultivation to crops can have greater environmental consequences. A challenge is to achieve acceptable levels (for the farmer) of quality herbage while at the same time ensuring provision of

additional ecosystem services. Opportunities for achieving environmentally sound herbage productivity include grasses bred for production and C sequestration and use of well-adapted multi-species swards. Appropriate N-fixing legumes in multi-species mixtures can also benefit root development, reduce methane emissions and improve the biodiversity relative to simple grass swards. However, the use of N-fixing legumes may be incompatible with grassland biodiversity if swards of conservation status are dependent on low nutrient levels.

The focus group proposed the following to address resource-use efficiency in forage production: (1) a need for site-specific soil information to help overcome edaphic limitations on plant growth potential, especially of productive species in the sward, (2) a need for information on forage resources to determine the opportunities for improvement of sward quality and growth potential appropriate to the site, and (3) identification of issues of incompatibility between sward improvement and local agri-environmental requirements.

Improving the efficiency of utilization of herbage from permanent grassland

Improved resource-use efficiency requires a high proportion of the metabolisable energy (ME) value of grass biomass to be converted to utilized ME (UME, energy for growth, lactation and maintenance); thus, losses due to senescence or spoilage should be minimized. Seasonal herbage growth and accumulation seldom match the seasonal demands of livestock. This can result in overgrazing and/or seasonal underutilization, with potential environmental damage and financial consequences for producers. A good combination of grazing with forage conservation is needed to increase resource efficiency and profitability. The focus group identified several examples of practices to address these limitations, including: (1) in Mediterranean rain-fed permanent pastures, grazing may be extended throughout the year, with conserved late-spring forage from crops specially grown for that purpose, or from irrigated permanent pastures, to optimize yield and quality; (2) utilization of pasture (often biodiverse) of low feed value in conjunction with areas of high feed value, e.g. the 'HFRO two-pasture' system in upland UK (Eadie, 1978) and later variants of this system under Mediterranean conditions; (3) use of sward height guidelines and adjustment of stocking rates to the average growth potential of a pasture to improve the efficiency of pasture herbage utilization, taking account of the important trade-off between growth and utilization.

Efficiency of utilization of grassland to convert utilized metabolisable energy into profitable output

This is the pivotal stage for producers in terms of efficiency of resource use from permanent grassland. The proportion of UME used for animal maintenance should be minimized. The focus group listed several resource inefficiencies in utilization, including: periods of slow growth and seasonal weight loss, periods of non-lactation in female livestock, high fodder intake per kg product, and high calf/lamb mortality. The focus group identified potential opportunities: (1) use of high-sugar forages to support utilization of the crude protein of legumes in the rumen, (2) strategic use of other protein sources to support low feed value forage, (3) use of species (e.g. lotus, sainfoin) in grassland swards beneficial to animal health and protein utilization, (4) reduced use of single-suckling cows, (5) reducing the period when dairy cows are not in lactation (by improved oestrus determination), (6) reducing losses of animals or animal products due to disease.

Resource efficiency that contributes to carbon sequestration and biodiversity

Here we consider how improving efficiencies of resource-use interacts with environmental objectives and the need for trade-offs. Soils and below-ground organic materials (roots, soil invertebrates, etc.) represent an important C pool that has potential to be increased to offset increasing atmospheric CO_2. Evidence suggests that permanent grassland contributes to C sequestration but this varies with composition, yield, soil and climate (conversely, conversion to arable cultivation reduces soil C). The effect of grazing on

soil C is complex; whether soil C increases or decreases in response to grazing may depend on severity, selectivity, effects on root biomass and extent of faecal returns (Bardgett and Wardle, 2010). Normally, mown grasslands are less efficient in promoting soil C sequestration than grazed pastures (Laidlaw and Sebec, 2012). Abandonment of permanent grassland might lead to short-term increased C sequestration but can greatly increase the likelihood of wildfires and C losses. Moderate grazing pressures should therefore be maintained.

Permanent grasslands are of particular value for supporting biodiversity, e.g. Mediterranean grasslands (a global biodiversity hotspot), and temperate grassland hay meadows. Improving economic profitability by changing the botanical composition and/or edaphic conditions affects biodiversity. There are trade-offs between agricultural and environmental goals, but sometimes there are synergies. In Mediterranean zones, biodiverse legume-rich sown permanent pastures are efficient in increasing pasture productivity and soil fertility, while also contributing to ecosystem services including capacity to sequester CO_2 in the soil, drought survival and erosion control (Cosentino *et al.*, 2014). More generally, intrinsic properties of regional types of permanent grassland can be utilized through valorisation of grassland products – thereby raising the economic and social efficiency of permanent grassland.

Innovative actions

The focus group identified potential actions, including: (1) greater use of N-fixing diverse legumes in permanent grasslands, especially where legumes are currently not well used; (2) increased use of nutritionally beneficial plants that might increase the value of pastures to support productive healthy animals; (3) attention to the role of soil microorganisms in phosphorus availability, due to its importance for legume growth (noting research requirements on this topic). The group also identified other challenges for permanent grasslands that could require innovative actions. These included developing improved mixed grazing systems; animal health and mortality problems due to parasites and predators; better use of silvo-pastoral systems for meat, bioenergy and biodiversity on the same area; and labour implications of new technology for supervising animals on large areas.

References

Bardgett R.D. and Wardle D.A. (2010) *Aboveground-belowground linkages: biotic interactions, ecosystem processes, and global change.* Oxford University Press, New York, NY, USA.

Cosentino S.L., Porqueddu. C., Copani V., Patane C., Testa G., Scordia D. and Melis R. (2014) European grasslands overview: Mediterranean region. *Grassland Science in Europe* 19, 41-56.

Eadie J. (1978) Increasing output in hill sheep farming. *Journal of the Royal Agricultural Society of England* 139, 103-114.

Laidlaw A.S. and Sebek L.B.J. (2012) Grassland for sustainable animal production. *Grassland Science in Europe* 17, 47-58.

Capacity of the soil to decompose organic matter in old and young grasslands

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Abstract

To study the effect of grassland renewal on soil quality and the eco-efficiency of grass production, we compared ten young grasslands (aged 5-10 years grassland without tillage) with ten old grasslands (age >20 year grassland without tillage) as pairs on ten dairy farms on marine clay in the North of the Netherlands. On these 20 grasslands we measured the capacity of a soil to decompose organic matter. This was tested by using the Tea Bag Index (TBI). TBI is determined through the burial and retrievement of green and rooibos tea bags, following by the measurement of mass loss after 90 days. The decomposition rate k and the stabilisation factor S of young grasslands were not significantly different from older grasslands; however, variation between locations was high. A negative correlation was found between age of the grassland and the stabilisation factor S, meaning that decomposition of organic matter in older grassland continues for a longer time and may be an indication of a higher soil biological activity.

Keywords: marine clay, permanent grassland, soil organic matter, Tea Bag Index

Introduction

More and more farmers in the Netherlands plough and reseed their grasslands to improve drainage and/ or to introduce the newest grass varieties. In the short term this gives a production increase, but in the long term the loss of soil quality caused by tillage could mean a reduction of production, especially with the recent legislative restrictions on the use of organic and artificial N fertilizers. Soils under grassland have advantages in soil quality in general, and specifically for carbon sequestration and soil biodiversity (Van Eekeren *et al.* 2010). As a consequence, on older grasslands with relatively high soil organic matter levels, lower inputs of N from fertilization may result in crop yields equal to those of grasslands with relatively low soil organic matter levels (Reijs *et al.* 2007; Van Eekeren *et al.* 2008). The objective of this experiment was to measure the effect of the age of grassland (old vs young) on the capacity of the soil to decompose organic matter. To test the capacity of the soil to decompose organic matter the Tea Bag Index (TBI) was used. The TBI is an innovative, cost-effective, standard method developed by Keuskamp *et al.* (2013) to gather data on decomposition rate and litter stabilisation of the soil. Since old grasslands contain, in general, a higher soil organic matter and soil biota than young grasslands it was hypothesised that the decomposition of organic matter would be higher (higher decomposition rate k and a lower stabilisation factor S) in old grasslands than young grasslands.

Material and methods

Measurements took place at 10 dairy farms on marine clay in the North of the Netherlands (Friesland and Groningen). Two grasslands were selected per farm, one young grassland (aged 5-10 years in grassland without tillage) and one old grassland (age >20 years grassland without tillage). For each plot 4 pairs of green and rooibos tea bags were buried as described in Keuskamp *et al.* (2013). (Rooibos (*Aspalathus linearis*) is a broom-like member of the legume family, of which the leaves are used to make a herbal tea.) After 90 days the tea bags were retrieved, oven dried (48 h, 105 °C) and weighed. Two parameters comprising the TBI were calculated: decomposition rate k and stabilisation factor S. The decomposition factor k is a measure for the turnover time of labile carbon. The stabilisation factor S is a measure for the

stabilisation of the decomposition of organic carbon (Keuskamp *et al*, 2013). An ANOVA procedure (Genstat 13.3, VSN international) to test for treatment effect (young versus old grassland) was used. Each of the 10 farms in which both treatments were compared was statistically regarded as a block. Apart from the treatment effect, correlations between decomposition rate k and stabilisation factor S and age of the grassland were tested.

Results and discussion

The decomposition rate k and the stabilisation factor S of young grasslands was 0.0158 and 0.224, respectively, and were not significantly different from older grasslands (k=0.0165 and S=0.208). Standard error for the decomposition rate k was 0.0014, and 0.010 for the stabilisation factor S. However, variation between the locations was high (Figure 1). The measurements took place at 10 dairy farms with the same soil type in the same climate and the same ecosystem. The amount of rain during the period that the tea bags were buried varied a little between the farms. Keuskamp *et al.* (2013) calculated the decomposition rate k and the stabilisation factor S for 100 different locations at different ecosystems and countries. Our teabags were oven-dried at 105 °C, whereas Keuskamp *et al.* (2013) dried at 70 °C. At 70 °C they found an average decomposition rate k of 0.013 (0.016 at 105 °C) and a stabilisation factor S of 0.24 (0.22 at 105 °C). Compared to their results, we found at both temperatures in most of the grasslands a higher decomposition rate k and a higher stabilization factor S (Figure 1).

At one farm we found significantly higher k rates at the young as well as at the old grassland in comparison with the other farms. This could be an effect of a different grassland management strategy on the farm. This will be further investigated in the near future. The age of the grassland and the stabilisation factor S was negatively correlated (*P*=0.038). This could mean that older grasslands have a higher capacity to decompose organic matter in the soil, which may be an indicator for a higher soil biological activity. No correlation was found between the age of the grassland and the decomposition rate k.

Conclusions

No significant differences in the decomposition rate k and the stabilisation factor S of organic matter were measured between young and old grasslands. A negative significant correlation between age of grassland and the stabilisation factor S could suggest a higher soil biological activity in older grasslands.
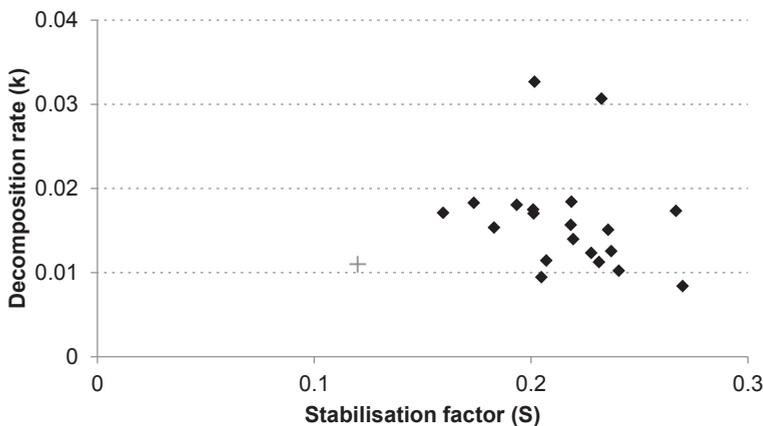
Figure 1. Stabilisation factor S and decomposition factor k for 20 different grassland sites at marine clay, and the NL pasture (the +symbol) measured by the method of Keuskamp *et al.* (2013).

References

Keuskamp J.A., Dingemans B.J.J., Lehtinen T., Sarneel J.M. and Hefting M.M. (2013) Tea Bag Index: a novel approach to collect uniform decomposition data across ecosystems. *Methods in Ecology and Evolution* 4, 1070-1075.

Reijs J.W., Sonneveld M.P.W., Sørensen P., Schils R.L.M., Groot J.C.J. and Lantinga E.A. (2007) Effects of different diets on utilization of nitrogen from cattle slurry applied to grassland on a sandy soil in the Netherlands. *Agriculture Ecosystems and Environment* 118, 65-79.

Van Eekeren N., Bommelé L., Bloem J., Schouten T., Rutgers M., De Goede R., Reheul D., and Brussaard L. (2008) Soil biological quality after 36 years of ley-arable cropping permanent grassland and permanent arable cropping. *Applied Soil Ecology* 40, 432-446.

Van Eekeren N., De Boer H., Hanegraaf M., Bokhorst J., Nierop D., Bloem J., Schouten T., De Goede R. and Brussaard L. (2010) Ecosystems services in grassland associated with biotic and abiotic soil parameters. *Soil Biology and Biochemistry* 42, 1491-1504.

Farm-specific development plan: a tool to manage and improve individual dairy farms

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Abstract

Pilot farm networks are very efficient in developing and implementing innovative measures and strategies to improve farm performances. At farm level, their specificities must be considered. A coordination of all actors, i.e. researchers, advisors, farmers and policy makers is essential. During the EU Dairyman project a strategy has been elaborated to establish coherent development plans. This method is applied on the four Luxemburgish commercial monitor farms, which are a part of the 'Autograssmilk' EU project with a farm network. Three steps have to be respected: (1) a detailed farm description; (2) a definition of objectives and their corresponding indicators; and (3) an implementation of a strategy, sub-divided into several actions. Farm data were collected and analysed during 2014, so that at the end of the year a specific development plan was elaborated on each farm. Due to the farm-specific approach, for identical farm objectives, concrete actions to reach the goal can differ significantly. Furthermore, the coordination between involved organizations is enhanced. The results were as positive as in the previous project and its seem therefore that they can be replicated. The method can be considered as an appropriate tool to monitor and improve commercial farms.

Keywords: dairy farm network, farm-specific development plan, grazing, automatic milking

Introduction

The key factors of the EU rural development strategy are: bottom-up approach, networking with multi-sectoral integration, and development of local solutions by implementing innovative tools and methods. Pilot-farm networks satisfy most of these objectives. Working with pilot-farm networks is a very efficient way to develop and implement innovative development at farm level. All activities of involved researchers, advisors, farmers and policy makers must be coordinated in order to realize coherent improvement at farm level. During the EU-Dairyman project (2009-2013) a strategy has been elaborated that allows the setting up, execution and documentation of a specific development plan on each of the 130 pilot farms in 10 regions in North-west Europe (Dairyman, 2013).

The convincing success of the approach used in this project led to its application as a tool on the 4 Luxemburgish monitor farms of the EU Autograssmilk project (Autograssmilk, 2013-2015) with the expectation of confirming its efficiency and to establish it as a standard approach for use in Luxemburgish farm advisory work.

Materials and methods

The network

The monitor farms network is part of the Autograssmilk project, in which research institutes from seven countries (joint project in Ireland, France, Belgium, the Netherlands, Denmark and Sweden, Luxembourg since 2014) cooperate, with the aim of combining automatic milking systems (AMS) and grazing. Data from 37 dairy farms equipped with AMS were selected to assess their performance. The Luxemburgish partner is a FILL initiative (association for sustainable farming Luxembourg) where four organisations (LTA – agricultural school; SER – service for farm accounting; ASTA – governmental agricultural support; Convis – farm advisory) collaborate. Since the Luxembourgish government does not have its

own agricultural research facilities, this study has been performed on four commercial monitor farms. Due to the participation criteria (a combination of grazing with AMS) these farms do not represent the Luxemburgish average farm. The short time period of the project (2014-2015) imposed a strict time schedule. During 2014, data on farm settings, such as economic situation and nutrient (N, P) flows, were collected following a methodology developed in the Dairyman project (Dairyman, 2013). Additionally, a daily feeding and grazing calendar (Kohnen, 2009) provided information about fodder intake. As combining grazing and AMS poses a high demand on farm layout and infrastructure to assure good cow traffic and high milking frequency, an external survey was conducted on all farms by a specialised enterprise (Grasstec Ltd., Ireland) during October 2014.

All farms are mixed farms and produce dairy and/or beef or cereals. The grazing period starts during April and ends in October with all-year feed supplementation and calving. During the grazing season, grass-silage feeding is reduced or stopped, whereas maize silage and concentrates are fed all-year round. Farms differ in grazable area, total milk production and milk yields. The farm LU1 (organic) has no maize. AMS saturation is actually low, but with abandonment of the milk quota system, all farms plan to increase milk production (Table 1) and so AMS will be saturated. High standards are needed for tracks and farm layout to assure cow traffic and the milking frequency of the cow herd. Therefore, cow traffic and tracks must be improved.

The tool

The Dairyman approach (Dairyman, 2013) can be considered as a tool to elaborate and implement farm improvement plans in order to help farmers take strategic decisions to improve their farm performances, respecting regional and farm specificities. Three main steps have to be respected: (1) description of farm performances, (2) definition of the objectives and their indicators and (3) implementation of a strategy by sub-dividing the objectives into several actions and involving farm advisers (Grignard A. 2012). The number of objectives should be limited to avoid congestion.

Due to the Autograssmilk objectives, all improvement planning (Figure 1) focuses on grazing and automatic milking.

Results and discussion

For all farms, a specific development plan was realized in winter 2014-2015. Objectives and actions differed greatly among farms. As LU1 has a relatively low grazing area, the farmer aims to improve forage

Table 1. Farm characteristics based on data registration 2013.

Farm		LU1	LU2	LU3	LU4
Grazable area (dairy only)	ha	11.5	40	12	22.6
Milk produced in 2013	Mg yr^{-1}	178	253	660	392
Milk expected in 2016	% of 2013	10	100	10	0-10
Dairy cows in 2013		56	35	85	60
Dairy cows in 2016		56	80	95	70
Cow per grazable area	cows ha^{-1}	5.1	0.9	7.1	2.7
Poaching risk		low-local	medium	low	high-extreme
AMS units[1]	number	1	1	2	1
AMS saturation	Mg milk AMS^{-1} y^{-1}	178	253	330	392
Grass intake in 2014	kg dry matter c^{-1} d^{-1}	5-10	12-16	<5	10-12
Selection gate		exit AMS	exit AMS	gate exit barn	exit AMS

[1] AMS = automatic milking system.
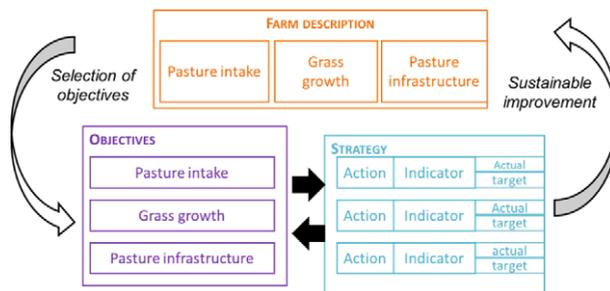
Figure 1. Schematic representation of the steps and elements required to establish a comprehensive farm development plan for farm monitoring of the Luxemburgish Autograssmilk project.

Table 2. Example of a development scheme (farm LU4) with farm objectives, concrete actions with indicators (actual and target).

Objective	Action	Indicator	Actual	Target
Increase grazed grass intake	• Improve cow track • Rearrange paddocks	Total fresh grass intake per year	130 Mg dry matter yr^{-1}	>150 Mg dry matter yr^{-1}
Increase AMS[1] saturation	• Install double cow track • Day-night paddocks	Milk production per AMS	350 Mg AMS^{-1}	500 Mg AMS^{-1}
Reduce fluke risk	Avoid poaching Strategic treatment dry off	Number of infections	100%	0%

[1] AMS = automatic milking system.

and protein supply during grass shortage by fresh-grass indoor feeding of temporarily produced grass-clover crops. LU2's dairy herd size will double; therefore the farmer is willing to change the farm layout and double the cow tracks in order to improve cow traffic and achieve a high AMS saturation with high pasture intake. LU3 will optimise grass intake by daily adapting the feed supply during the grazing season. A more detailed development plan for farm LU4 is described in Table 2.

Conclusions

The dairyman methodology provides good results even in a network as specific as Autograssmilk. Respecting farm specificities by defining actions with the corresponding indicators are key features. Involving farmers and their advisers during the whole process enhances long-term results even beyond the project's end. The novice partners inside the working group adopted the method without any apprehension.

References

Autograssmilk (2013-2015) Project website. Available at: http://www.autograssmilk.eu.

Dairyman (2013) A practical manual to assess and improve farm performances. Available at: http://www.interregdairyman.eu/en/dairyman/products.htm.

Grignard A., Bailey J., Bijttebier J., Boonen J., Castellan E., Tirard S., Lorinquer E., Jilg T., De Haan M., Mihailescu E., Stilmant D. and Hennart S. (2012) La définition de plans d'amélioration pour améliorer les performances environnementales des élevages laitiers. *Rencontres autour des Recherches sur les Ruminants* 19, 269-272.

Kohnen H. (2009) L'Abaque pâturage: un outil pour déterminer et optimiser la quantité d'herbe pâturée à partir de la production laitière et de la complémentation. *Fourrages* 199, 393-396.

Impact of sowing date of maize catch crops on yield and environmental effects – a trade-off?

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Abstract

Regions in northern Germany that are characterised by high livestock/biogas plant density, light sandy soils and extensive silage maize production are facing major challenges with respect to environmental pollution, in particular nitrate leaching. The objective of the current study was to investigate a management strategy, i.e. an optimisation of maize harvest date and catch crop species, for mitigating the environmental pollution risk, based on a 2-year field study. Rye turned out more effective in N uptake than Italian ryegrass when sown no later than the second decade of September. A trade-off between maize yield, catch-crop N uptake, or N losses need not necessarily occur.

Keywords: *Zea mays*, harvest date, catch crop, leaching, nitrous oxide emission

Introduction

Growing silage maize for high output dairy farming or energy production on light sandy soils with a long manuring history may lead to high residual soil nitrogen (N) in autumn, which can be lost via nitrate leaching or as nitrous oxide (N_2O) emission (Oenema *et al.,* 1998). Catch crops may contribute to a mitigation of environmental pollution when residual N is taken up in autumn and after successful carry-over reduces the N-fertiliser demand of the following maize. However, the remaining growing season in autumn often is limited. The main objective of the present study was to analyse the impact of maize harvest date and catch crop species on maize yield, catch crop N uptake before winter, nitrate leaching and N_2O emission.

Materials and methods

The study is based on a 2-year (April 2012-April 2014) field experiment conducted in three environments in Schleswig-Holstein, northern Germany. The experimental farm 'Ostenfeld' is located in the Eastern Upland with an average annual precipitation of 847 mm, a mean air temperature of 8.9 °C and a silty sand soil. The experimental farm 'Schuby', located in the Geest region (885 mm, 8.6 °C, carbic sand), provided two environments, which differed with respect to irrigation (with/without) and preceding crops. The experimental setup was a 4-factorial randomised block design with three replicates and a plot size of 51 to 72 m^2. Treatments comprised two years, three environments ('Ostenfeld' (OF); 'Schuby' with irrigation (SI); 'Schuby' without irrigation (SnI)), four maize harvest/catch crop sowing dates (10 September (hd1) and 20 September (hd2) after early maize cv. Suleyka; 30 September (hd3) and 15 October (hd4) after mid-early cv. Ronaldinio) and four different winter catch crop treatments (Italian ryegrass cv. Gisel (LM); rye cv. Protektor; bare fallow after shallow soil cultivation (SC); undisturbed bare fallow (BF)). N fertilisation to maize was 180 kg N ha^{-1} taking soil mineral N in spring into consideration, applied shortly after maize sowing as calcium-ammonium-nitrate. Selected maize and catch crop treatments remained unfertilised. Maize was harvested with a plot harvester to determine dry matter yield. The catch crops were sampled manually to ground level at the end of the vegetation period in November to obtain aboveground biomass and N content, determined by near-infrared spectrometry. N_2O fluxes were determined weekly in selected treatments (hd1 and hd3, fertilised rye and unfertilised BF) using the closed-chamber technique by Hutchinson and Mosier (1981). Ceramic suction cup samplers were used to obtain leachate samples for N analysis, with three P80 suction cups installed per plot (70 cm depth).

Treatments comprised the rye and Italian ryegrass catch crops as well as unfertilised bare fallow of the first and third harvest date. Leachate was sampled weekly from catch crop sowing until end of March/ beginning of April. Nitrate load was calculated from the nitrate concentration and the drainage obtained from a climatic water-balance. Analyses of variance were calculated using 'R' software by assuming year, environment, harvest date, catch crop species and interactions as fixed and block as random. Multiple comparisons of means were conducted by linear contrasts. In addition, a regression model was developed to quantify the catch crop N uptake before winter as function of temperature sum.

Results and discussion

Aboveground N uptake (AGN) of the catch crops varied substantially between 0.5 and 52.3 kg N ha^{-1}, and was significantly affected by the interactions of environment × sowing date × catch crop ($P \leq 0.05$) and year × sowing date × catch crop ($P \leq 0.01$). Therefore, the four-way interaction is presented (Figure 1). Earlier maize harvest (hd1 vs hd3) resulted in higher catch crop N uptake, except for rye grown at OF in 2012 and Italian ryegrass grown at SI in 2013. Rye achieved higher N uptake than Italian ryegrass when sown early (hd1), with the exception at OF 2012, where rye performed better than Italian ryegrass at hd3 instead of hd1. Finally, more favourable weather conditions in 2013 resulted in generally higher AGN than in 2012.

The data allowed the derivation of two functions quantifying the aboveground N uptake of rye and Italian ryegrass, respectively, as function of temperature sum. When applying an exponential function, a base temperature of 5 °C gave best model fit (Figure 2). For typical silage maize harvest date, i.e. October 1st (long-term average), a temperature sum of 175 °Cd can be expected until the end of the vegetation period. This corresponds to an AGN of below 10 kg N ha^{-1}, for both species. An N uptake of 20 kg N ha^{-1}, regarded as the minimum for efficient ground water protection, would require a temperature sum of 285 °Cd (rye) or 330 °Cd (Italian ryegrass) and a latest sowing in the second decade (rye) or the first decade of September (Italian ryegrass). Considering a root:shoot ratio of 0.35 (Thorup-Kristensen, 2001) with appropriate additional belowground N uptake, opportunity for delayed sowing is given to reach the target N-uptake. Earlier maize harvest need not necessarily result in yield losses. We found significant year × harvest date ($P \leq 0.001$) and environment × harvest date ($P \leq 0.01$) interactions. Very early harvest (hd1) caused a significant yield reduction of up to 22% in each environment, whereas harvest later than hd2 showed a yield increase only at SI in 2013. Thus, from a yield perspective there was no need to harvest silage maize later than the second decade of September, which would provide potential for N uptake by a rye catch crop. However, forage quality aspects, e.g. rumen by-pass starch, may advocate later harvesting (Zom *et al.,* 2012). Cumulative N$_2$O emission showed a significant N fertilisation effect
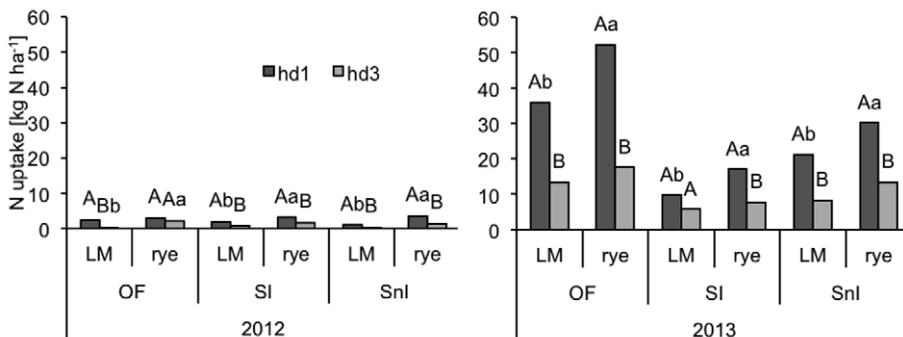
Figure 1. Aboveground catch crop N uptake at the end of vegetation period. Capital letters denote significant differences between sowing dates within a year × environment × catch crop species combination; lowercase letters indicate significant differences between catch crops within a year × environment × sowing date combination.
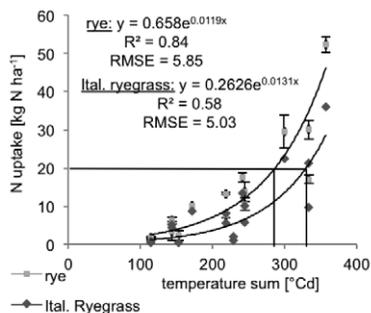
Fig. 2: temperature sum and aboveground
N uptake by catch crops before winter

Figure 2. Temperature sum and aboveground N uptake by catch crops before winter.

($P \leq 0.001$) and a significant year × harvest date interaction ($P \leq 0.05$). Overall, emissions were at a very low level, ranging between 0.1 and 0.85 kg N_2O-N ha^{-1} (data not shown). As expected, N fertilisation nearly doubled emissions compared to unfertilised control treatment. Catch-crop seedbed preparation in autumn did not cause any considerable N_2O peak fluxes, which mainly occurred during the maize growth period. Our results are in good agreement with van Groenigen *et al.* (2004) who reported low N_2O peaks for sandy soils and showed that N_2O emissions are raised significantly by the use of manure. Thus, the low N_2O emission found in our study can be mainly attributed to the use of mineral N fertiliser and the high draining capacity of the upper soil layers. Nitrate leaching was significantly influenced by year × environment × catch crop species ($P \leq 0.05$). Substantial nitrate leaching of up to 82 kg NO_3-N (2013/2014) ha^{-1} was found, with fertilised treatments tending to cause higher losses than unfertilised control. Furthermore, leaching tended to increase with later maize harvest. Significant differences, however, were detected only in the comparably warm winter period of 2013/2014 at SnI between rye and BF (hd1) and between Ital. ryegrass and BF (hd3).

Conclusions

Silage maize harvested in the second decade of September latest, followed by a rye catch crop seems to be a suitable management strategy to reduce environmental pollution while not adversely affecting maize yield. Earlier or later maize harvest/rye establishment will inevitably reduce maize yield or increase nitrate leaching. Future work will focus on residual effects on maize following a catch crop.

References

Hutchinson G.L. and Mosier A.L. (1981) Improved soil cover method for field measurement of nitrous oxide fluxes. *Journal of the Soil Science Society of America* 45, 311-316.

Oenema O., Boers P.C.M., Van Eerdt M.M., Frater B., Van der Meer H.G., Roest C.W.J., Schröder J.J. and Willems W.J. (1998) Leaching of nitrate from agriculture to groundwater: the effect of policies and measures in the Netherlands. *Environmental Pollution* 102(S1), 471-478.

Thorup-Kristensen K. (2001) Are differences in root growth of nitrogen catch crops important for their ability to reduce soil nitrate-N content, and how can this be measured? *Plant and Soil* 230, 185-195.

Van Groenigen J.W., Kasper G.J. and Velthof G.L., Van den Pol-Van Dasselaar A. and Kuikman P.J. (2004) Nitrous oxide emissions from silage maize fields under different mineral nitrogen fertilizer and slurry applications. *Plant and Soil* 263, 101-111.

Zom R.L.G., Bannink A. and Goselink R.M.A. (2012) *Effect of increased maturity of silage maize at harvest on conservation dairy cow performance and methane emission*. Report 578. Livestock Research Wageningen, Wageningen, the Netherlands.

Species-rich grasslands for a higher biodiversity on highly productive dairy farms

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Abstract

During the past decade trials have shown the value of species-rich grasslands for farmland biodiversity. On four highly productive dairy farms, where farming was combined with management of species-rich grasslands and habitat creation for meadow birds, we analysed the value of these species-diverse swards with respect to grass production and quality, farm management and biodiversity. Compared with grass, herbs and legumes generally contained higher levels of minerals and their herbage offered more structure in the cattle diet. Speeding up the creation of species-diverse swards is possible by reseeding with species-rich mixtures. On these farms a species richness of 17-30 species per 100 m^{-2} was obtained. Previous research showed that replacement of 25-30% *Lolium perenne* silage by silage from comparable species-rich swards is possible without a decline in milk production. When highly productive dairy farms create species-diverse swards on part of their acreage, it will be possible to produce healthy forage while also providing a good habitat for meadow birds.

Keywords: species-rich grassland, dry matter production, mineral composition, dairy farming, biodiversity

Introduction

The appreciation of herbs and legumes in grassland swards is increasing. Herbs and legumes support animal health and contribute to increasing farmland biodiversity. Many highly productive dairy farms are working on the edge, which causes extra costs due to health problems. Acidification of the rumen is a problem on one third of Dutch farms, caused by a biased ration of grass, maize and concentrates with high levels of energy and protein. Roughage that is rich in structure (fibres) can reduce the acidification considerably (Bruinenberg *et al.*, 2006). Moreover, various herbs and legumes contain high levels of healthy components, which,for instance, have a positive effect on the fatty acid composition of milk (Moloney *et al.*, 2014). In general, herbs and legumes contain higher levels of minerals and trace elements than grass species (Fisher *et al.*, 1996; Pirhofer *et al.*, 2011).

We performed a number of experiments to re-introduce species-rich grassland by sowing species-rich seed mixtures (Korevaar and Geerts, 2009, 2012). The experiments showed that many of the re-introduced species were relatively persistent in the swards, and under low-fertilized conditions these species-rich grasslands can compete with *Lolium perenne* swards for production. Next, we tested the value of species-rich grasslands on dairy and beef farms (Geerts *et al.*, 2014). In this paper we present the results obtained on four dairy farms that combined a highly productive dairy herd with species-rich grasslands on part of their fields.

Materials and methods

In 2012 a farm network was established in the Netherlands. The network consisted of 10 dairy and beef farms, a bird protection agency, research and advisory organisations, agricultural colleges, a province, and a seed company. On some farms species-rich grasslands had already been sown before the start of the network which made it possible to analyse the value of well-established swards for dairy production, farm management and biodiversity.

Species-rich seed mixtures were collected from an *Arrhenatheretum elatioris* community and sown in autumn 2002 on fields of two farms (Tervoert and Esselink) in Winterswijk (Province of Gelderland). Cattle slurry (18 Mg ha^{-1}) was applied annually to the swards. The swards were cut two or three times per year. On the farm De Kleijne, on a dry sandy soil in Landhorst (Province of Noord-Brabant), three different seed mixtures were sown in October 2005: a seed mixture of 9 grass species, 3 legumes and 4 herbs; a seed mixture collected from an *A. elatioris* community; and a seed mixture of 4 grass species dominated by *L. perenne*. Cattle slurry (20 Mg ha^{-1}) was applied annually to these swards. On the farm Agema, on a fertile clay soil in Kollumerpomp (Province of Friesland), the *A. elatioris* mixture was sown in 2011. In 2013 the established sward received farmyard manure (15 Mg ha^{-1}) and was harvested twice. Species composition and dry matter production were monitored on all farms. On the farms in Winterswijk and Landhorst the feeding value and mineral content were measured in fresh grass samples. On the farm in Kollumerpomp the samples were taken from wilted silage.

In addition to the monitoring programme we performed a literature survey to compare the mineral content of a number of legume and herb species with the minerals in grass species.

Results

The four farms studied produced more milk cow^{-1} than the Dutch average of 8,000 kg year^{-1} and there was also a lower concentrate consumption per cow on three of the farms (Dutch average: 2,110 kg cow^{-1} year^{-1}). On three farms the milk production ha^{-1} was lower than the Dutch average of 14,670 kg ha^{-1} year^{-1} (Table 1).

Data on the grass or silage composition are presented in Table 2. The results of the farm in Landhorst show that under conditions of low inputs of manure, the species-rich swards can compete with *L. perenne* swards in terms of productivity, content of minerals and trace elements and the feeding-value parameters of the herbage. The overall production on this farm was low due to the limitations of the dry sandy soil. In Winterswijk and Kolumerpomp soil fertility and moisture conditions were more favourable. From the literature survey (results not shown here) we concluded that, in general, the content of minerals and trace elements in herbs and legumes is significantly higher than in grasses.

Discussion and conclusions

Compared to grass species, herbs and legumes generally contain higher levels of minerals and offer more structure in the diet, whereas their digestibility is only slightly lower. Earlier research showed that replacement of 25-30% of *L. perenne* silage by silage from species-rich swards showed no negative impact on milk production (Bruinenberg *et al.*, 2006). In addition to this, farmers are able to contribute to the meadow bird biodiversity, as the plant species mixture attracted a range of insects, which are main component in the diet of young birds (Kentie *et al.*, 2013).

Table 1. Some characteristics of the four dairy farms (year 2013).

Farm	De Kleijne (Landhorst)	Tervoert (Winterswijk)	Esselink (Winterswijk)	Agema (Kollumerpomp)
Soil type	sand	sand	sand	clay
Total grassland (ha)	32	44	31	70
Silage maize (ha)	14	16	9	10
Other crops (ha)		4	1	10
Dairy cows (number)	83	66	48	95-100
Milk (kg cow^{-1} year^{-1})	8,500	9,185	9,300	12,000
Milk (kg ha^{-1} year^{-1})	15,400	10,072	11,250	13,000
Concentrates (kg cow^{-1} year^{-1})	1,870	1,956	2,190	ca. 2,050
Species-rich grassland (ha)	15	4.5	3.5	15

Table 2. Species numbers, dry matter (DM) production, net energy content and mineral and trace element composition of species-rich grass compared to a *Lollium perenne* sward at low manure applications.

	Farm					
	De Kleine			Tervoert and Esselink	Agema	
Soil type	Dry sandy soil			Sand	Clay	
Experimental details	Fresh grass, average of 2 cuts a year			Fresh grass, 2 or 3 cuts a year	Silage from 1st and 2nd cut of one field	
Years	2006-2010			2005-2010	2013	
Fertilisation	20 Mg cattle slurry ha⁻¹ year⁻¹			18 Mg cattle slurry ha⁻¹ year⁻	15 Mg farm yard manure ha⁻¹ year⁻¹	
Seed mixture	Species- rich	*A. elatioris*	*L. perenne*	*A. elatioris*	*A. elatioris*	
Species (numbers 100 m⁻²)	17 b[1]	22 c	13 a	28	30	
DM yield (t ha⁻¹)	4.9 a	4.7 a	4.4 a	8.0	7.8	
Net energy (MJ kg⁻¹DM)	5.08 a	4.87 a	5.26 a	5.04	5.09	5.42
Sugar (g kg⁻¹)	90.5 a	100.6 ab	109.9 b	107.0	123	96
Crude protein (g kg⁻¹)	107.7 b	90.2 a	99.4 ab	100.2	85	154
P (g kg⁻¹)	3.7 a	3.6 a	3.6 a	3.6	2.9	3.8
K (g kg⁻¹)	23.8 a	21.2 a	22.4 a	19.1	24.7	27.5
S (g kg⁻¹)	2.1 a	2.1 a	2.3 a	2.0	12	3
Na (g kg⁻¹)	0.6 a	0.7 a	0.5 a	2.4	0.9	2.4
Ca (g kg⁻¹)	6.4 b	4.7 a	4.7 a	7.8	8.0	13.1
Mg (g kg⁻¹)	2.6 b	2.0 a	2.1 a	2.5	1.9	2.9
Fe (mg kg⁻¹)	93 a	85 a	79 a	195	571	272
Zn (mg kg⁻¹)	94 b	65 a	71 a	66	25	3.8
Mn (mg kg⁻¹)	228 a	316 b	220 a	230	65	130

[1] Different letters in a row: parameters are different $P \leq 0.05$.

Speeding up the creation of species-diverse swards is possible by reseeding with species-rich seed mixtures. The persistence of these swards is good, if there are adaptations in the management and fertilization level. When highly productive dairy farms create species-rich swards on part of their acreage, it will be possible to produce healthy forage while providing a good habitat for meadow birds.

References

Bruinenberg M.H., Geerts R.H.E.M., Struik P.C. and Valk H. (2006) Dairy cow performance on silage from semi-natural grassland. *Netherlands Journal of Agricultural Science* 54, 95-110.

Fisher G.E.J., Baker L.J. and Tiley G.E.D. (1996) Herbage production from swards containing a range of grass, forb and clover species and under extensive management. *Grass and Forage Science* 51, 58-72.

Geerts R., Korevaar H. and Timmerman A. (2014) *Kruidenrijk grasland. Meerwaarde voor vee, bedrijf en weidevogels.* [Species-rich grassland, added value for cattle, farm and meadow birds]. PRI-Wageningen UR/Skalsumer Natuurbeheer, the Netherlands.

Kentie R., Hooijmeijer J.C.E.W., Trimbos K.B., Groen N. M. and PiersmaT (2013) Intensified agricultural use of grasslands reduces growth and survival of precocial shorebird chicks. *Journal of Applied Ecology* 50, 243-251.

Korevaar H. and Geerts R.H.E.M. (2009) Re-introduction of grassland species still successful after a decade. *Grassland Science in Europe* 14, 497-500.

Korevaar H. and Geerts R.H.E.M. (2012) Productivity and feeding value of species-rich grassland mixtures *vs* ryegrass. *Aspects of Applied Biology* 115, 67-74.

Moloney A.P., Monahan F.J. and Schmidt O. (2014) Quality and authenticity of grassland products. *Grassland Science in Europe* 19, 509-520.

Pirhofer-Walzl K., Søegaard K., Høgh-Jensen H., Eriksen J., Sanderson M.A., Rasmussen J. and Rasmussen J. (2011) Forage herbs improve mineral composition of grassland herbage. *Grass and Forage Science* 66, 415-423.

Partial replacement of grass silage with faba bean whole-crop silage in the diet of dairy cows

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Abstract

Grain legumes are an interesting alternative to grass as cattle forage owing to their nitrogen fixing ability and high biomass production. The objective of this study was to investigate the effect of a mixture of grass silage and faba bean-spring wheat (*Vicia faba – Triticum aestivum*) whole-crop silage (FB) on feed intake, nutrient utilization and milk production of dairy cows. Eight multiparous Finnish Ayrshire cows averaging 100 d in milk and producing 45 kg d^{-1} milk were used in a replicated 4×4 Latin square study. Experimental treatments consisted of timothy-meadow fescue (*Phleum pratense – Festuca pratensis*) silage (GS) and a mixture of GS and FB (1:1 on a dry matter (DM) basis). Both forages were fed *ad libitum* and supplemented with 13 kg d^{-1} of concentrate containing 2.0 or 3.5 kg rape seed meal (RSM). The crude protein content of the concentrate was 175 or 200 g kg^{-1} DM, respectively. Replacing half of the GS with FB maintained silage DM intake and milk yield despite the lower digestibility of FB silage. Increasing RSM in the diet had no effect on milk yield but significantly decreased milk fat concentration with both forages.

Keywords: *Vicia faba*, *Triticum aestivum*, whole crop silage, dairy cow

Introduction

Bi-crop cultivation of legumes and cereals was reported to have a positive effect on dairy production, farm economy and environment (Hauggaard-Nielsen *et al.*, 2008). The nitrogen fixing ability of legumes and their potential to improve the protein self-sufficiency adds special interest to this topic. In boreal growing conditions, grain legumes, like white lupin (*Lupinus albus*) and faba bean (*Vicia faba*), do not always have time to ripen for seed production. Therefore, having a relatively high biomass production capacity, grain legumes are an interesting alternative to grass as cattle forage. Although the energy value of faba bean silage is slightly lower than that of grass silage, the growth or milk production results using faba bean silage-based diets have been reported to be comparable to those based on grass silage or other whole-crop silages (McKnight and MacLeod, 1977; Ingalls *et al.*, 1979).

The current experiment compared the effects of grass silage (GS) and a mixture of GS and faba bean-wheat whole-crop silage (FB) on feed intake, nutrient utilization and milk production of dairy cows. Further, the effects of protein supplementation of the silages were studied.

Materials and methods

A mixture of faba bean (cv. Kontu, seed rate 200 kg ha^{-1}) and wheat (*Triticum aestivum,* cv. Marble, 94 kg ha^{-1}) was sown and fertilized with 50 kg N ha^{-1} on 22 May 2013 at the University of Helsinki (60°N, 25°E). At harvest 75 days after sowing, wheat was at the dough stage and the seeds of faba bean were green and filled the pod cavity, which corresponds to the growth stage of 80 according to Weber and Bleiholder (1990) and Lancashire *et al.* (1991). Grass silage was harvested on 10 June 2013 from a primary growth of mixed timothy (*Phleum pratense* L.) and meadow fescue (*Festuca pratensis* Huds.) sward. Both forages were mown using a mower conditioner, harvested with a self-loading wagon after wilting, treated with a formic acid-based additive and ensiled in bunker silos.

Eight multiparous Finnish Ayrshire cows averaging 100 d in milk and producing 45 kg d^{-1} milk were used in a replicated 4×4 Latin square study with 21 d periods and 2×2 factorial arrangement of treatments. Experimental treatments consisted of GS and a mixture of GS and FB (1:1 on a dry matter (DM) basis) and two amounts of rape seed meal (RSM) as a protein supplement. Both forages were fed *ad libitum* and supplemented with 13 kg d^{-1} of concentrate containing 2.0 or 3.5 kg RSM. The crude protein (CP) content of the concentrate was 175 or 200 g kg^{-1} DM, respectively. Feed intake and milk production data was subjected to analysis of variance using the MIXED procedure of SAS® (version 9.3) to analyse the effects of forage type, protein supplementation and their interaction.

Results and discussion

Part of the faba bean field ripened prematurely, which, together with the warm wilting conditions, explains the relatively high DM concentration of FB silage (Table 1). The DM yield of faba bean-wheat bi-crop was 5,500 kg ha^{-1}, the proportion of wheat being only 0.10. The fermentation quality of both silages was good as evidenced by low pH and concentration of volatile fatty acids. Grass silage had slightly lower CP concentration but clearly higher concentration of neutral detergent fibre and *in vitro* digestible organic matter (DOMD) than FB-silage. The chemical composition of FB was in agreement with Pursiainen and Tuori (2008).

Replacing GS partially with FB had no effect ($P>0.05$) on DM intake or milk, fat and protein yields despite the lower DOMD value (678 vs 611 g kg^{-1} DM) of FB than GS (Table 2). The results are in agreement with the results of replacing grass-legume silage with faba bean silage (Ingalls *et al.*, 1979; McKnight and MacLeod, 1977) and replacing grass silage with cereal whole-crop silages (Jaakkola *et al.*, 2009). Increasing the amount of RSM decreased milk fat content and fat yield ($P<0.05$) and as a result the energy corrected milk (ECM) yield tended to be lower with the higher CP content of the concentrate ($P<0.10$). Higher RSM content increased milk urea content in both silage diets. However, the increase was significantly higher in GS-FB (interaction $P<0.01$).

No significant treatment effects were observed in feed conversion rate ECM kg^{-1} DM. Feed N utilization (milk N/N intake) was impaired when the amount of RSM was increased ($P<0.01$). Inclusion of FB silage in the diet had no effect on nitrogen utilization for milk protein synthesis.

Conclusions

Partial replacement of grass silage with faba bean-wheat silage maintained animal performance despite the lower digestibility of faba bean-wheat silage. Thus, mixing grass silage and a bi-crop silage of grain

Table 1. Chemical composition of experimental silages.[1]

	Grass silage (GS)	Faba bean-wheat silage (FB)	Mixture (1:1) of GS and FB
Dry matter, g kg^{-1}	288	389	325
Crude protein, g kg^{-1} DM	155	165	160
NDF, g kg^{-1} DM	517	433	477
Starch, g kg^{-1} DM	na	115	65
pH	3.97	3.96	4.00
NH$_4$-N, g kg^{-1} N	65.2	58.0	58.7
WSC, g kg^{-1} DM	93	94	96
Lactic acid, g kg^{-1} DM	47	17	33
Volatile fatty acids	13.0	6.1	9.9
In vitro DOMD, g kg^{-1} DM	678	611	642

[1] DM = dry matter; NDF = neutral detergent fibre; WSC = water soluble carbohydrates; DOMD = digestible organic matter in the dry matter; na = not analysed.

Table 2. The effect of treatments on feed intake, milk production and feed utilization.[1]

Silage	GS		FB-GS		SEM	Significance		
Concentrate CP, g kg^{-1} DM	175	200	175	200		Silage	CP	Interaction
n	8	7	6	8				
Dry matter intake								
Silage, kg d^{-1}	13.6	13.9	14.5	13.7	0.48	0.466	0.529	0.261
Concentrate, kg d^{-1}	11.3	11.3	11.3	11.3				
Total, kg d^{-1}	25.0	25.2	25.8	25.0	0.48	0.459	0.550	0.272
Milk production and composition								
Milk, kg d^{-1}	35.5	35.4	36.1	35.8	1.02	0.226	0.565	0.760
ECM, kg d^{-1}	38.1	36.8	38.4	37.1	0.81	0.608	0.062	0.975
Fat, g d^{-1}	1,634	1,542	1,630	1,542	42.0	0.955	0.033	0.957
Protein, g d^{-1}	1,249	1,231	1,268	1,252	23.6	0.329	0.693	0.958
Lactose, g d^{-1}	1,571	1,562	1,604	1,600	49.8	0.077	0.690	0.895
Fat, g kg^{-1}	46.0	44.6	46.5	43.6	1.45	0.795	0.032	0.444
Protein, g kg^{-1}	35.4	35.5	35.8	35.3	0.84	0.726	0.511	0.377
Lactose, g kg^{-1}	44.3	44.1	44.4	44.7	0.30	0.138	0.816	0.322
Urea, mg (100 ml)$^{-1}$	30.5	32.0	33.7	39.7	1.22	<0.001	<0.001	0.002
Efficiency of utilization								
ECM/DM intake, kg kg^{-1}	1.55	1.49	1.52	1.52	0.044	0.907	0.290	0.397
Milk N/N intake	0.298	0.277	0.291	0.279	0.060	0.678	0.007	0.389

[1] GS = grass silage; FB = faba bean-wheat silage; CP = concentrate crude protein content; DM = dry matter; ECM = energy corrected milk yield.

legumes and cereal for dairy cow diets can be recommended. Increasing protein supplementation of the silages had no beneficial effects on feed intake or milk yield but it significantly decreased milk fat content and feed N utilization for milk protein.

References

Hauggaard-Nielsen H., Jørnsgaard B., Kinane J. and Jensen E. (2008) Grain legume-cereal intercropping: the practical application of diversity, competition and facilitation in arable and organic cropping systems. *Renewable Agriculture and Food Systems* 23, 3-12.

Ingalls J.R., Sharma H.R., Devlin T.J., Bareeba F.B. and Clark K.W. (1979) Evaluation of whole plant fababean forage in ruminant rations. *Canadian Journal of Animal Science* 59, 291-301.

Jaakkola S., Saarisalo E. and Heikkilä T. (2009) Formic acid treated whole crop barley and wheat silages in dairy cow diets: effects of crop maturity, proportion in the diet, and level and type of concentrate supplementation. *Agricultural and Food Science* 18, 234-256.

Lancashire P.D., Bleiholder H., Langelüddecke P., Stauss R., Van den Bloom T., Weber E. and Witzen-Berger A. (1991) An uniform decimal code for growth stages of crops and weeds. *Annals of Applied Biology* 119, 561-601.

McKnight D.R. and MacLeod G.K. (1977) Value of whole plant faba bean silage as sole forage for lactating dairy cows. *Canadian Journal of Animal Science* 57, 601-603.

Pursiainen P. and Tuori M. (2008) Effect of ensiling field bean, field pea and common vetch in different proportions with whole-crop wheat using formic acid or an inoculant on fermentation characteristics. *Grass and Forage Science* 63, 60-78.

Weber E. and Bleiholder H. (1990) Erläuterungen zu den BBCH-dezimal-codes für die entwicklungsstadien von mais, raps, faba-bohne, sonnenblume und erbse – mit abbildungen. *Gesunde Pflanzen* 42, 308-321.

Regrowth pattern of *Lotus corniculatus* L. natural populations under limited irrigation

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Abstract

Lotus corniculatus L. (birdsfoot trefoil) is a perennial legume forage species native to the Mediterranean basin, well adapted to marginal environments. In the present study, the regrowth pattern of two *L. corniculatus* natural populations from different origins was examined under optimum and limited irrigation. Plants from two semi-arid areas of northern Greece (Macedonia) were selected and transplanted to pots. They were grown under a transparent shelter in two water regimes: (1) irrigation up to field capacity, and (2) limited irrigation (40% of optimum). Plants were harvested at different dates (phenological stages) in spring and left to regrow. The harvested plants grew for 8, 30, 39 and 46 days. The yield, the leaf and stem weight and the number of stems were measured and the leaf weight ratio (LWR) was calculated. The results showed that limited irrigation reduced the yield and the number of stems of both tested populations. There was a greater decrease in stem biomass than of leaves, giving higher LWR under limited irrigation, especially in the 'Drama' population. This decline in yield suggests that this species is suitable for cultivation in semiarid Mediterranean areas under rain-fed conditions.

Keywords: birdsfoot trefoil, legume, drought, productivity, stem number

Introduction

Drought, a common phenomenon in Mediterranean areas, especially during summer, has many adverse impacts on plants, inhibiting their growth (Asgharipour and Heidari, 2011). The selection of species that produce more under drought can lengthen the time that farmland is productive and enhance eco-efficiency. The identification of morphological characteristics contributes to the study of species tolerance to stress (Acuna *et al.*, 2012; Keating *et al.*, 2010). *Lotus corniculatus* L. (birdsfoot trefoil) is an herbaceous, perennial legume, native to the Mediterranean basin, Europe and parts of Eurasia and Africa. It is an agronomicaly important legume of high nutritive value (Escaray *et al.*, 2012) similar or even higher value than *Medicago* spp. and *Trifolium* spp., mainly because of its non-bloating features when grazed directly by livestock. It is drought-tolerant and well adapted to marginal environments (Carter *et al.*, 1997; Escaray *et al.*, 2012).

The aim of the present study was to compare the regrowth pattern of two natural populations of *Lotus corniculatus* L. of different origin under optimum and limited irrigation.

Materials and methods

Two natural populations of *Lotus corniculatus* L. were sampled from semi-arid areas of central Macedonia, Greece: Drama (temperature 15.22 °C; precipitation 621.3 mm; altitude 100 m.a.s.l.) and Theodosia Kilkis (Kilkis) (temperature 12.2 °C; precipitation 585 mm; altitude 570 m.a.s.l.) in autumn of 2012. The collected plants were transplanted into small pots, at the farm of the Aristotle University of Thessaloniki, Northern Greece (40°31' E, 23°59' N; altitude 6 m.a.s.l.), where the climate is Mediterranean semi-arid with mean annual air temperature of 15.5 °C. In the beginning of March of 2013, 32 plants from each

population were transplanted – one plant per pot – into larger pots (16 cm diameter and 45 cm height), filled with medium-texture soil from the farm. After a period of plant establishment, a transparent shelter was placed over the plants. Two irrigation treatments were applied by drip: full irrigation up to field capacity (Ir) and limited irrigation (LI) (40% water of that received by Ir). The first plant harvest was performed at 4 cm above the soil surface, at four different dates (phenological stages): 1st cut: 21 May 2013, 2nd cut: 29 May 2013, 3rd cut: 5 June 2013, 4th cut: June, 2013. After that, all the pots were harvested simultaneously on 5 July in order to estimate the plant regrowth. The regrowth days were: 8, 30, 39 and 46, depending on the first harvest date. The fresh and dry yield of each plant was measured after each cutting. The number of stems per plant, the stem and leaf dry weight was measured. Leaf weight ratio (leaf dry weight/shoot dry weight: LWR) was calculated. A completely randomized design with four replications of each treatment was used. Three-way ANOVA analysis was performed using IBM SPSS statistical software v. 21.0 (SPSS Inc., Chicago, IL, USA), in order to determine differences among populations, days of regrowth and irrigation treatments. The least significant difference (LSD) at the 0.05 probability level was used to detect the differences among means.

Results and discussion

The number days of regrowth and the irrigation level significantly affected the yield, but there were no significant differences between the populations and no significant interactions among the main effects (data not sown). On average (mean across the irrigation level and the populations), significantly lower yield was recorded at 8 and 30 days of regrowth (Table 1). No significant differences were detected between 39 and 49 days of regrowth. That means that the highest growth was at 39 days, for both populations at both irrigation treatments, which is suggested as the appropriate harvest time. Under LI both populations produced less than half the yield of Ir. Similar reductions of yield under drought stress has been reported for this species by many researchers (Acuna *et al.*, 2012; Karatassiou *et al.*, 2014) and for field-grown lucerne (Lazaridou *et al.*, 2003). This result suggests there is potential for use of both of these *L. corniculatus* populations for improving farmland eco-efficiency.

The number of stems was significantly increased up to 39 days, with no significant differences between populations, and there were significantly fewer stems under limited irrigation in both populations (Table 1). The stem number increased during the regrowth period (and also the yield), and the increase was greater under limited irrigation. The leaf weight ratio (LWR), one of the most important allometric indexes determining the photosynthetic rate, plant growth and forage quality, was also significantly affected by population, irrigation and days of regrowth. The LWR increases during regrowth and it is higher under LI than in Ir. Moreover, the 'Drama' population had a significantly higher LWR in both

Table 1. The yield per plant (g), the number of stems per plant and the leaf weight ratio (LWR) of two natural populations of *Lotus corniculatus* under full and limited irrigation.[1]

Treatment	Irrigation			Regrowth days			Populations		
	Yield, g	Stem/plant	LWR	Yield, g	Stem/plant	LWR	Yield, g	Stem/plant	LWR
Full irrigation	44 a	60 a	0.33 b						
Limited irrigation	19 b	53 b	0.50 a						
8 days				3 c	14 c	0.51 b			
30 days				35 b	64 b	0.40 a			
39 days				44 a	71 ab	0.39 a			
46 days				45 a	77 a	0.37 a			
Drama							34 a	56 a	0.46 a
Kilkis							30 a	56 a	0.37 b

[1] Values given are the means of four replicates. Different letters in each column indicate significant differences (*P*≤0.05).

irrigation treatments than 'Kilkis'. No significant effect of limited irrigation on LWR was recorded at the first growth of the plant (Karatassiou *et al.*, 2014). Erice *et al.* (2010) reported that the effect of water deficit on LWR varies, and it depends on cultivar and on severity of drought.

Conclusions

Limited irrigation decreased the yield and the number of stems of both the tested populations of *Lotus corniculatus*. There was a greater decrease in stem biomass than of leaves, giving a higher LWR under limited irrigation, especially in the 'Drama' population. This decline in yield suggests that the species is suitable for cultivation in semiarid Mediterranean areas under rain-fed conditions.

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References

Acuña H., Inostroza L. and Tapia G. (2012) Strategies for selecting drought tolerant germplasm in forage legume species. In: Rahman I.M.M. (ed.), *Water Stress*, In Tech, Croatia, pp. 277-300.

Asgharipour M.R. and Heidari M. (2011) Effect of potassium supply on drought resistance in sorghum: plant growth and macronutrient content. *Pakistan Journal of Agricutlural Science* 48(3), 197-204.

Carter E., Theodorou M. and Morris P. (1997) Responses of *Lotus corniculatus* to environmental change I. Effects of elevated CO_2, temperature and drought on growth and plant development. *New Phytology* 136, 245-253.

Erice G., Louahlia S., Irigoyen J.J., Sanchez-Diaz M. and Avice J-C. (2010) Biomass partitioning, morphology and water status of four alfalfa genotypes submitted to progressive drought and subsequent recovery. *Journal of Plant Physiology* 167, 114-120.

Escaray F.J., Menendez A.B., Gárriz A., Pieckenstain F.L., Estrella M.J., Castagno L.N., Carrasco P., Sanjuán J. and Ruiz O.A. (2012) Ecological and agronomic importance of the plant genus *Lotus*. Its application in grassland sustainability and the amelioration of constrained and contaminated soils. *Plant Science* 182, 121-133.

Karatassiou M., Kostopoulou P., Lazaridou M., Merou T., Giagourta P. and Noitsakis B (2014) Impact of limited irrigation on the growth characteristics of *Lotus corniculatus*. *Options Mediterraneenes, Series A: Mediterannean seminars* 109, 173-177.

Keating B.A., Carberry, B., Bindrabanc P.S., Assengd S., Meinkee H. and Dixon J. (2010) Eco-efficient agriculture: concepts, challenges and opportunities. *Crop Science* 50, S109-S119.

Lazaridou M. and B. Noitsakis (2003) The effect of water deficit on yield and water use efficiency of lucerne. *Grassland Science in Europe* 8, 344-347.

Is it possible for large herds to graze while keeping a high milk yield level? The experience of two Belgian dairy farms

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Abstract

Grazing is more and more abandoned because of increasing size of herds and automation of herd management (e.g. automatic milking system – AMS). In this context, this study aims to evaluate milk production and composition of 2 large Belgian dairy herds equipped with AMS during winter and summer. These herds were followed over 2 years. At grazing, 30% of the offered feed was grass. Milk production in both herds was similar in summer and winter (30.2 ± 7.14 vs 29.7 ± 7.8 in Herd 1 and 26.9 ± 0.8 vs 26.4 ± 0.8 in Herd 2) while milk their composition differed. In conclusion, it is possible for grazing to be preserved even in large herds without noticeably impact on the herd performance.

Keywords: grazing, dairy cows, automatic milking system, milk performance, large herd management

Introduction

In Europe, the number of farms is decreasing while their size is generally increasing. In parallel, the working unit per exploitation has dropped, opening the way for use of new technologies allowing the farmer to manage larger herds with little labour, such as automatic milking systems (AMS). The use of AMS is considered difficult to combine with grazing. However, grazing is beneficial from several points of view, including economic aspects. The aim of this study is to assess the impact of grazing on milk performance in two Belgian dairy herds equipped with AMS and followed over 2 years.

Material and methods

Two dairy herds (H1 and H2) equipped with AMS (DeLaval for H1 and Lely for H2) were followed in 2013 and 2014. In H1, 102 Holstein dairy cows in 2013 and 124 in 2014 grazed on 35 ha pastures, divided into 10 plots from 1.4 to 7.7 ha. In H2, 122 Holstein cows in 2013 and 136 in 2014 grazed on 42 ha pastures, divided into 8 plots. Strip grazing allowed the cows to be provided with fresh grass every day.

The grazing period extended from 30 April to 31 October 2013 (184 d) in both herds and from 25 April to 31 October 2014 (192 d) for H1 and from 14 April to 15 November 2014 for H2 (216 d). The cows had access to pastures from 06:00 until 18:00 on average. Those cows that did not return voluntarily to the barn were fetched. Each received a total mixed ration (TMR) whose composition and amounts offered were recorded. Additional concentrate was given during milking in the AMS. In both herds, calvings took place throughout the year.

To estimate grass availability, grass height was measured on the pastures by using a Jenquip® rising plate meter when the cows came in and out of the parcel. The forage mass available for grazing was estimated by weighing a 10 meter-long strip of cut grass. Cut samples were analysed to determine dry matter (DM) available per ha and per cow. Production data and cow-traffic parameters were obtained from the robots while the data about milk composition were gathered from reports of milk deliveries.

Results and discussion

For H1, in 2013 the forage mass was estimated (mean ± standard deviation) at $1,322\pm564$ kg DM ha^{-1} and in 2014 it was $1,660\pm299$ kg DM ha^{-1}. For H2, in 2013 forage mass was $1,277\pm633$ kg DM ha^{-1}, but

the amount was greater in 2014 (1,476±418 kg DM ha^{-1}). The DM ingested by the cows was estimated at 22 kg; this amount was based on winter consumption. In both herds, grass intake was calculated by subtracting DM provided by the TMR and concentrate, from 22 kg. The proportions of feeds were calculated monthly and grass intake averaged 30%.

In H1, milk yield (MY) in summer 2013 was 30.2 kg cow^{-1} d^{-1} with 3.67 kg cow^{-1} d^{-1} concentrate consumed, and in 2014 it was 29.7 kg cow^{-1} d^{-1} produced with an average of 3.70 kg concentrate cow^{-1} d^{-1}. No significant difference was noted between summer and winter MY (Table 1). In H2, the MY was higher during the grazing period. The MY in 2014 was higher than in 2013, despite the increase in number of animals and the relative saturation of the robot. This yield increase was associated with an increase of nearly 2 kg concentrate in the AMS per 100 kg milk produced (0.60 kg cow^{-1} d^{-1}). In 2013, the numbers of milkings in summer and winter were similar, whereas in 2014, milkings decreased during summer. There were fewer refusals in the summers of both years.

In both herds, milk composition was modified during the grazing season (Table 2). Recorded values are in accordance with the literature (Prendiville *et al.*, 2009).

Table 1. Milk production (MY), days in milk (DIM), amount of concentrates given in the automatic milking system and number of milkings day^{-1} during the winter 2014 (December – March) and the summer 2014 (May – October) in herd 1 and during summers (May – October) and winters 2013-2014 (December – March) in herd 2.[1]

	Herd 1		Herd 2			
	2013-2014		2013		2014	
	Winter	Summer	Winter	Summer	Winter	Summer
Nbr cows	87±11	91±11	122±4	122±4	127±7	137±3
MY (kg cow^{-1}.d^{-1})	30.2±7.2	29.7±7.8	25.9±0.7***	26.3±1.7	26.8±0.9***	27.4±0.7
DIM (d)	240±164	221±142	201±4***	211±10	185±6***	201±10
Concentrates (kg cow^{-1}.d^{-1})	3.67±1.66	3.70±0.99	2.43±0.15***	2.69±0.21	3.00±0.11***	3.30±0.18
Milkings (kg cow^{-1}.d^{-1})	2.64±0.50	2.47±0.40***	2.59±0.01	2.60±0.02	2.63±0.08***	2.54±0.06
Refusals (kg cow^{-1}.d^{-1})			1.34±0.08***	1.06±0.31	1.30±0.19***	0.90±0.10

[1] Values are means ± standard error. Values statistically different are indicated by asterisks: * *P*<0.05; *** *P*<0.001.

Table 2. Milk composition: fat % (F%), protein % (P%), urea (mg l^{-1}) and somatic cell count (SCC) recorded during summer 2013-2014 (May – October) and compared with those recorded in winter 2013-2014 (from December – March) in Herd 1 and Herd 2.[1]

	2013		2014	
	Winter	Summer	Winter	Summer
Herd 1				
%F	4.07±0.05***	3.89±0.15	4.05±0.07***	3.92±0.10
%P	3.41±0.04***	3.36±0.14	3.40±0.04***	3.33±0.09
Urea (mg dl^{-1})	197±47^{NS}	197±40	252±28***	238±39
SCC (1000 ml^{-1})	223±50***	322±70	208±38 ***	224±45
Herd 2				
%F	4.30±0.07***	4.12±0.17	4.29±0.06***	4.08±0.14
%P	3.43±0.09	3.45±0.14	3.51±0.06***	3.46±0.06
Urea (mg dl^{-1})	220±28*	234±35	245±36***	225±44
SCC (1000 ml^{-1})	190±43***	241±64	154±137***	220±98

[1] Values are means ± standard error. Statistically significant values are indicated by asterisks: * *P*<0.05; *** *P*<0.001, NS not significant.

Incorporation of grass in the cows' feed could be increased based on measurements of grass forage mass available for grazing. Variations in milk composition could be minimized by a better adjustment of TMR composition.

Conclusions

These results demonstrate that, in farms equipped with an AMS, grazing is possible even in large herds with high milk production levels.

Acknowledgement

References

Prendiville R., Pierce K.M. and Buckley F. (2009) An evaluation of production efficiencies among lactating Holstein-Friesian, Jersey, and Jersey × Holstein-Friesian cows at pasture. *Journal of Dairy Science* 92, 6176-6185.

Working with farmers to make the most of soil nutrients for eco efficiency – The PROSOIL PROJECT

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Abstract

Working with key industry stakeholders and farmers, the PROSOIL project aims to achieve a better understanding of soil and nutrient management to optimise farm productivity. Linked to IBERS research that is scientifically determining the impact of improving soil health on forage and livestock productivity and quality, farmer participation is a key part of the dissemination. Eight commercial development farmers (CDF), who volunteered during a series of events, are working with IBERS Grassland Development Centre to explore the effects of their farming practices on soil health and productivity by making field-scale measurements. The farms represent different agriculture sectors including three dairy farmers who use a range of systems for recycling animal manures and other soil nutrients. Results from the CDF, including the implications of nutrient management methods, and a survey of Welsh dairy farmers' soil nutrient management practices will be presented. Findings are disseminated through a range of knowledge exchange methods, from indirect factsheets to active learning through participation that encourages farmers to actively adopt and evaluate soil management approaches when they meet, discuss and share results.

Keywords: soil health, soil nutrients, slurry, earthworms, management

Introduction

PROSOIL aims to develop producer-led co-operation across Wales to better understand and improve soil management to optimise farm productivity; to scientifically determine the impact of improving soil health on forage and livestock productivity and quality; and to disseminate key findings. Linking the farmers' activity to the studies at the university is central to the project.

Materials and methods

To ensure active participation, eight commercial development farmers were selected from a pool of forty-two farmers who volunteered to be part of the project which was promoted at a range of agricultural events in Wales. Selection was based on geographic region, farm type and suitability of both resources and the farmer's enthusiasm and interest in soil management. The three dairy farmers selected management options that focussed on soil nutrient management which included slurry aeration, use of anaerobic digestate and slurry analyses to guide application rates. The farmers also monitored the project fields including counting earthworm numbers as an indicator of soil health. Using data from the dairy farmers questioned in a soil management survey, results were collated on key nutrient questions.

Results and discussion

On Farm 1, analysis of slurry and manipulating its application was of key importance in cutting fertiliser use and for farming within the Nitrate Vulnerable Zone (NVZ) rules. Its variability (dry matter ranged from 2.6 to 10.7%, and the total value of the nutrients ranged from £22 to £54.59 per 10 m^3) demonstrated how the standard 'RB209' book values (Defra, 2010) are useful only as a guide. Using a trailing shoe maximized the use of available nitrogen in slurry and contributed to meeting the needs of entry to the Welsh agri-environment scheme 'Glastir'. It also reduced slurry damage to the leys and reduced slurry odour in an urban area. On Farm 2, the liquid digestate (feedstock included breadwaste,

Table 1. Financial value of on farm slurries and liquid digestate (£/10 m^3)[1] on PROSOIL commercial development farms.

Years 1-4 £ /10 m^3	Farm 1 Dairy slurry	Farm 2 Liquid digestate	Farm 3 Aerated slurry	Farm 3 Non-aerated slurry
Highest	54	107	63	50
Lowest	22	47	33	6
Mean	40	73	44	31
RB209	44	44	44	44

[1]Calculated as the fertiliser value based on N, P and K content at 80, 66 and 47 pence kg^{-1} respectively, and based on current UK prices.

slurry and apple pomace) was consistently higher, averaging £73 per 10 m^3 with a range of £43-107 per 10 m^3. (The 'RB209' standard value for slurry is £44 per 10 m^3). On Farm 3 the mean increase in the value of aerated slurry pre-application was £13 m^{-3} rising to a difference of £27 m^{-3} at the lowest estimated values.

The results of a survey of 66 dairy farmers in Wales showed that 79% did not obtain analyses of their slurries or manures to guide application rates of manures and fertilisers. However, 63% did change their fertiliser applications to follow a whole-farm nutrient management plan.

Earthworms are essential to healthy soils including soil formation and for the NPK value of their casts. On the 3 dairy farms the economic value of soil formation by earthworms was estimated from earthworm counts at key times of the year (Sandhu *et al.*, 2008), at between £2.63 and £3.39 ha^{-1} year^{-1}. Using the average biomass per earthworm from IBERS plot data of 0.37 g and that 1000 kg of earthworms can turnover 1000 kg soil ha^{-1} (Sandhu, 2008) the value was estimated from the current price of topsoil at £78 Mg^{-1}. On farm 2, under different management methods the value of soil formation by earthworms was estimated as £3.67 under ryegrass and no digestate and £4.51 ha^{-1} year under red clover receiving digestate application. The PROSOIL commercial development farmers regularly counted earthworms and an economic value was calculated; however, from the survey just 30% of the farmers questioned counted earthworms in their soils.

Conclusions

Dairy farmers in the PROSOIL project were able to understand the value of slurry and digestate by routinely analysing its nutrient content and adjusting their fertiliser applications to meet grassland needs. The variation from the standard RB209 figures highlights the importance of slurry/digestate analyses in soil nutrient management from both an economic and environmental perspective. Participation in the PROSOIL project enabled farmers to share these experiences with other farmers. The survey highlighted that although more than half the farmers followed a whole-farm nutrient management plan, only 31% had their slurries and manures analysed. There is potential to improve economic and eco efficiency of dairy farmers in Wales by improving the understanding of the value of manure analyses and slurry treatments through further participative learning.

Acknowledgements

References

Sandhu H.S., Wratten S.D., Cullen R. and Case B (2008) The future of farming: the value of ecosystem services in conventional and organic arable land. An experimental approach. *Ecological Economics* 64, 835-848.

Defra (2010). *The fertiliser manual (RB209).* 8th edition. Department for Environment Food and Rural Affairs, UK.

Perennial ryegrass variety ranking responses to inclusion of white clover and altered nitrogen fertility

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Abstract

Perennial ryegrass (*Lolium perenne*) is the most widely used ryegrass species for high-output pasture based dairy farms in Europe. Repeated selective breeding has enhanced dry matter (DM) productivity potential, elevated nutritive value and provided a large diversity of varieties adapted to variant growing conditions and farming practices. With renewed interest in white ryegrass-clover swards mixtures, there is a concern that sward interactions between perennial ryegrass varieties and white clover will have a significant effect on the dry matter yield performance of a recommended grass variety. The aim of this study was to establish if perennial ryegrass varieties re-rank in DM yield when sown with/without white clover at two nitrogen applications under intensive grazing. Eight perennial ryegrass varieties were sown with (+C) /without (-C) white clover. Swards received two levels of nitrogen 250 (HN) and 100 (LN) kg N ha^{-1}. Treatments were HN+C, HN-C, LN+C and LN-C. A significant nitrogen by clover interaction occurred because LN-C gave the lowest yield, but although high nitrogen increased both the with and without clover treatments, the highest yielding treatment was LN+C. Grass variety had a significant effect *(P*>0.001*)* on DM yield, but the ranking of the ryegrass varieties was unaffected by the imposed treatments and so represented a robust estimation of the relative DM production potential of each ryegrass variety. The inclusion of clover also did not affect the relative performance of the ryegrass varieties, indicating that any inter-species competitive interactions were not variety specific.

Keywords: dry matter, perennial ryegrass, white clover, nitrogen, intensive grazing

Introduction

Perennial ryegrass (*Lolium perenne*) (PRG) is the most widely used forage grass in North-Western Europe (Wilkins and Humphreys, 2003). With the intensification of agriculture throughout Europe, the ability of farmers to increase forage yield, through increased fertiliser inputs is limited (Parsons *et al.*, 2011). The inclusion of white clover in perennial ryegrass pastures has been shown to increase herbage and animal performance production while reducing artificial N inputs. In Europe, perennial ryegrass varieties are generally evaluated in monoculture swards under a mechanically harvested, simulated grazing protocol with high levels of N fertiliser (e.g. 350 kg N ha^{-1} year^{-1}; DAFM, 2010). However, on farm, PRG swards are grazed directly by animals and often sown in a mixture with white clover (WC) under reduced N inputs. As perennial ryegrass and white clover can interact in a mixed sward (Camlin, 1981), it is important that grass varieties are ranked according to the conditions under which they are used to ensure that the best-adapted and highest performing can be identified. If ryegrass varieties interact differently with white clover and, if this is modified by fertility levels, then grass variety evaluations will need to account for this variable when making recommendations. Therefore, this study was designed to compare the relative dry matter (DM) performance of perennial ryegrass varieties with and without white clover at two nitrogen inputs under intensive cattle grazing.

Materials and methods

An experiment was established in June 2012 at the Animal and Grassland Research and Innovation Centre, Moorepark, Co. Cork, Ireland. The experiment was a randomised block design with a 2×2

factorial arrangement of treatments with 5 replicates of 18×3 m plots. Eight perennial ryegrass varieties (4 diploids and 4 tetraploids) were sown as grass-only (-C) or grass with WC (+C). Two fertiliser N rates were applied: 100 (low) and 250 (high) kg N ha^{-1}. Sowing rates were 37 kg ha^{-1} for the tetraploid varieties and 34 kg ha^{-1} for the diploid varieties while the medium leaf WC, Crusader was included in the +C plots at 5 kg ha^{-1}. Treatments were high nitrogen sown without clover (HN-C), high nitrogen sown with clover (HN+C), low nitrogen sown without clover (LN-C), and low nitrogen sown with clover (LN+C). Rotation length was adjusted depending on the N application (HN – 21 days; LN – 30 days). Plots were grazed by dairy cattle to a target post-grazing residual height of 4 cm in the first year. Experimental measurements commenced in March 2014, employing the same grazing strategy. Dry matter yield was estimated in each plot by cutting a strip (approx. 5×1.2 m) with an Etesia mower. Harvested herbage was weighed and a subsample of 100 g was used to determine DM content. There were nine grazing rotations on the HN plots and seven grazing rotations on the LN plots from 18 March to 14 October 2014. Seasonal yields composed of spring (March-April), mid-season (May-July) and autumn (August-October). Data were analysed using PROC MIXED in SAS (version 9.3) with block, treatment, variety and their interactions tested for in the model.

Results and discussion

The grass varieties differed significantly *(P<0.001)* in annual DM yield (Figure 1). When averaged across all treatments, the range was from Glenveagh (12,140 kg DM ha^{-1}) to Aston Energy (9,870 kg DM ha^{-1}). With such a wide but progressive range in performance, it would be expected that if varieties reacted differentially to the imposed treatments then this could be detected within this yield range. Furthermore, a significant nitrogen by clover interaction occurred between treatments *(P<0.001)*, due to LN-C giving the lowest yield, but while high nitrogen gave greater yields with and without clover, the highest yield of all was from LN+C (Table 1). This was evident in the total annual yields (LN-C 9,126 kg DM ha^{-1} and LN+C 13,021 kg DM ha^{-1}) and also in each seasonal period. This response also meant that there was no significant difference between nitrogen treatments (HN-C and HN+C vs LN-C and LN+C) in total annual yield or in spring or summer productivity. In the autumn period HN did out yield the LN *(P<0.01)* possibly due to the LN-C sward receiving insufficient N with a response of 26 kg DM per additional kg N in favour of the HN-C treatment creating a greater difference between treatments. Despite all these significant responses, there was no interaction between variety ranking and treatment in seasonal or annual DM yields, indicating that the relative performance of the eight varieties was not differentially affected by either altering the nitrogen fertility or by including white clover into the sward. These findings are similar to previous reports by McDonagh *et al.* (2014) and Rossi *et al.* (2014). The degree of resilience in rank order was despite the absolute DM yields changing significantly between
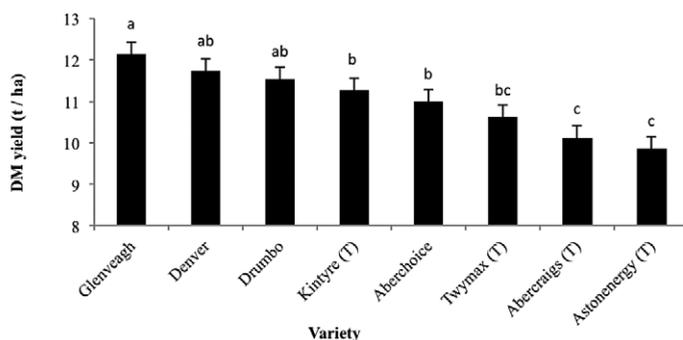
Figure 1. Annual range in dry matter (DM) yield of eight perennial ryegrass varieties as an average of the clover and nitrogen treatments. T = tetraploid variety; bars with different letters (a-c) differ at *P<0.05*.

Table 1. Effect of nitrogen, clover and their interaction on dry matter (DM) yield of perennial ryegrass varieties.[1,2,3]

	HN-C	HN+C	LN-C	LN+C	SED	N	Clover	N × Clover
Annual (kg DM ha^{-1})	10,554[a]	11,450[b]	9,126[c]	13,021[d]	202	NS	***	***
Spring (kg DM ha^{-1})	2,052[a]	2,221[b]	1,944[a]	2,486[c]	78	NS	***	***
Summer (kg DM ha^{-1})	6,283[a]	6,763[b]	5,503[c]	7,912[d]	166	NS	***	***
Autumn (kg DM ha^{-1})	2,220[a]	2,466[b]	1,678[c]	2,623[d]	42	**	***	***

[1] HN = 250 kg N ha^{-1}; LN = 100 kg N ha^{-1}; +C / -C = with/without white clover.; SED = standard error of the diference.

[2] Means within a row with different superscripts differ ($P<0.05$).

[3] NS = not significant; * $P<0.05$, *** $P<0.001$.

treatments ($P<0.001$) (Table.1), with the greatest difference occurring in the mid-season period (+2,403 kg DM ha^{-1}) when clover content peaked (data not shown).

Conclusions

The results from this study indicate that for the perennial varieties examined, their relative DM productivity ranking is not modified when white clover is introduced into the swards and this resilience is maintained even when nitrogen levels are also substantially changed. This indicates that it is not necessary to have separate testing protocols to assess the DM yield potential perennial ryegrass varieties for use in grass-only and mixed grass-clover grassland systems.

References

Camlin M.S. (1981) Competitive effects between ten cultivars of perennial ryegrass and three cultivars of white clover grown in association. *Grass and Forage Science* 36, 169-178.

DAFM (2010) *Grass and clover recommended variety list Ireland 2010.*

McDonagh J., McEvoy M, Gilliland T.J. and O'Donovan M. (2014) Genotype × management interactions in perennial ryegrass pastures. In: *Proceedings of Irish Grassland and Animal Production Association conference.*

Parsons A.J., Edwards G.R., Newton P.C.D., Caradus J.R, Rasnusseb S. and Rowarth J.S. (2011) Past lessons and future prospects: plant breeding for yield and persistence in cool-temperate pastures. *Grass and Forage Science* 66, 153-172.

Rossi L., McDonagh J., McEvoy M., O'Donovan M., Lee J.M, Chapman D.F. and Edwards G.R. (2014) Implications of species and management interactions for ranking perennial ryegrass (*Lolium perenne* L.) varieties: a progress report from the two hemispheres. In: *Proceedings of the 5th Australasian Dairy Science Symposium 2014.*

Wilkins P.W and Humphreys M.O. (2003) Progress in breeding perennial forages for temperate agriculture. *Journal of Agricultural Science* 140, 129-150.

Forage pea yield after application of different rates of pig and cattle manure

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Abstract

Animal production should be mostly based on farm resources as this reduces animal product costs. Forage legumes like peas are adequate for fulfilling part of the animals' protein needs. Fertiliser prices have also added to high input costs for farmers in recent years, and this make the use of manures produced on farms more important. This study aims at evaluating the effect of two different rates of pig and beef cattle manure on forage pea yield, compared with the traditional mineral fertiliser used in the area. An analysis of the manures was carried out showing that pig manure has a higher level of nutrients than cattle manure. Both manures resulted in a higher seed yield than was obtained by using mineral fertiliser.

Keywords: fertiliser, protein, production, management, legumes

Introduction

Galicia (NW Spain) is the main Spanish region for the production of milk and meat. This region is located in the Atlantic region of Europe. However, compared with the northern European Atlantic regions, Galicia has a drought period of around two months in summer. This makes it necessary to feed animals indoors during the summer, using silage (mainly maize silage) and concentrates. The protein supply in the feed for animals is the main factor determining the price of concentrates (Heuzé *et al.*, 2013). Increased legume yield in European farms should be promoted in order to reduce production costs, and also because of the environmental impact attributed to the use soybean imports mainly from America. Legume yield depends on fertiliser supply; this is mainly just P and K on acid soils, as legume crops are able to fix nitrogen from the atmosphere. Due to the high density of pigs and dairy cattle, the amount of manure produced per farm in Galicia is high. This makes it necessary to provide adequate disposal for this residue. The aim of this paper was to evaluate the effect of two different rates of pig and beef cattle manure on the yield of forage pea, compared with using the traditional mineral fertiliser of the area.

Materials and methods

The experiment was established in Goo (NW Spain) in 2014 when the soil was ploughed and the experimental plots were established. Each plot occupied 9 m^2 and in June 2014 the plots were sown with forage peas. The experiment followed a randomized complete block design with four replicates and five treatments. Initial soil analyses are listed in Table 1. Soil pH was very acid as is usual in the area. The levels of nutrients and heavy metals were low.

The treatments consisted of two rates (low (L) and high (H)) of two types of fertilisers (pig manure (P) and cattle manure (C)). The total amounts of manure added were 27.24 and 54.48 Mg ha^{-1} for the low and high rates of fresh cattle manure, and 37 and 74 Mg ha^{-1} for low and high rates of the pig manure. Therefore, these rates supplied 61 and 123 kg N ha^{-1}, 13.8 and 27.8 kg P ha^{-1} and 84 and 168 kg K ha^{-1} when the cattle manure was applied, and 27.6 and 55.1 kg N ha^{-1}, 16.6 and 33.3 kg P ha^{-1} and 30.1 and 60.2 kg K ha^{-1} when pig manure was used. These are actual values based on samples taken while the fertilisation was being carried out at field level. The quality of the both types of manure is presented in Table 2. Pig manure has a lower amount of dry matter, higher concentrations of nutrients and also a

Table 1. Initial soil analyses. All concentration values are on a dry matter basis.

pH (H$_2$O)	pH (KCl)	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Na (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	Fe (g kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Ni (mg kg^{-1})	Zn (mg kg^{-1})
5.26	3.84	0.8	1.2	5.9	1.1	3.2	14.3	30.7	3.61	15.79	41.19	29.78	125.32

Table 2. Properties of cattle and pig manure used in this experiment. All concentration values are on a dry matter basis.

	Dry matter (%)	N (g kg^{-1})	P (g kg^{-1})	K (g kg^{-1})	Na (g kg^{-1})	Ca (g kg^{-1})	Mg (g kg^{-1})	Fe (g kg^{-1})	Cr (mg kg^{-1})	Cu (mg kg^{-1})	Mn (mg kg^{-1})	Ni (mg kg^{-1})	Zn (mg kg^{-1})
Cattle manure	10.19	22.1	5	30.3	1	9.8	8.2	2.1	1.7	15.65	9.6	2.35	61.2
Pig manure	2.38	31.3	18.9	34.2	2.7	18.3	2.51	2	3.55	162.2	11.35	8.65	1,266.29

higher concentration of heavy metals compared with cow manure. Mineral fertilisation (MIN) consisted of inputs of 40, 52.8 and 66.4 kg of N, P and K per hectare in the form of mineral compound 8:24:16.

To estimate the yield of forage peas, in each plot a surface of 2.5×2.5 m^2 was harvested and weighed in the field in October 2014. Before the harvest, the crop establishment rate in each plot was determined by visual estimation. In the laboratory, a subsample was separated into the components of pod, stem and seeds. These components were dried and weighed to estimate the dry matter yield and the dry matter weight of 100 peas. Data were analysed using ANOVA and differences between averages were shown by the least significant difference (LSD) test, if ANOVA was significant. The statistical software package SAS (2001) was used for all analyses.

Results and discussion

The establishment of the crop (Figure 1) was quite adequate considering the yield that the forage crop reached (between 8 and 9 Mg ha^{-1}), which is within the usual range for forage peas (Bilgili *et al.,* 2010; FAO, 2012). However, the total yield was significantly increased by the use of manure, both pig and cattle (5.05, 8.36, 9.71, 9.64, 8.59 Mg ha^{-1}, respectively for MIN, PL, PH, CL, and CH). The differences between treatments were mainly linked to the different amounts of seed yield. Seeds were better developed when manure was used, as indicated the variable of weight of 100 seeds. No differences between rates or type of the organic fertiliser were found. The results can be explained by the action of the manure in supplying a wider range of nutrients and organic matter than the mineral fertiliser. This could avoid the negative effect of the Al content in the soil due to the addition of Ca and also the inputs of organic matter, which could retain Al and release it from the soil nutrient solution. The lack of differences in the effects of manure rates makes us recommend using the low manure rate, whether it comes from cattle or pig farms. Similar results were also found by Olusegun (2014).

Conclusions

The use of manure, both cattle and pig manure, caused a higher seed yield when compared with using mineral fertiliser. Therefore, the use of manure at low rates will allow farms to be more sustainable and profitable from an economic point of view.
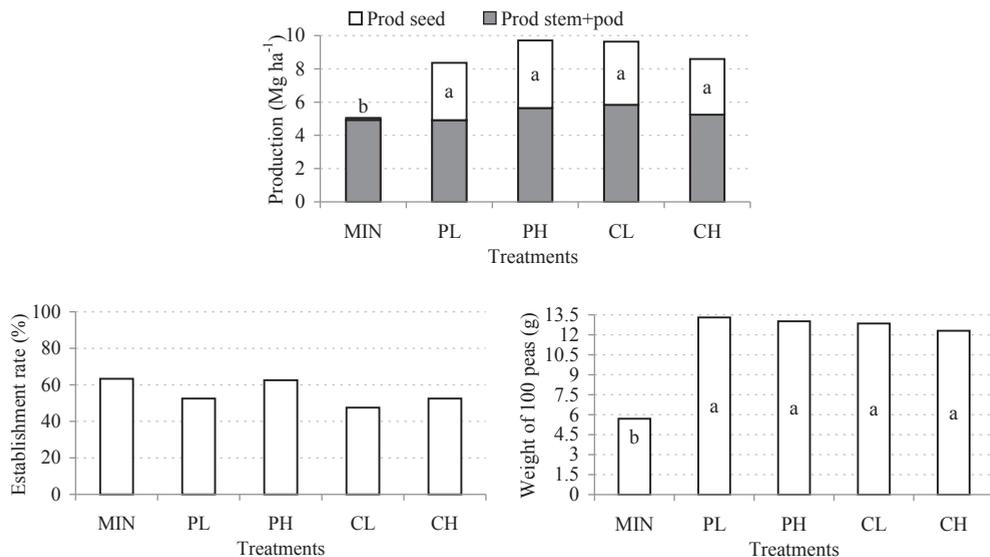
Figure 1. Yield per seed (Prod seed) and stem + pod (Prod stem + pod), establishment rate and dry matter weight of 100 peas in the different treatments. MIN: mineral fertilisation; PL: pig manure at low rates; PH: pig manure at high rates; CL: Cattle manure at low rates; CH: cattle manure at high rates. Different letters indicate significant differences between treatments.

References

Bilgili U., Uzun A., Sincik M., Yavuz M., Aydinolu B., Cakmakci S., Geren H., Avciolu R., Nizam I., Tekel S., Gül S., Anlarsal E., Yücel C., Avci M., Acar Z., Ayan I., Ustün A. and Acikgoz E. (2010) Forage yield and lodging traits in peas (*Pisum sativum* L.) with different leaf types. *Turkish Journal of Field Crops* 15, 50-53.

FAO (2012) Grassland index. A searchable catalogue of grass and forage legumes. FAO, Rome, Italy. Available at: http://tinyurl. com/kjrcuq8.

Olusegun O.S. (2014) Influence of NPK 15-15-15 fertiliser and pig manure on nutrient dynamics and production of cowpea, *Vigna Unguiculata* L. Walp. *American Journal of Agriculture and Forestry* 2, 267-273.

Heuzé V., Tran G. and Giger-Reverdin S. (2013) Pea forage. Feedipedia.org. A programme by INRA, CIRAD, AFZ and FAO. Available at: http://www.feedipedia.org/node/7047.

SAS (2001) SAS/Stat user´s guide: statistics. SAS Institute Inc., Cary, NC, USA, 1223 pp.

Some critical points of dairy farming based on grazing compared to indoor feeding systems

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Abstract

Grazing is not currently a common practice on dairy farms in Hungary. There are several possible reasons for this situation: the necessary conditions are not available for grazing, or technical considerations about grazing are not favourable in practice. These questions were investigated on two dairy farms through farm visits and technical interviews. Farm 1 has grazing, whereas Farm 2, which used to graze its animals, currently does not graze but there are plans to establish pasture for grazing. The main results of the investigations are as follows: neither farm has enough pasture/land area available to meet the requirements of grazing; the period of adequate grass growth/supply is relatively short, it is a maximum of two months in the beginning of spring; the nutritive value of grass decreases sharply in spring, and for this reason only animals requiring less-intensive feeding can be grazed (dry cows, heifers and perhaps low yield cows); grazing can result in remarkable savings in terms of inputs and costs; grazing does not need specific labour, and staff currently on the farms can manage grazing at the necessary technical level; the safety of outdoor animals from theft were not considered to be an obstacle to grazing on the farms.

Keywords: dairy farms, grazing, seasonal herbage allowance, safety of grazing animals

Introduction

The most important overall characteristics of dairy farming in Hungary are as follows: production is based on large dairy herds having several hundred cows per farm unit; the overall management system is intensive, with indoor confinement; and the feeding technology is based on single diet total mixed ration (TMR) systems. Grazing on dairy farms has become increasingly rare over the last few decades; consequently, the role of grazing in dairy farming has become negligible in recent years. What are the reasons why dairy farmers do not want to, or cannot utilize the benefits of grazing in milk production? This was the basic question of an empirical study based on farm visits and technical interviews. The objectives of the study were (1) to select two dairy farms with some relevance to grazing, (2) to search the critical points in favour of and/or against grazing under farm conditions, and (3) to find the critical economic and labour management points of grazing in dairy production.

Materials and methods

Two dairy farms were selected for the study. Farm 1 still grazes about half of its dairy stock and the remainder of the herd is fed by TMR. Farm 2 used to graze, but recently it has not grazed its stock and its overall feeding system is TMR. Farms 1 and 2 have 186 and 318 dairy cattle, respectively. The housing system on both farms is a free-stall system with deep litter. Milk production on Farms 1 and 2 are 6,000 and 12,300 litre cow^{-1} lactation^{-1}, respectively. Available pasture area for grazing on Farms 1 is 100 ha and on Farm 2 has no grassland area for grazing (in the past it had 20 ha). The number of employees is 12 on both dairy farms.

The grazing-related questions investigated during farm visits, and asked by experienced farm experts, were as follows: the relationship between grassland area demanded for grazing and the available grassland area on the farms; difference between grass demand for grazing and the grass supply during the grazing season on the farms; changes in the nutritive value of the grass available for grazing during the season; technical skills of employees on the farms regarding grazing management; potential replacement of preserved

forage from TMR by grazing and their financial value; animal physiological and economic benefits of grazing experienced under practical conditions; safety of grazing/outdoor animals from theft in farming systems.

Results and discussions

Farm 1

Dry cows, growing heifers and late-milking cows (at the very end of lactation) are the preferred animals that are grazed on this farm. According to the experienced farm manager the daily savings by grazing compared to indoor technology and its financial value is as follows:

- for dry cows   18 kg fresh maize silage cow^{-1} day^{-1} (160 HUF cow^{-1} day^{-1})
- for heifers   6 kg fresh maize silage heifer^{-1} day^{-1} (60 HUF heifer^{-1} day^{-1})
            8 kg grass hay heifer^{-1} day^{-1} (120 HUF heifer^{-1} day^{-1})
            3 kg farm grain heifer^{-1} day^{-1} (120 HUF heifer^{-1} day^{-1})
- for late milking cows   9 kg fresh maize silage cow^{-1} day^{-1} (80 HUF cow^{-1} day^{-1})
            4 kg farm grain cow^{-1} day^{-1} (160 HUF day^{-1} cow^{-1}).

In addition, the saving on straw litter on days when animals are grazed is 5 kg animal^{-1} day^{-1} (50 HUF animal^{-1} day^{-1}). Altogether, total savings due to grazing of dry cows, heifers and late-milking cows are 210 HUF, 350 HUF and 290 HUF animal^{-1}day^{-1}, respectively.

The manager listed some additional benefits of grazing. The carotene content of the blood of grazed animals, as tested regularly by a local veterinary, is optimal. The reproductive performance of the cows is favourable. Retained placenta in cows after calving does not occur. Indirect proof of the benefits of grazing on this farm are that the average age of milking cows is greater than 6 years (40% of the cows are older than 5 years), compared to the national average, which is approximately 3.5 years (Béri *et al.*, 1995). Practical experiences with grazing on the farm were positive. Technical skills for grazing management are provided by the employees of the farm. Safety of animals from theft is not a critical point in grazing management.

There are some conditions that hinder the most efficient use of grazing: there is not enough grassland area available for grazing, and there is no chance to buy or rent extra land for grazing. The period of optimal grass growth is limited to two months (April and May) at the beginning of the grazing season. There are large differences in grass growth between years due to changeable weather conditions (Nagy, 2008). Nutritive value of the grass declines sharply in late spring (Nagy, 2008). All these conditions make it impossible on the farm to graze high performance dairy cows.

Farm 2.

This farm used to graze its cattle but gave up grazing for a number of reasons. For example, the available pasture area for grazing became very limited, and renting or buying extra land became impossible. The production per cow has increased remarkably up to 12,300 l cow^{-1} lactation^{-1} on the farm and this high level of production requires reliable and stable daily feeding all the year round, which cannot be provided with grazing under practical conditions. In spite of all these issues the manager had very positive experiences with grazing, so the farm plans to establish 20 ha of grassland for grazing its dry cows.

According to the experienced farm manager the daily savings by grazing dry cows, compared to indoor technology and its financial value are as follows: 6 kg fresh maize silage cow^{-1} day^{-1} (60 HUF cow^{-1}day^{-1}) and 6 kg meadow hay cow^{-1} day^{-1} (90 HUF cow^{-1}day^{-1}).

The past experiences with grazing regarding retained placenta, carotene content of the blood, reproductive performance of cows, reproductive life span of the cows, were as positive as on Farm 1. Farm managers observed that the vitality of new-born calves was much better if cows were grazed during the dry period. Although grazing has not been practised recently on the farm, meadow hay as a grass product is fed *ad libitum* to maintain efficient digestion for high animal performance.

Technical skills for grazing management can be provided by the present employees of the farm. Safety of animals from theft is not a critical point in grazing management. Conditions that hinder the most efficient use of grazing on the farm are connected to the limited period of good grass growth. The feeding value of grass from pastures cannot meet the requirements of high-producing dairy cows. On intensive dairy farms, like this one, grazing can be practised only for dry cows because of animal nutritional reasons. All these findings support the results of previous studies (Béri *et al.*, 1995; Nagy, 2005), which analysed the situation of grazing management in the country.

The results of existing on-farm technical skills for grazing management, and the situation that there were no problems with safety of animals from theft on either of the farms, can be considered as new findings regarding previous publications dealing with practical constraints of grazing management in the country (Nagy, 2000).

Conclusions

The main outcomes from the study are: (1) neither of the studied farms has enough pasture/land area to meet the requirements of grazing; (2) the period of substantial herbage growth is relatively short – a maximum of two months at the beginning of the season; (3) the nutritive value of grass decreases sharply in spring; (4) only animals requiring less-intensive feeding can be grazed (first of all dry cows, than heifers and perhaps low yield cows); (5) grazing can result in remarkable savings regarding inputs and costs; (6) the physiological benefits of grazing are undoubted; (7) necessary skills for grazing management exist on farms, and (8) safety of grazing animals from theft is not a problem.

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References

Béri B., Nagy G. and Vinczeffy I. (1995) Az időszakos legeltetés hatása tejhasznosítású szarvasmarha-állományok termelésére 1. Hatások a tejtermelésre és a termelt tej szomatikus sejtszámára. *Állattenyésztés és Takarmányozás* 44(1), 37-49.

Nagy G. (2000) Gyepterületeink hasznosításának kérdései a húsmarhatartásban. *Állattenyésztés és Takarmányozás* 49(5), 439-457.

Nagy G. (2005) *Gyepgazdálkodás és vidékfejlesztés* [Grassland Management and Rural Development]. PhD Thesis, Debrecen University DE ATC AVK Debrecen, pp. 147.

Nagy G. (2008) Spring phenological development of perennial ryegrass and its response to annual weather conditions. In: *Cereal Research Communications. VII Alps-Adria Scientific workshop*. Stara Lesna, Slovakia, 28 April – 2 May, Akadémiai Kiadó, Budapest, CD, p. 787.

Improving grassland management on commercial pilot dairy farms: the role of intensive coaching

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Abstract

In the Netherlands, more than 60% of agricultural land is used for dairy farming. Grass is the most important crop, followed by maize silage. To explore possibilities to increase nutrient-use efficiency and reduce nutrient losses, the method of prototyping a combination of system modelling and system implementation was applied on the experimental farm 'De Marke'. To promote development and adoption of similar systems in commercial dairy farming, the project 'cows & opportunities' (C&O) was initiated in 1999 to bridge the gap in nutrient-use efficiency between experimental farms and commercial pilot farms. Total nitrogen (N) and phosphorus (P) application rate declined from 530 in 1998 to 400 kg N ha^{-1} in 2013 and from 57 in 1998 to 48 kg P ha^{-1} in 2013. Average grass dry matter yields were 11 Mg ha^{-1} but with a huge variation amongst pilot farms. Substantial improvements in grassland management are possible on many commercial dairy farms, but strategies differ amongst farms.

Keywords: dairy farming systems, N-use efficiency, P-use efficiency, dry matter yields

Introduction

In north-western Europe, most cattle production systems are characterized by high stocking densities and intensive use of grassland with high nitrogen (N) and phosphorus (P) inputs through manure and chemical fertilizers (cf. Aarts, 2000). Grassland and crops use these nutrient inputs inefficiently. Generally, more than 50% of the N applied is not assimilated by plants (Mosier *et al.*, 2004) and is a potential source of environmental pollution that compromises the quality of groundwater and surface waters (Galloway *et al.*, 2008). In addition to pollution, nutrient losses represent a waste of energy and money. Losses can be reduced by improved grassland management. The objective of this paper is to present the results of dry matter (DM) yields, N-use efficiency (NUE) and P-use efficiency (PUE) on the commercial pilot farms in the project 'cows & opportunities' (C&O), each of which applied their own strategy. By considering the spectrum of farms, we demonstrate the possibilities for improvement in grassland management.

Materials and methods

The project C&O was initiated in 1999 to promote adoption of proven and tested measures to reduce nutrient losses on the experimental farm 'De Marke'. It is characterized by agreements with the farmers on realization of measurable targets and intensive coaching through frequent interaction between researchers, extension agents and farmers. The project started with a group of 17 motivated farmers. In 2003, one farm left the project because of difficulties in collecting data. In 2009, five farms were replaced. An intensive monitoring programme was used to collect data on the pilot dairy farms (Oenema, 2013). To benchmark results of the pilot farms, a 'national average' was calculated for specialized dairy farms from the Dutch Farm Accountancy Data Network (FADN) (land area >15 ha; at least 80% grassland and fodder crops; >30 milking cows) (Aarts *et al.*, 2008; Oenema *et al.*, 2013). Farm milk production in C&O ranged from 11 to 23 Mg ha^{-1} and grassland occupied ca. 80% of the total land area. Total milk production on the pilot farms was higher than the 'national average' at a similar farm size. Hence, production intensity of the pilot farms was on average higher (by around 2,800 kg milk ha^{-1}), as was milk

production per cow (approximately 500 kg). The N and P application rate on grassland (kg ha^{-1} year^{-1}) is defined as the applied amount in organic manure (total N) and mineral fertilizer, in excreta during grazing, biological N fixation by clover (estimated from % clover in grassland × total yield (Mg DM) × 45) and atmospheric N deposition, minus ammonia losses during application and grazing. The NUE and PUE are defined as the input/output ratio (expressed as a percentage) of N or P in the yield over the N and P in the total application.

Results and discussion

The N and P application with manure in C&O remained almost constant during the entire period (245 kg N and 43 kg P ha^{-1}), while the N and P in excreta during grazing showed a decrease over time (from 85 to 25 kg N ha^{-1} and from 12 to 4 kg P ha^{-1}, respectively). The N application from mineral fertilizer decreased from 225 kg ha^{-1} in 1998 to 130 kg ha^{-1} in 2001, while in the remainder of the period the inter-annual variation was very low. The P application from mineral fertilizer decreased threefold in the initial years (from 12 to 4 to 1 kg ha^{-1} in the last two years). On average, total N and P application rates in C&O were almost equal to the 'national average'. Differences were found in the share of the different sources, i.e. pilot farms applied more manure and less mineral fertilizer and a lower input in excreta during grazing. The N fixation by clover in C&O was low (between 5 and 12 kg N ha^{-1}) and was not monitored in the 'national average' (but assumed to be negligible; Aarts *et al.*, 2008).

Table 1. Average dry matter (DM) yield (Mg ha^{-1}), N- and P-use efficiency on grassland in the period 2000-2013 on commercial pilot dairy farms.

Farm	Soil type	Years	DM yield (Mg ha^{-1})	Use efficiency (%)	
				N	P
1	clay	4	15.2	69	137
2	sand	8	9.6	91	103
3	clay on peat	4	10.9	63	103
4	clay	14	14.2	65	89
5	sand	10	11.9	78	102
6	peat	4	9.2	68	78
7	sand	14	11.4	66	88
8	sand	4	10.7	61	90
9	loess	14	10.3	66	94
10	sand	14	10.1	63	72
11	sand	12	10.0	61	83
12	sand	10	11.4	68	80
13	sand	14	10.2	54	73
14	clay on peat	7	10.6	70	68
15	sand	14	11.7	63	93
16	sand	14	11.3	63	82
17	sand	9	12.4	62	89
18	clay	14	9.3	67	82
19	peat	11	10.6	80	94
20	clay	14	11.2	64	69
21	clay on peat	4	11.3	69	93
AVG C&0[1]			11.1	67	89
AVG NatAver[2]			10.1	61	80

[1] Average of the dairy farms in the project 'cows & opportunities'.

[2] National average.

Average DM yields on grassland in the period 2000-2013 in C&O were 11 Mg ha^{-1} (Table 1) and 20% of the total DM yield was grazed. Dry matter yields in the 'national average' were always lower apart from the years 2010 and 2011, resulting in a lower average DM yield (10 Mg ha^{-1}) with a slightly higher share for grazing (28%). Average NUE and PUE in C&O were higher than the 'national average' (10% higher for N and 28% for P). Variation in mean DM yields, NUE and PUE between farms were substantial. Mean DM yields varied from 9.2 to 15.2 Mg ha^{-1}. The NUE and PUE varied from 54 to 91% and from 68 to 137%, respectively.

Conclusions

Dry matter yields, NUE and PUE on commercial pilot dairy farms in C&O in the period 1998-2013 were higher than the 'national average' (1 Mg ha^{-1}, 6% NUE and 9% PUE, respectively), while the total N and P application rates (applied manure, mineral fertilizer and excreta during grazing) were almost equal. Variation among the pilot farms in DM yields (between 9.2 to 15.2 Mg ha^{-1}), NUE (between 54 to 91%) and PUE (between 68 to 137%) were substantial. Results on and for a specific farm cannot be interpreted without the context of that farm and hence cannot readily be extrapolated to other farms. Management options that result in improved NUE include reduced grazing time which results in increased dry matter yields, NUE and PUE as a consequence of better utilization of organic manure (less excreta voided during grazing and more collected manure which can be distributed and applied when needed).

References

Aarts H.F.M. (2000) *Resource management in a 'De Marke' dairy farming system*. PhD thesis, Wageningen University, Wageningen, 222 pp.

Aarts H.F.M., Daatselaar C.H.G. and Holshof G. (2008) *Bemesting, meststofbenutting en opbrengst van productiegrasland en snijmaïs op melkveebedrijven*. Rapport 208, Plant Research International, Wageningen, the Netherlands, 50 pp.

Galloway J.N., Townsend A.R., Erisman J.W., Bekunda M., Cai Z., Freney J.R., Martinelli L.A., Seitzinger S.P. and Sutton M.A. (2008) Transformation of nitrogen cycle: recent trends, questions, and potential solutions. *Science* 320, 889-892.

Mosier, A.R., Syers J.K. and Freney J.R. (eds.) (2004) *Agriculture and the nitrogen cycle*. Scope 65. Island Press, London, UK.

Oenema J. (2013) *Transitions in nutrient management on commercial pilot farms in the Netherlands*. PhD thesis, Wageningen University, Wageningen, the Netherlands.

Economic impact of grazing dairy cows on farms equipped with an automatic milking system

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Abstract

Automatic milking Systems (AMS) have been practised for a number of years in Denmark, France and the Netherlands. During these years, combining automatic milking (AM) and pasture access for feeding has remained problematic. Grazing has, however, many benefits, both for farmers, animals, landscape, biodiversity, and for the overall image of dairy farming. In this study we compared the economic results of dairy farms with AMS (AMS farms) which practice grazing with those of AMS farms without grazing. The economic impact of grazing dairy cows on AMS farms was analysed using accounting data of commercial dairy farms in Denmark, France and the Netherlands. In the Netherlands grazing was economically beneficial but this effect declined with increasing farm size. In France, income tended to be higher on farms that practised grazing, and in Denmark no economic difference of farmer incomes were found. A complicating factor of the analysis was that the actual feed uptake during grazing was not recorded in the database in any of the three countries. A key recommendation from this study is that the level of grazing and intake from grazing as a proportion of the total diet is recorded in the future.

Keywords: automatic milking, grazing, economic performance

Introduction

Automatic milking has been practised for a number of years in Denmark, the Netherlands and France. Grazing in combination with automatic milking (AM) appears to be problematic, in particular for farms with large herds (Oudshoorn and Spörndly, 2013). The actual economic returns were usually not the major driver for investing in AM (Oudshoorn *et al.*, 2013). However, the increasing pressure on farm net income associated with the removal of milk quotas and milk price volatility justifies critical analysis of the economic effects of grazing in AM systems.

Since the overall management of the farm is the dominating factor affecting net income on farm, either with or without grazing, single key performance indicators cannot explain the overall economic effect at farm level. Nevertheless, if an analysis of accountancy data should find a consistent economic advantage associated with grazing across a large number of farms, then strong conclusions can be drawn. The objective of this study was to conduct an economic appraisal of dairy farms deploying AM with and without integrated grazing, using on-farm accountancy data from farms in France, the Netherlands and Denmark.

Materials and methods

The comparisons have been completed on a per-litre of milk produced, per-hectare of land farmed, and a per-farm basis. The accounting databases were different for the three countries involved and are specified for (1) Denmark, (2) France and (3) the Netherlands.

1. The Danish economic database, containing data from all dairy farms, was made available. However, this dataset did not indicate whether or not Danish farms grazed. Information on whether a farm grazed or not in the accountancy year 2012 was obtained by asking the milk quality assessor from the different regions to identify farms with grazing. Afterwards these farms and their advisers were

contacted by telephone for confirmation. Having identified 14 dairy farms with grazing, 67 parallel dairy farms without grazing were identified and used in the analysis. Economic parameters were computed using the dimensions MJ NEL (Net Energy Lactation) for feed intake and kg of ECM (energy corrected milk).

2. 37 French farms equipped with an automatic milking system (AMS) among 630 farms (in total) with available data were identified for 2011. All data for these farms are stored annually in a database named 'Diapason'. Within the sample of AMS farms, the economic results of the farms, according to the share of grazed grass in the cows' diet, were compared. Three consecutive years were used: 2010, 2011 and 2012. The farms were then ranked according to an increasing proportion of grazed grass to create three groups within the sample: In the first group (no grazing), the grazed grass represents less than 16% of the total DM intake (average: 8%). In the second group (intermediate grazing), the share of grazed grass represents between 16 and 30% of the total DM intake (average: 22%). In the third group (grazing), the grazed grass represents more than 30% of the total DM intake (average: 37%).

3. In the Netherlands, data from approximately 10% of all Dutch commercial dairy farms in 2011 were used to assess economics associated with grazing. In this dataset, 81% of the farms practised grazing (however, not known how much) and 17% used automated milking. The dataset contained financial data (revenues, costs, depreciation, etc.), technical data (land area, number of animals, soil type, milk yield, milk quality, etc.) and social data (successor, age, etc.).

Results and discussion

In Denmark significant differences in production price per kg ECM, feed costs per kg ECM, yield in kg ECM, veterinary and medicine costs per cow and purchased feed costs per cow per year could be found in the Danish dataset (Table 1).

In France, practising grazing was associated with lower feeding costs, and with lower costs of inputs, both for animals and forage areas, and extra cost of 'buildings and equipment' (Table 2). The production cost before repaying the labour force was lower in the intermediate and grazing groups. In addition, some revenues of the dairy unit related to subsidies for grassland were higher for the grazing farms. This led to 'the more grazing, the higher profits', either per working unit or per 1000 l milk produced.

In The Netherlands, on average, grazing resulted in more efficient management and a higher gross operating profit (data from Hogeveen *et al.*, 2013). However, these positive results declined in relation to increasing farm size. In 2011 the transition point was, on average, a farm size of 85-90 dairy cows. If grazing was combined with automatic milking, much of the efficiency and financial advantage of grazing disappeared. In the dataset, the gross operating profit of farms using grazing was on average € 21,628

Table 1. Results of comparison between 14 automatic milking system (AMS) farms with grazing and 67 AMS farms without grazing in Denmark.[1,2]

	No grazing		Grazing		Grazing 2		Dif.
	mean	SD	mean	SD	mean	SD	
Milk costs, Euro cents per kg ECM	40.15	4.85	39.26	7.51	38.27	4.26	NS
Feed cost, Euro cents per kg ECM	21.73	3.31	21.80	5.94	20.46	3.31	NS
Yield, kg ECM per cow	9,238	834	9,321	655	9,282	699	NS
Vet. and Medicine cost, Euro cow[-1]	89	36	97	41	95	40	NS
Purchased feed cost, Euro cow[-1]	1,003	157	962	195	977	196	NS

[1] One outlier set of farm results from the grazing group was removed as the figures were considered unrealistically high for the feed and production prices; corrected values are in Grazing 2.

[2] ECM = energy corrected milk yield; SD = standard deviaiton; NS = not significant.

Table 2. Production costs of the three groups over the three years period in France.[1]

	No grazing	Intermediate grazing	Grazing[2]
Number of farm years	31	30	32
Cattle input costs (€ / 1000 l)	99	83	90
Crops input costs (€ / 1000 l)	31	28	27
Breeding costs (€ /1000 l)	46	39	46
Mechanization (€ /1000 l)	83	89	82*
Buildings and equipment (€ / 1000 l)	56	64	70
Land and capital cost (€ / 1000 l)	37	40	45
Labour cost if 1.5 SMIC (€ / 1000 l)	61	76	68
Dairy production per WU dairy (1000 l)	428	370	413
Production cost (€ / 1000 l)	431	439	448
Gross operating profit (€ / 1000 l)	289	274	278
Labour repayment (SMIC per WU dairy)	1.08	1.26	1.47
Farmer's profit (€ / 1000 l)	33	50	57

[1] WU = working unit; SMIC = minimum wage in France

[2] No statistical analysis of results.

higher per farm (P=0.001). Automatic milking reduced this effect by € 16,151 (P=0.04). So the positive effect of grazing was still present in situations of automatic milking, but was much smaller.

Conclusion

In the Netherlands an economic benefit to grazing was found for AM farms, which declined with increasing farm size. In France, income tended to be higher on AM farms that practised grazing, and in Denmark no economic difference could be found. A complicating factor of the analyses of the existing accounts was that the actual amount of feed from grazing was not recorded in any of the countries.

References

Hogeveen H., Emvalomatis G., Daatselaar C. and De Haan M. (2013) Economie van weidegang; de praktijk in 2011. In: Van den Pol-van Dasselaar A., Philipsen A.P., De Haan M.H.A. (eds.) *Economisch weiden*. Rapport 679. Lelystad, the Netherlands, 126 pp.

Oudshoorn F.W. and Spörndly E. (2013) Operational strategies for optimizing grazing when using automatic milking systems in organic dairy production. In: *Proceedings NJF Seminar 461. Vol. 93*. udg. NJF, Nordic Association of Agricultural Scientists, 2013, pp. 129-130.

Oudshoorn F.W., Kristensen T., Van der Zijpp A.J. and De Boer I.J.M. (2012) Sustainability evaluation of automatic and conventional milking systems on organic dairy farms in Denmark. *Netherlands Journal of Agricultural Sciences* 59(1-2), 25-33.

Grass proves its value on Welsh dairy farms

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Abstract

Wales has some of the most favourable climates for growing grass in the whole of the UK. It means grass can be grown very efficiently and it makes economic sense to optimise the use of that grass. Dairy farmer numbers in Wales have been falling since the 1960s, but there has been a more rapid decline in recent years. The main reason for this has been the downward pressure on milk price and an increase in the cost of production. It was interesting to see that with the 2013-2014 improvement in price the rate of decline slowed down. Wales has always received a lower milk price than areas in England that are closer to the higher density population areas, so making the most of grass to keep production costs down is clearly a priority. Milk from forage used to be a more common benchmark of performance and still has a very close correlation with profitability on forage based systems. The reason for the reduced interest in milk from forage as a performance indicator has been the increase in high input systems where milk from forage is not considered to be the right benchmark of performance. However, on grazing and high forage systems 4,000+ litres per cow of milk from forage is achievable.

Keywords: dairy, grass, grass value project, Wales

Introduction

The purpose of the Grass Value project was to identify best practice from high performing farms, to be able to recommend methods for improving grassland management and utilisation on dairy farms across Wales. The Grass Value project was set up to record grassland production and utilisation on dairy farms in Wales and to inform dairy farmers of the advantages of efficiently utilising the grass, so that they can gain a competitive advantage in the market. It was important to select a good cross section of farms across Wales, representing a range of different climatic conditions, altitude, soil types and production systems, including two organic farms. We set a benchmark in the first year of recording in 2011, endured the wettest summer in 100 years in 2012 and the coldest and latest spring for grass growth in 2013. Year 2 and 3 were very difficult seasons to manage and really challenged all farmers involved, but conditions did highlight what is possible to achieve under the most difficult circumstances, if the right farm infrastructure and grassland management skills are available.

Farm selection and method

Project farms were selected from all the main milk producing areas in Wales, with a focus on producers that were keen to make good use of quality grass. The farms covered a range of rainfall and soil types and included a mixture of spring and autumn calving herds and two organic herds.

All the project farms were visited by a technician every week for the duration of the project. Each paddock was measured with a rising plate meter to ascertain the grass growth and to work out the average farm cover.

Any Welsh producer that wishes to increase the value that grass contributes to their herd performance and profitability should be able to relate to one or more of the project farms in terms of location, size and system.

The weather conditions encountered in each of the three years were very different and at times challenging. For the project, this proved beneficial as it allowed the monitoring of grass growth and utilisation to be evaluated against management practices in the different growing conditions.

Results and discussion

The project farms averaged 37 weeks or 260 days grazing per year, with the highest achieving in excess of 290 days of full grazing in a year. On average, 10.4 Mg dry matter (DM) of grass per ha was grown on the twelve project farms. The highest yielding farm averaged 12.3 Mg DM ha^{-1}, and 84% of the grass grown was utilised by the cows. Milk from forage averaged 3,511 litres per cow and 10,341 litres per ha. Well managed grass had a production cost of £97 per Mg DM and a value of £197 per Mg DM – a 100% return on cost. This compares very favourably to conserved forages.

Accurate measuring and recording of grass helped to keep control of grazing management and ensure that supplements are used cost effectively. On all project farms there was a range in paddock performance, with the poorest 10% of paddocks typically growing half the grass of the 10% best performing paddocks on an individual farm. The project farmers used their records to target improvements cost effectively at under-performing paddocks. Well-managed, long-established permanent pastures can have a high ryegrass content and be as productive as many younger leys. Rotational grazing opened up swards and helped to encourage ryegrass growth. Poor swards, with less than 50% ryegrass content, produced 25% less grass, and swards with a high proportion of weed grasses recorded 14% less production.

Under organic management, swards with a high clover content produced 19% more grass than those with a low clover level. A sward with 30% clover can fix up to 200kg N ha^{-1}, but within conventional non-organic swards, clover did reduce sward productivity when the percentage of clover in the sward exceeded 50%.

The crop growing capability was determined by soil moisture. The limiting factors for crop growth are infiltration rate (drainage), water-holding capacity, soil structure, compaction and rainfall. The twelve project farms covered a range of soil types, from peat to heavy clays to light loams, sharing different challenges of low or excessive rainfall, and at times, unseasonal temperatures. The grass growth was evaluated relative to soil type. To limit the impact of different nitrogen regimes, paddocks receiving 200 to 300 kg nitrogen per hectare were compared and over the three-year period heavy soils produced just over 1 Mg more DM ha^{-1} than medium or light soils. Early spring and autumn grass growth was relatively similar across the soil types. Grass growth was less on lighter soils during the drier summer of 2011, but greater in the wet summer of 2012. All soils suffered restricted growth during the cold spring of 2013, and improved production later in that year did not make up for this loss. These results show that although soil type has a significant influence on grass production, as would be expected, the management of that soil is a key factor.

The profitability of the project farms was expressed as the proportion of the farm output that was retained as net margin. The average results over the three years showed that 31% was retained as margin. This compares very favourably with other UK dairy herds evaluated within DairyCo Milkbench+ (2013) which, on average, retained 4% of output as net margin, with the top 25% retaining 22%.

Conclusions

- The project farmers grazing higher covers produced more grass, but grazing a sward at too high a cover did increase wastage and reduce utilisation.

- Ideally the right cow for the system is available; she needs to produce quality milk efficiently, while maintaining body condition, to be able to walk long distances and most importantly, get back into calf, with a target of 1 kg milk solids per kg of live-weight.
- Good paddock access is vital: 90% of paddocks on the project farms had good track access.
- Flexibility: all the project farms had a flexible approach to grassland management.
- Simply growing grass does not mean it will be cheap and cost effective – it needs to be grown and utilised efficiently.
- Rotational grazing encourages ryegrass growth, so swards last longer.
- Target: good physical soil structure, correct chemical and mineral balance and abundant biological activity.
- Achieving value from grass is not just the focus of block-calving, low-input herds. All but the highest yielding herds have potential to exploit well managed grazed grass and improve herd profitability. Many herds with yields up to 9,000 litres per cow achieve a proportion of their yield from forage, with a good share of this from grazing. With the right infrastructure and effective management, grazed grass can replace more expensive conserved forages without compromising yield, leading to increases in herd profitability.

Acknowledgements

Are there alternative paths towards more self-sufficient and resilient systems in dairy farms?

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Abstract

This paper synthesizes a selection of socio-economic studies from France and the Netherlands, and an ethnographic study in Belgium. It compares grassland-based farms with 'more intensive farms'. The first ones use less concentrates, crop less green maize, manage grasslands better and can be smaller (surface, quotas) than the intensive farms. The grassland-based farms of these studies have similar or better economic performances per farm than more intensive farms. They are also more resilient; they can better survive periods of low milk price and high price of concentrates. These studies show that alternative paths to scale enlargement and spurred intensification are feasible.

Keywords: alternative paths, scale enlargement, intensification, self-sufficiency, income

Introduction

In a quest for more productivity and competitiveness in European farming, there has been a large reduction in the number of dairy farms since the 1960s. While farmer population has decreased, farm size and the use of external inputs (e.g. fertilizer, concentrate, fossil energy) increased and many other parameters changed. The price of land became more and more important, dairy production required huge investments in terms of buildings, machinery, land and cattle, while production costs for fertilizers, animal feed and veterinary costs increased a lot. The milk quota ensured a stable market between 1984 and 2004 but since then milk prices are much more unstable and do not always allow profitability of dairy farms. The farmer population is ageing because young people hesitate to enter the sector because of the necessity to contract important loans and the lack of good economic prospects. The system is thus questioned and many farmers in Europe have started to develop alternative paths, towards more 'autonomous' farming systems. The paper discusses these alternatives and analyses their impact on farm profitability.

Data sources

In Belgium, Delobel (2014) studied why and how nine farm families spontaneously changed their practices and in favour of 'novelty production'. This ethnography consisted in participant observation on these farms and sought to understand better farmer-led innovation processes happening beyond agriculture modernization. The study considered the 'novelties' as part of unique farm projects that were alternatives to the usual model 'get big or get out'.

In France, Peyraud *et al.* (2014) compared average data of grassland-based and more intensive dairy farms from the 'Sustainable Agricultural Network' (SAN) (about forty farms) and from the French Farm Accounting Agency (RICA) between 2008 and 2012. They analysed the technical and economic performances of dairy farms from three French lowland regions (Brittany, Lower Normandy and Loire Region) according to their intensification level, in a sample of specialized dairy farms from the RICA network over 3 years (2004-2006). Their farm typology distinguishes three classes of intensification/self-sufficiency rate on the basis of thresholds of input costs: extensive/more self-sufficient (<390€ ha^{-1}), intermediate (between 390 and 590€ ha^{-1}) and intensive/less self-sufficient (>590€ ha^{-1}).

In the Netherlands, Oostindie *et al.* (2013) studied a sample of 1000 dairy farms containing precise farm accountancy data for the 2007-2010 period. A group of so-called 'economical farmers' could be distinguished (using farming style analysis). Keeping costs associated with the acquisition of external inputs as low as possible was key in their strategy. The same applies to financial costs: debts were kept at low levels.

The paper makes results available in English that were originally published in French or Dutch.

Results and discussion

The ethnographic study in Belgium (Delobel, 2014) showed that farm families face 'modern problems' that threaten the continuity of the farm. These problems emerge from social institutions and practices promoted by modernization discourse, including global commodity markets, farm credits, subsidy schemes and purchase of inputs. In response to these problems, the farm families constructed their own farm project and re-designed their farm according to objectives they considered relevant and desirable. These farmers completed actual farm transitions by creating alignment between various 'novelties' within their farm, notably grass-based feeding (rotational grazing, hay dryer, grass-clover mixtures), mixing cattle breeds at grazing, processing milk on the farm, developing niche markets (distinctive farm products, network of local producers, weekly street markets, farm shops), and ensuring soil fertility with compost and legume use. Obviously, the production of 'novelties' requires human and farming resources (time, space, money, energy, labour); it implies lots of reading, testing, adapting, fine-tuning and risk-taking. Novelties induced both internal re-organisation of the farm (labour and resources) but also re-negotiation of relationships with external actors (down and upstream agro-industries, regulation apparatuses, scientific and technical organisations). In the ethnographic interviews, farmers said these changes allow them to keep on farming 'in a freer way'.

The French studies put figures on different farming paths and compare them in terms of performance and viability. The farms of the French SAN network are on average smaller than those of the RICA network (56 vs 78 ha), use more grass (87 vs 67% of their Main Forage Area) and thus less silage maize (11 vs 32%) and produce less cereals (8 vs 20 ha). In spite of a lower quota (266,500 vs 349,900 l yr^{-1}) and a smaller total value of products per agricultural working unit (AWU) (88,454 vs 104,840€ AWU^{-1}), the farms of the SAN network produce an income before tax that is higher (21,907 vs 17,261€ AWU^{-1}) than on the average farms of the RICA, because of savings on the production costs (248 vs 568€ ha^{-1}). These savings relate mainly to the purchases of concentrated feed (154 vs 320€ ha^{-1}) and inorganic fertilizers (21 vs 92€ ha^{-1}). The economic result before tax and without subsidies, which reveals the real technical performance of the system, is much higher in the farms of the SAN network (7,180 vs 1,490€ AWU^{-1}) (Peyraud *et al.*, 2014). The three classes of intensification/self-sufficiency based on the input costs per ha of the RICA network are closely associated to a variation of grassland in the main fodder area (grasslands + other green forage cropped on arable area). More self-sufficient farms include more grasslands than less self-sufficient ones. The degree of intensification does not seem to be a key explanatory factor for the differences in technical-economic performances. The differences in net margins per worker between the three levels of intensification are low, Brittany being the only region where the net margin increases with the levels of intensification (respectively 9,800, 10,800 and 12,100€ AWU^{-1} from extensive to intensive levels) whereas, in the other regions, the most extensive class has on average better performances than the most intensive class (respectively 13,600, 10,300 and 6,800€ UWA^{-1} on average). In this study, the most self-sufficient, which are also the more grassland-based systems, appear to be more resilient to price crises because the share of variable costs in the cost of milk production is always significantly lower than in the more intensive systems (0.10 vs 0.13 vs 0.16€ l^{-1} respectively for the extensive, intermediate and more intensive systems) whereas the market price of milk practically does not vary from one system to another. The strong reduction in milk price in 2009 had relatively less impact on the systems of the SAN

network than on the specialized farms of the RICA network. The average level of income before the price crisis was reached again in 2010 after an improvement in the milk price level. In the latter study, as well as in the previous one, the variability of the results within farm class is very important which shows that progress in margins exist in all these systems.

In the Netherlands, Oostindie *et al.* (2013) showed that in the economical farms the costs for animal feed per dairy cow equalled 393€ cow^{-1} year^{-1} (in 2010). This is far below the level of large-scale intensive farms (560€ cow^{-1} year^{-1}) and of small-scale intensive farms (619€ cow^{-1} year^{-1}). Similar or even larger differences were found for fertilizer use. In years with relatively good milk prices (2007, 2010), the net farm incomes realized within the different styles were similar, even while the size of the large-scale, intensive farms (1,400,000 kg of milk) was far beyond the one of 'economical farmers' (560,000 kg of milk). However, in years with low milk prices (2008, 2009), the income of the latter was far higher than of large-scale, intensive farmers. A part of the large-scale, intensive farms even faced a negative cash flow.

Maximising grass, reducing green maize and concentrates, using the right animal (Normande or Jersey crosses instead of pure Holstein cows), reducing investments and loans are key-parameters to achieve this. Intensive dairy systems are in a rationale of high investments, high use of concentrates, high production per cow and have to increase herd and farm size to be able to survive. That makes them very susceptible to sudden fall of milk price and increase of input prices. Moreover, Belgian farmers reduced expenses linked to banks and agro-industries (e.g. fertilizer, feed) and also often increased their economic margin by food processing and short marketing chains. They tried to improve the use of local resources which necessitated creativity and innovation. They demonstrated their capacity to produce these novelties and to construct alternative futures for improving their income and welfare.

Conclusions

In the dairy farms of these studies, grassland-based systems that have lower variable costs (e.g. concentrates) and are more forage self-sufficient, have similar income per AWU, are sometimes more profitable whatever the economic context and always more profitable in a low milk price context than 'more intensive' systems. These studies show that paths alternative to scale enlargement and spurred intensification are feasible.

Acknowledgements

References

Delobel V. (2014) *Les Indomptables: an ethnography of niche novelty production in Walloon agriculture*. MSc thesis, Wageningen University, Wageningen, the Netherlands, 138 pp. Available at: http://orgprints.org/25218.

Oostindie H., Van der Ploeg J.D. and Van Broekhuizen R. (2013) *Buffercapaciteit, bedrijfsstijlen in de melkveehouderij, volatiele markten en kengetallen*. WUR/ALFA, Wageningen, the Netherlands, 50 pp.

Peyraud J.-L., Delaby L., Delagarde R. and Pavie J. (2014) Les atouts sociétaux et agricoles de la prairie. *Fourrages* 218, 115-124.

Performance of red clover mixtures in high output dairy systems: an agro-economical comparison

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Abstract

Inclusion of red clover (*Trifolium pratense*) in grasslands offers important economic and environmental advantages as nitrogen (N) fertilizer is replaced with N from N_2 fixation. These advantages seemed to be reduced under high fertilization rates. In a field experiment we compared perennial ryegrass swards (*Lolium perenne*) with grass-clover mixtures in which the artificial N fertilizer was omitted. The experiment was conducted at two locations (sandy and clay soil) at high fertilization levels (254 and 306 kg total-N ha^{-1} on grass-clover and 389 and 489 kg total-N ha^{-1} on the pure grass swards). Grass-clover mixtures produced more dry matter (+18%), digestible energy (+12%), crude protein (+45%) and digestible protein (+27%). Economic evaluation at farm level shows that grass-clover mixtures had a surplus of €510 ha^{-1} year^{-1} over pure grass swards. This surplus would be reduced (to €282 ha^{-1}) if the higher crude protein content of grass-clover cannot be balanced in the feed ration, resulting in extra N excretion of the animals and subsequent higher costs for manure disposal if maximum allowable manure application rates per ha are exceeded. These results show that inclusion of red clover in grasslands has agro-economic benefits, also under high fertilization rates.

Keywords: *Trifolium pratense*, ecological intensification, protein production, economic advantages

Introduction

Inclusion of red clover in grassland offers important economic and environmental advantages as nitrogen (N) fertilizer is replaced with N from N_2-fixation. The economic benefits of grass-red clover mixtures for organic dairy farms have been described by Doyle and Topp (2002). However, the yield advantages seem to be reduced under high levels of N fertilization (Nyfeler, 2009). Nevertheless, for conventional dairy farmers, the relevant question is: What are the differences between grass-red clover (fertilized with animal manure) and grass (fertilized with animal manure and artificial fertilizer) in terms of yield, fodder quality and economic cost and benefits? A field experiment was conducted to make such an agro-economic comparison.

Materials and methods

Experimental fields were established on two intensive dairy farms early September 2011 on sandy soil (52°19' N, 6°28' E) and clay soil (51°62' N, 4°62' E). Red clover (*Trifolium pratense,* 7 kg ha^{-1}) and white clover (*Trifolium repens,* 3 kg ha^{-1}) were sown with five different grass mixtures specifically selected for cutting regimes at commercially advised seeding rates, and compared with perennial rye grass (*Lolium perenne*). Mixtures were sown in two replicates and pure grass was sown in four replicates per location.

Measurements were conducted in the second and third production year (2013 and 2014). In each year, grass-clover mixtures received on average 254 (sand) and 306 (clay) kg N ha^{-1} from slurry, whereas pure grass received on average 135 (sand) and 183 (clay) kg N ha^{-1} from artificial fertilizer in addition. Plots were harvested four (2013) or five (2014) times per year. Dry matter yield was determined by cutting a strip of 0.81×5 m with a two-wheel-drive tractor. After weighing the fresh biomass, sub-samples were analysed for nutritive value by NIR at a commercial lab. (By mid-2012 red clover had almost disappeared from one of the mixtures on clay; therefore this treatment was not included in the analyses.) Results

were tested by analysis of variance (unbalanced design) using GenStat 13.3. Experimental results were combined with actual historical prices and literature data for economic comparison.

Results and discussion

Dry matter yield was 18% higher in grass-clover plots than in plots with only grass (Table 1), and had a 22% higher crude protein content and a 8% higher intestinally digestible protein content (Table 2). Subsequently, crude protein yield was 43% higher and intestinally digestible protein was 27% higher in grass-clover (Table 1). Net energy lactation content of grass-clover was slightly lower than that of grass (Table 2), but due to the higher dry matter yield the net energy lactation yield of grass-clover surpassed that of grass (Table 1). Yields differed between years (+3 Mg dry matter for grass and grass-clover in 2014) and somewhat between locations, but differences between grass and grass-clover were constant.

The average economic value of these differences is given in Table 3. Average annual costs for grass-clover were comparable to those for grass only. Higher costs for seed and sowing and the higher renewal rate of grass-clover compared with grass resulted in higher annual establishment costs, but costs for artificial fertilizer and weed control were absent. Higher crude protein production may result in extra N-excretion of the cattle, and the total amount of N in animal manure may exceed the maximum application level for the farm. If all additional N produced needs to be disposed elsewhere, the costs for manure disposal increase to €228 ha^{-1} (or higher, if the manure needs to be transported long distances), resulting in an economic benefit of grass-clover, compared to grass, of €282 ha^{-1}. However, if either the N-surplus can be applied on own land or the additional protein production is used to replace the use of off-farm protein-rich fodder, the economic benefit of grass-clover compared with grass can rise to €510 ha^{-1}. On most farms the costs for manure disposal are likely to be around €114 ha^{-1}, as part of the extra crude protein from the grass-clover can be balanced by using more maize silage or concentrate with a lower protein level. In that case the net annual result is €396 ha^{-1}.

Conclusions

Successful inclusion of red clover in grasslands has major agro-economic advantages, and these also apply under high fertilization rates. Dry matter production, total energy production and protein production

Table 1. Mean yields of pure grass (n=8) and grass-clover mixtures (n=18) of two years.

	Dry matter Mg ha^{-1}	Net energy lactation MJ ha^{-1}	Crude protein kg ha^{-1}	Intestinally digestible protein kg DVE ha^{-1}
Grass only	11.0	6.97×10^4	1.88×10^3	8.20×10^2
Grass-clover	13.0	7.76×10^4	2.69×10^3	10.4×10^2
Difference	18%	11%	43%	27%
Significance	<0.001	<0.001	<0.001	<0.001

Table 2. Mean energy and protein content of pure grass (n=8) and grass-clover mixtures (n=18) of two years.

	Net energy lactation MJ kg^{-1}	Crude protein g kg^{-1}	Intestinally digestible protein g DVE kg^{-1}
Grass only	6.32	169	74.0
Grass-clover	5.98	207	80.1
Difference	-5%	22%	8%
Significance	<0.001	<0.001	<0.001

Table 3. Differences in annual costs and benefits in € ha[-1] for grass and grass-clover mixtures, based on measured yield differences in experimental plots.

	Grass only	Grass-red clover	Difference
Costs			
Seed & sowing[1]	48	114	66
Manure & fertilizers	396	189	-207
Weed control	15	0	-15
Harvesting[2]	750	790	40
Manure disposal[3]			114
Total costs			-2
Benefits			
Energy yield difference[4,5]			152
Protein yield difference[5,6]			241
Total benefits			393
Net annual result			396

[1] Assuming €455 and €385 seed and seeding costs and 4 and 8 productive years for grass-clover and grass, respectively.

[2] Slower sowing and harvesting may result in slightly higher costs for grass-clover.

[3] Assuming 50% of the additional N-yield needs to be disposed at a cost of €7 Mg manure[-1] (mean value 2010-2013 (LEI, 2014)), and assuming an N-content of 4 kg N × Mg manure[-1], thus €1.75 kg N[-1] disposed.

[4] Assuming €0.0192 MJ[-1].

[5] Mean value 2013-2014, based on Wageningen UR Livestock Research, 2014.

[6] Assuming €1.09 kg DVE[-1] (intestinally digestible protein).

are increased in grass-clover compared with grass. Grass-clover fodder has a higher protein content and slightly lower energy content than grass. The economic benefits mainly result from the higher production in combination with avoiding the costs of artificial fertilizer. The financial benefits of grass-clover depend on the farming system into which it is integrated, as well as on the extent to which a farmer is able to adapt his fodder regime.

Acknowledgements

References

Doyle C. and Topp C. (2002) An economic assessment of the potential for increasing the use of forage legumes in north European livestock systems. In: Wilkins R.J. and Paul C. (eds.) *Legume silage for animal production: Legsil*. FAL, Braunschweig, pp. 75-85.

LEI, Wageningen UR (2014) Bedrijven-Informatienet 2010-2013.

Nyfeler D., Huguenin-Elie O., Suter M., Frossard E., Conolly J. and Lüscher A. (2009) Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding. *Journal of Applied Ecology* 46, 683-691.

Wageningen UR Livestock Research (2014) *Voederwaardeprijzen Rundvee*. Available at: at bit.ly/1DKh6r6.

Element concentrations in forage plants grown on power station ash deposit

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Abstract

Intensive livestock production is concentrated in the northern part of Serbia, particularly in the vicinity of Belgrade. This area is very important for forage production, but the main power stations of the Serbian power supply system are located in this region and these produce high emissions of fly ash. Forage plants are exposed to the pollution effects of fly ash, and some agricultural systems are located very close to the Nikola Tesla A (TENT-A) power station. A study of three forage plants (*Medicago sativa, Phalaris arundinacea, Melilotus officinalis*) was done on 'TENT-A' ash deposit in order to analyse bioaccumulation of maximally exposed plants. Plant samples were collected at tillering stage and concentrations of 10 elements were analysed. The results show lower concentrations of trace metals in the herbage shoots than in the ash, which had excessive contents of As, Ni and Cr. None of the examined species accumulated a high amount of the above-mentioned elements, even though they were from different families, with different morphology and dry matter yield. Alfalfa had the highest concentrations of As and Ni among the species that were analysed.

Keywords: *Medicago sativa, Phalaris arundinacea, Melilotus officinalis*, trace elements

Introduction

The use of coal to produce electricity in the 'TENT-A' thermal power station in Obrenovac, Serbia requires large quantities of coal annually. The production of by-products of coal combustion is very large and the vegetation of the region is exposed to emissions of different types of pollutants (Pavlović *et al.*, 2004). To prevent ash dispersion by wind, spare lagoons are covered by vegetation, consisting of adaptive grass-leguminous species. There is interest in studying bioaccumulation in plants because they form the base of the food chain and also because of their potential use in phytoextraction. Absorption depends upon the availability of the metal rather than the total amount of metal in the soil (Kelepertsis and Andrulakis, 1983). Uptake of heavy metals by plants is largely a function of the physiology of the species and the availability of the element concerned. Since coal residues contain potentially hazardous substances, improper handling and disposal could cause undesirable environmental effects (Adriano *et al.*, 1980). The latter may be influenced by the strength of organometalic complexes in the soil. The study reported here covered three species: alfalfa (*Medicago sativa* L.), reed canarygrass (*Phalaris arundinacea* L.) and sweetclover (*Melilotus officinalis* (L.) Pall.). The primary objective of this research was to evaluate trace element concentrations in plant shoots, on a site at the Obrenovac ash deposit site, which is very close to the Serbian capital and main livestock production area of Serbia. The high concentrations of pollutants in the air and those contained in the ash in these areas are considered severe stress factors for the metabolism of plants. Since the thermal power station of TENT-A and the ash disposal sites are in the vicinity of a densely populated area, the same pollutants could be potentially detrimental to the health and well-being of animals and humans.

Materials and methods

For the purpose of determining the concentrations of metals and microelements in plants (alfalfa, reed canarygrass, sweetclover), samples were collected from ash deposits at the TENT-A power station in Obrenovac in May 2005, at the stage of full vegetative development. Plant material was washed in deionized water, then dried at 25 °C, digested with ccHNO$_3$ and the concentrations of As, Pb, Cd, Hg, Zn, Cr, Ni, Fe, Cu and B in the upper plant parts were measured using spectrometry (Perkin-Elmer 5000 for AAS and FES techniques; MHS-10 (hydride technique); MHS-1 (cold vapour technique), as well as by atomic emission spectrometer with inductively coupled plasma, Perkin-Elmer ICP/6500, MHS-10/5000,0). The concentration of macroelements (N, P$_2$O$_5$, K$_2$O and Ca) in the ash was determined after melting with lithium borate, lithium tetra-borate and lithium iodide, at 1000 °C. The results were processed by calculating average value and standard deviation for each sample. The following analytical methods were applied: for metal determination in plants – AOAC 986.15, and for the determination of other elements in plants – AOAC 985:01. Analysed substrate was neutral in reaction (pH [KCl]7.03), with low P and N content (P<1 mg kg^{-1}), and well-supplied with available K.

Results and discussion

The concentrations in the soil of As, Cr and Ni exceeded the maximum permissible concentrations. Various plants grown on ash deposits that had elevated As, Ni and Cr contents (Table 1) were analysed for their contents of heavy metals and microelements. The observed range of Zn in the plants from the ash deposit was below the critical concentration for normal plant growth. On the other hand, although the ash deposit was contaminated by As, concentrations of As in plants were around 1 mg kg^{-1}, which was below the tolerated concentrations for fodder. Lead (Pb) is considered to be the metal with the lowest biological accessibility and all the examined species had low contents (<1 mg Pb kg^{-1}). The measured content of Cd in ash was low and Cd was neither readily soluble nor easily phytoavailable. The Hg concentration was <0.2 mg kg^{-1} in the deposit and, consequently, the Hg concentration in plant tissue samples was also low. Total Cr content in ash was twice that of the maximum permissible amount and its concentration in all the analysed samples of plant material ranged from 1.19 (sweetclover) to 3.20 mg Cr kg^{-1} (reed canarygrass). The Ni content measured in fly ash was two-and-a-half times higher than the amount allowed in the soil. The highest accumulation level was noted in alfalfa (8.97 mg kg^{-1}), while the lowest level was in reed canarygrass (3.01 mg kg^{-1}), both of which were below the critical concentration for normal plant growth. For these species, the Cu concentrations were found to be within the normal range. According to Adriano *et al.* (1980), there is a toxic effect of B at concentrations of more than 100 mg kg^{-1}; this amount was not observed in plants from the deposit, although the concentration was near critical in *Melilotus officinalis* (99 mg kg^{-1}). Analyses showed a lower bioaccumulation of some elements in alfalfa grown and collected in the ash deposit of 'TENT-A', in comparison with the results reported for alfalfa grown under the same conditions: in their studies Dželetović and Filipović (1995), found fivefold lower concentrations in Pb and Cd, and threefold lower concentartions for Zn and Cu. A possible reason for the difference in concentrations in plant tissue was the higher element concentration observed in the substrate in previous studies. However, the As and Ni content in alfalfa is slightly higher than the range for plant tissue of other herbaceous plants. Although some elements (As, Ni, Cr) exceeded the maximum permissible amounts for soil and water, the ability of plants collected from the ash deposit to accumulate micronutrients was generally low. This could be explained by the pH of fly ash, which influences the relatively low mobility of trace elements in soil solution and, consequently, low uptake by plants (Kabata-Pendias, 2010).

Conclusions

Based on the results obtained, it could be concluded that the three forage species grown on the ash deposit of a coal-fired power station did not hyperaccumulate any of the ten heavy metals and micronutrients that were monitored in this work. Although As, Cr and Ni contents exceeded the maximum permissible

Table 1. pH-value and chemical composition of deposit and trace elements concentrations in herbage from the TENT A ash deposit (mg kg^{-1}).

Deposit depth 0-20		Ash deposit	MTA[1]	*Phalaris arundinacea*	*Medicago sativa*	*Melilotus officinalis*	MTL[2]
As	mg kg^{-1}	34.7	25	1.24	1.80	0.84	4
Pb	mg kg^{-1}	56.7	100	0.65	0.24	0.78	40
Cd	mg kg^{-1}	0.8	3	0.05	0.03	0.10	1
Hg	mg kg^{-1}	<0.2	2	0.44	0.74	0.29	1-8
Zn	mg kg^{-1}	75.9	300	24.3	15.3	23.5	2,000
Cr	mg kg^{-1}	205	100	3.20	1.49	1.19	1-10
Ni	mg kg^{-1}	123	50	3.01	8.97	5.61	50
Fe	g kg^{-1}	21.7	-	180	180	180	1,250
Cu	mg kg^{-1}	62.7	100	2.64	2.61	4.70	12-50
B	mg kg^{-1}	0.71	-	76.5	83.7	99.0	-

[1] Maximum tolerated amount in the soil (Kabata-Pendias, 2010).

[2] Maximum tolerated level for fodder (NRC, 2005).

concentrations in the nutritive medium, their values did not exceed levels considered as the threshold for fodder plants. Iron, boron and zinc were the most prevalent elements in plant tissues, in absolute values. Alfalfa had the highest concentration of As and Ni among the species that we analysed. High pH level, antagonistic relationships among elements and their interactions, as well as physiological features of plants are factors that led to low metal and microelements accumulation in alfalfa, reed canarygrass and sweetclover. The concentrations of trace elements did not exceed values that are taken as tolerable in forages, as presribed by normatives for ruminants' feed.

Acknowledgements

References

Adriano D.C., Page A.L., Elseewi A.A., Chang A.C. and Straughan I. (1980) Utilization and disposal of fly ash and other coal residues in terrestrial ecosystems: a review. *Journal of Environmental Quality* 9, 333-344.

Dželetović Ž.S. and Filipović R. (1995) Grain characteristics of crops grown on power plant ash and bottom slag deposit. *Resources, Conservation and Recycling* 13, 105-113.

Kabata-Pendias A. (2010) *Trace elements in soils and plants*, Fourth edition. CRC Press, Boca Raton, FL, USA.

National Research Council (NRC) (2005) *Mineral tolerance of animals*: Second Revised edition. The National Academies Press, Washington, DC, USA.

Pavlović P., Mitrović M. and Djurdjević L. (2004) An ecophysiological study of plants growing on the fly ash deposits from the 'Nikola Tesla-A' Thermal Power Station in Serbia. *Environmental Management* 33, 654-663.

Peganova S. and Edler K. (2004) Zinc. In: Merian E., Anke M., Ihnat M. and Stoeppler M. (eds.) *Elements and their compounds in the environment*, 2nd ed. Wiley-VCH, Weinheim, Germany, pp. 1203-1239,

White clover content and grassland productivity in simulated grazing systems

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Abstract

Maintaining white clover (*Trifolium repens*) content in grasslands is a challenge for high output eco-efficient dairy farms on mineral soils that use biological N-fixation as a relevant source of N-input. Lower cutting height and cutting at an early growth stage have positive effects on the white clover content in grass-clover mixtures in mowing systems. Our objective was to quantify the effect of three grazing systems (rotational, continuous and lenient strip stocking) on clover content and dry matter production. Grazing was simulated with a Haldrup grass harvester and dried cattle manure pellets were applied to resemble the organic matter input from grazing cattle ($50 \, kg \, N \, ha^{-1} \, yr^{-1}$). The experiment was established on sandy soil in 2011 in four replicates in sown grass-clover. Average clover content measured in June and October 2014 was lowest for lenient strip stocking and highest for continuous stocking. This resulted in 2014 in the highest grassland dry matter production for continuous stocking ($15.0 \, Mg \, DM \, ha^{-1}$) and the lowest for lenient strip stocking ($6.9 \, Mg$ dry matter $(DM) \, ha^{-1}$). Rotational stocking occupied an intermediate position ($11.9 \, Mg \, DM \, ha^{-1}$).

Keywords: white clover content, stocking, persistence, production, high output dairy systems

Introduction

Eco-efficient dairy farms on mineral soils with a low N-delivering capacity often use clover in grassland for its ability to fix atmospheric N_2 in symbioses with *Rhizobium* bacteria. To have a stable high output of grass-clover pastures on mineral soils, the clover content should be maintained at approximately 20-40%. However, persistency of white clover can be a challenge. Grass mixture, clover cultivar, soil properties, fertilization level and weather conditions are all known to influence the persistency of white clover. Moreover a lower cutting height and cutting at an early growth stage have a positive effect on the white clover content in grass-clover swards under mowing (Schils and Sikkema, 2002; Seresinhe, 1992). Both factors are also expected to influence the white clover content under grazing. However, in the Netherlands grassland management is mainly based on pure-grass stands and therefore little attention is put on clover and its maintenance in grassland The objective of our experiment was to measure the effect of the three most commonly used grazing systems in the Netherlands (rotational, continuous and lenient strip stocking) on clover content and dry matter production, on a mineral soil with a low N-delivering capacity. Since continuous stocking has the lowest stubble height and lowest height at defoliation it was hypothesised that continuous stocking had the highest clover content. We expected that lenient strip stocking would have the lowest clover content because of the highest stubble height. Moreover it was hypothesised that rotational stocking, with an intermediate clover content but a leaf area for photosynthesis close to lenient strip stocking, would have the highest dry matter (DM) production.

Material and methods

In 2011 a grassland field experiment was established on a sandy soil in Wageningen, the Netherlands. The site has an average temperature of 9.8 °C, average rainfall of 797 mm and a N-delivering capacity (including wet-deposition) of $30 \, kg \, N \, ha^{-1} \, yr^{-1}$. A mixture of perennial ryegrass (*Lolium perenne* L. cvs. Barflip and Barforma), tall fescue (*Festuca arundinacea* Schreb. cvs. Barolex and Bariane) and white clover

(*Trifolium repens* L. cvs. Alice and Riesling) was sown. Seeding rate was 30 kg grass and 3 kg clover ha^{-1}. The experiment consisted of three treatments: continuous, rotational and lenient strip stocking, in a randomised block design with four replicates. Plot size was 2.75×10 m. The three grazing systems were simulated by mowing with a Haldrup grass harvester at different stubble heights and grass heights at the time of defoliation (Table 1). Fields were fertilized in one application with cattle manure pellets (50 kg N ha^{-1} yr^{-1}) to resemble the organic matter input from grazing cattle. Furthermore, fields were fertilized with sufficient P, K and micronutrients to compensate for the nutrients that were removed by mowing. At each harvest in 2014 biomass was weighed from a strip of 1.50×10 m, sampled and dried at 70 °C. In July and October 2014, prior to each harvest, samples were taken from two quadrats (0.25 m[2]) for determination of the clover content. Grass and clover were separated by hand and subsequently dried at 70 °C. The effect of grazing system on clover content and DM production was assessed with SPSS, 19th edition using one-way ANOVA (*P*<0.05).

Results

Clover content was on average 45% in July compared to 34% in October. Fields under continuous stocking had significantly higher clover content than fields under lenient strip stocking (Table 2). DM production was significantly affected by the stocking system. Continuous stocking had the highest DM production followed by rotational stocking. The average clover content was positively correlated with DM production (r=0.53).

Discussion

Continuous stocking resulted in the highest clover content, while this was lowest for lenient strip stocking. The lower clover content under lenient strip stocking was most likely a result of shading by grasses (due to stubble height and/or grass height) which is known to reduce the number of leaf-bearing nodes and number of growing points (Lüscher, 1989; Seresinhe, 1992). Furthermore, Schwank *et al.* (1986) reported that light competition is the main factor that limits the proportion of clover in mixed swards. Our findings were in line with Seresinhe (1992) who investigated the effect of cutting heights of 4 cm and 10 cm on regrowth of perennial ryegrass-clover mixtures under similar climatic conditions in a two-year field experiment. In the second production year, the defoliation treatment of 10 and 4 cm had clover proportions of 30 and 41%, respectively.

Table 1. Overview of simulated grazing systems with stubble height and average grass height at the time of defoliation (incl. stubble height) in 2014.

	Stocking		
	Continuous	Lenient strip	Rotational
Stubble height (cm)	4	10	4
Average grass height at defoliation in 2014 (cm)	11	17	18
Number of cuts per year (n)	9	8	4

Table 2. White clover content and dry matter (DM) production in 2014 as affected by stocking system.[1]

	Stocking		
	Continuous	Lenient strip	Rotational
Average white clover content (%)	52 a	27 b	40 ab
DM-production (kg DM ha^{-1} year^{-1})	14,985 a	6,937 c	11,914 b

[1] Values followed by the same letter in a row are not statistically different at the 5% error level.

Contrary to our hypothesis, the DM-production of fields under continuous stocking was higher than under rotational stocking. Lower yields were obtained under rotational and lenient strip stocking, probably due to a lower clover proportion and thus a lower amount of nitrogen being fixed. Apparently, the nitrogen had a more limiting effect on production than leaf area for photosynthesis. On a soil with higher nitrogen-delivering capacity the difference would probably have been smaller or reversed.

Conclusions

On a high-output eco-efficient dairy farm on mineral soils with a low N-delivering capacity that depends on white clover for N-input, the influence of the grazing system on clover content is highly determinative for DM production. Grazing systems with a low stubble height and low height at defoliations are to be preferred on these farms.

Acknowledgements

References

Lüscher A. (1989) *Ueberwinterung und Frühlingsaufwuchs von Weissklee (*Trifolium repens *L.) – Dynamik der Kohlenhydratenreserven und der biologischen N$_2$-Fixierung*. PhD thesis. Swiss Federal Institute of Technology, Zurich, Switzerland.

Schils R.L.M. and Sikkema K. (2002) The effect of cutting height and management system on the performance of a grass/clover sward. In: *Lowland and grasslands of europe: utilization and development.* FAO/CIHEAM, Interregional and Cooperative Research and Development Network on Pastures and Fodder Crop Production, Rome, Italy. Available at: http://tinyurl.com/ky2jnqj.

Schwank O., Blum H. and Nösberger J. (1986) The influence of irradiance distribution on the growth of white clover (*Trifolium repens* L.) in differently managed canopies of permanent grassland. *Annals of Botany* 57, 273-281

Serensinhe R.T. (1992) Regrowth, productivity and symbiotic nitrogen fixation of white clover (*Trifolium repens* L.) Monocultures and white clover rye grass (*Lolium perenne* L.) mixed swards at two cutting heights. PhD thesis. Swiss Federal Institute of Technology, Zurich, Switzerland.

Effect of organic fertilization of maize forage on greenhouse gas emissions by dairy cows

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Abstract

The emission of methane by dairy cows, as enteric and manure fermentation, is the main source of greenhouse gas (GHG) emission in the dairy sector. The second most important GHG is the N_2O emission as a result of nitrogen addition to the soil. An empirical model was used to predict the methane production by dairy cows feeding on two diets based on maize silage grown with organic (MSF) or conventional (ChF) fertilization (IPCC Tier 2) and the emission of N_2O by both types of fertilization (IPCC Tier 1). The results were converted to carbon dioxide equivalent (CO_2eq) using the Global Warming Potential of 25 and 296 for CH_4 and N_2O respectively. More than 70% of GHG emissions were due to enteric fermentation. Milk production did not show differences between treatments; however, a 10% higher production of CO_2eq kg^{-1} of milk was observed in ChF than MSF. The difference observed was due to the diet and not to the type of fertilization, because there were no differences between both soil managements. The results demonstrate that it is possible to reduce GHG emissions with the use of manure and slurry as fertilizers, without affecting milk production.

Keywords: greenhouse gas, dairy cows, manure, fertilizers

Introduction

Nowadays there is a growing interest in steering agricultural production towards more sustainable systems, because agricultural livestock account for about 9% of total anthropogenic greenhouse gas (GHG) emissions (IPCC, 2007). In most dairy farms, the crop rotation of maize-Italian ryegrass is repeated continuously, demanding high amounts of nitrogen fertilization and causing negative effects on the soil (Heinze *et al.*, 2011). Therefore, the production of forages must be environmentally and ecologically sound and aligned with public values. The efficiency of chemical fertilizer used in maize cropping has become a major issue of concern, as the crop often has negative connotations with N-aspects of surface and groundwater quality (Schröder *et al.*, 2000). On another note, manure and slurry applications can recycle animal wastes and be a valuable soil nutrient resource. The benefit of dairy manure application on maize silage production has been reported (Butler *et al.*, 2008) and has been attributed to the improvement of physical and chemical edaphic properties. The objective of this study was to evaluate the effects of organic (manure and slurry) or chemical fertilization applied to maize forage crop on the emissions of nitrous oxide and enteric methane.

Materials and methods

Two adjacent plots of 1.7 ha each were sown with maize as summer crop, using chemical (ChF) or organic (MSF) fertilization respectively. The annual fertilization of the ChF plot was as follows: a basal dressing fertilization of 60 kg N ha^{-1}, 40 kg P_2O_5 ha^{-1} and 120 kg K_2O ha^{-1} before the sowing of the previous winter crop (Italian ryegrass); 60 kg N ha^{-1} applied as topdressing after the first Italian ryegrass cut for silage; 125 kg N ha^{-1}, 150 kg P_2O_5 ha^{-1} and 250 kg K_2O ha^{-1} after the second silage cut, before sowing the maize; and finally, 75 kg N ha^{-1} as topdressing when the maize plants were 20 cm high. The MSF plot was fertilized with 50 m^3 ha^{-1} of slurry distributed in three applications: the first in the previous autumn before the sowing of the winter crop, and the remaining two applications after each of the spring Italian ryegrass silage cuts. Before sowing the maize, 45 Mg ha^{-1} of manure were also applied. The slurry

supplied 0.52 kg N m^{-3}, 0.28 kg P$_2$O$_5$ m^{-3}, 0.72 kg K$_2$O m^{-3} and 0.20 kg MgO m^{-3}, and the manure had 3.24 kg N Mg^{-1}, 1.93 kg P$_2$O$_5$ Mg^{-1}, 6.23 kg K$_2$O Mg^{-1} and 1.34 kg MgO Mg^{-1}. Both types of maize were harvested in autumn 2011, when the maize grain was doughy-vitreous, and ensiled in trench silos that were opened in January 2012 to make two isoenergetic and isoproteic partial mixed rations (ChF PMR and MSF PMR). The PMRs consisted of ChF or MSF silage, grass silage, barley straw and concentrate.

Eighteen dairy cows in the second third lactation were allocated into two groups, and assigned to one of the PMRs throughout 4 months between February and May 2012. Cows were milked twice daily, remained indoors until 11:30 a.m., and then moved to the grazing area, where they stayed until the evening milking.

The model used to predict CH$_4$ emission was IPCC Tier 2 and IPCC Tier 1 was used to predict N$_2$O emission (IPCC, 2006). The first model incorporates the CH$_4$ conversion factor for milking cows, animal production and gross energy intake. The second one uses the source of N added to soil (inorganic, organic, urine and manure of grazing animals, crop residues). The results were converted to carbon dioxide equivalent (CO$_2$eq) using the Global Warming Potential of 25 and 296 for CH$_4$ and N$_2$O respectively. GHG emissions were analysed using the MIXED procedure of the SAS (1999) for repeated measurements, with a model considering the treatment effect (ChF or MSF). When the ANOVA was significant ($P<0.05$), means were separated by Tukey's test pairwise comparison.

Results and discussion

The MSF diet had 10% less total dry matter intake than the ChF, with 17.7 and 19.8 kg DM day^{-1} respectively, and the concentrate intake included on PMR was lower in the treatment based on MSF silage than ChF silage (2.8 vs 3.2 kg d^{-1} resp.; $P<0.05$). No differences were seen between treatments with respect to milk production per cow (25.4 kg d^{-1}).

The values for greenhouse gas emissions per cow, per dry matter intake and per milk production are given in Table 1. More than 70% of GHG total emissions are due to enteric fermentation, being higher in ChF than in MSF diet (13.46 vs 11.76 kg CO$_2$eq kg^{-1} respectively, $P<0.05$). The prediction of total CO$_2$eq emission in ChF treatment was higher than in MSF (up to 13%; $P<0.05$). The difference observed in this study was due to the diet and not to the kind of fertilization, because there were no differences in either soil management or in manure excretion between treatments. There were no differences when GHG emissions were related to dry matter intake; however, a 10% higher production of CO$_2$eq per kg of milk was observed in ChF than in MSF (0.74 vs 0.67 kg CO$_2$eq kg^{-1} respectively, $P<0.05$). The estimated enteric CH$_4$ emissions in this study were higher than those calculated by Legesse *et al.*, (2011) or measured values in a respiratory chamber (Brask *et al.*, 2013). However, the proportion of forage in

Table 1. Estimated emissions of carbon dioxide equivalent related to cow, dry matter intake and milk yield for the two treatments: diets based on maize silage fertilized with organic (MSF) and chemical (ChF) fertilization.[1]

	MSF	ChF	Standard error	P-value[2]
Enteric fermentation (kg CO$_2$eq cow^{-1} d^{-1})	11.76	13.46	2.049	*
Manure (kg CO$_2$eq cow^{-1} d^{-1})	1.23	1.55	0.228	NS
Soil management (kg CO$_2$eq cow^{-1} d^{-1})	3.78	3.95	0.122	NS
Total (kg CO$_2$eq cow^{-1} d^{-1})	16.77	18.97	1.553	*
kg CO$_2$eq kg^{-1} dry matter intake	0.95	0.96	0.008	NS
kg CO$_2$eq kg^{-1} milk	0.67	0.74	0.050	*

[1] CO$_2$eq calculated from the values of the Global Warming Potential: 25 for methane and 296 for nitrous oxide (IPCC, 2006). Values are means for n=9.

[2] Statistical significance: * $P<0.05$; NS = not significant.

all these studies was 60% or less. Aguerre *et al.* (2011) studied the effect of forage-to-concentrate ratio in dairy cow diets on GHG emission, and noted that increasing the forage proportion in the diet from 47% to 68%, the CH_4 emission was increased from 0.538 to 0.648 per cow and day. In our study, the diets had 79% of forage, and therefore, this could explain our higher estimated GHG emissions.

Conclusions

On the basis of the results obtained, it could be concluded that it is possible to reduce the GHG emissions using maize forage with manure and slurry as own fertilization sources for a sustainable soil management, with a good management of the diets and without lowering the milk production.

References

Aguerre M.J., Wattiaux M.A., Powell J.M., Broderick G.A. and Arndt C. (2011) Effect of forage-to-concentrate ratio in dairy cow diets on emission of methane, carbon dioxide, and ammonia, lactation performance, and manure excretion. *Journal of Dairy Science* 94, 3081-3093.

Brask M., Lund P., Hellwing A.L.F., Poulsen M. and Weisbjerg M.R. (2013) Enteric methane production, digestibility and rumen fermentation in dairy cows fed different forages with and without rapeseed fat supplementation. *Animal Feed Science and Technology* 184, 67-79.

Butler T.J., Han K.J., Muir J.P., Weindorf D.C. and Lastly L. (2008) Dairy manure compost effects on corn silage production and soil properties. *Agronomy Journal* 100, 1541-1545.

Heinze S., Oltmanns M., Joergensen R.G. and Raupp J. (2011) Changes in microbial biomass indices after 10 years of farmyard manure and vegetal fertilizer application to a sandy soil under organic management. *Plant and Soil* 343, 221-234.

IPCC (2006) *IPCC guidelines for national greenhouse gas inventories. vol. 4: agriculture, forestry and other land use,* IGER, Hayama, Japan.

IPCC (2007) *Climate Change 2007: contribution of working groups i, ii and iii to the fourth assessment report of the intergovernmental panel on climate change*. IPCC, Geneva, Switzerland.

Legesse G., Small J.A., Scott S.L., Crow G.H., Block H.C., Alemu A.W., Robins C.D. and Kebreab E. (2011) Predictions of enteric methane emissions for various summer pasture and winter feeding strategies for cow calf production. *Animal Feed Science and Technology* 166-167, 678-687.

SAS (1999) *SAS/STAT TM. User's Guide,* Statistical Analysis System Inst., Cary, NC, US.

Schröder J.J., Neeteson J.J., Oenema O. and Struik P.C. (2000) Does the crop or the soil indicate how to save nitrogen in maize production? Reviewing the state of the art. *Field Crops Research* 66, 151-164.

Effect of harrowing and watering on disappearance of dung pats in pastures

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Abstract

Dung pats in pastures limit grass production, and lead to grazing losses and a lower eco-efficiency in dairy systems. Immediate harrowing after grazing could help to break up the pats and distribute the manure more evenly. However, in the absence of rain this may result in flattened, manure-smeared grass. Harrowing after some days of dung deposition may overcome smearing of the grass. Watering the pasture immediately after harrowing can help to wash the manure off the foliage. In a field experiment we compared the disappearance of (artificial) dung pats in the following treatments: (1) dung pat – untreated (control); (2) harrowing immediately after deposition (day 0); (3) harrowing + watering (10 mm) immediately after deposition (day 0); (4) harrowing at 7 days after deposition; and (5) harrowing + watering (10 mm) at 7 days after deposition. The results after three weeks show that harrowing fresh dung pats (day 0) did not significantly increase the disappearance of dung (43% disappeared versus 40% disappeared of the untreated pats). Harrowing 7 days after deposition resulted in a significant lower dung disappearance (31%) than observed for the untreated pats (40%), even when watered (34%). The best result was obtained when fresh dung pats were harrowed in combination with water at day 0 (61% disappearance).

Keywords: dung pats, pasture, harrowing, watering, dry matter disappearance

Introduction

Fouling of pastures by dung pats is an important problem on dairy farms. A cow produces around 8-10 dung pats per day. Depending on the grazing management most of the dung pats are deposited on the pasture. Dung pats reduce the surface of grass growth and cows reject herbage around pats, which decreases the area on which cows forage and lowers the utilization of the pasture (Bosker *et al.*, 2002; Castle and MacDaid, 1972; Dohi *et al.*, 1991). Moreover, the pats form a breeding medium for cattle pests (Castle and MacDaid, 1972). Rapid disappearance of dung pats enables faster recycling of nutrients and their utilization, better grass growth and a faster recovery of the grass surface. Because of these effects a rapid disappearance of cow dung pats is desirable for farmers. A wide range of biotic and abiotic factors and grassland management measures can influence the degradation and disappearance of dung pats (Barth *et al.*, 1994). One management measure is harrowing. Harrowing immediately after grazing could help to break up the pats and distribute the manure more evenly. However, in the absence of rain this may result in flattened, manure-smeared grass. Harrowing after some days of dung deposition may overcome smearing of the grass. Harrowing in combination with watering the pasture immediately after harrowing can help to wash the manure off the foliage. The objective of this experiment was to study the effect of timing of harrowing and watering on the disappearance of dung pats.

Material and methods

In a field experiment with a randomised block design we compared the following treatments: (1) dung pat – untreated (control); (2) harrowing immediately after deposition (day 0) (3) harrowing + watering (10 mm) immediately after deposition (day 0); (4) harrowing at 7 days after deposition; and (5) harrowing + watering (10 mm) 7 days after deposition. Harrowing was carried out with a commercial

chain harrow. The experiment was carried out in July 2014 at VIC Zegveld in the western peat soil region in the Netherlands. The dung used for the experiment was collected from a herd of cows on a fresh grass diet. Dung was collected direct from the cows' rectums. At the start of the experiment the dung was thoroughly mixed mechanically. Before placement of each artificial dung pat, the grass was mowed to a height of 7 cm and the field was irrigated. There were five pats per treatment. Two kilos of dung per pat were weighed and poured into round pie tins in order to provide the same shape and weight of each dung pat. Wire netting (mesh size 1 cm) was placed underneath each dung pat to assist with their recovery. The dung pats were harvested and weighed at 21 days after placement to examine the rates of dung decomposition. There was no rain during the experiment.

Results

The mean rates of disappearance of dung (as % of dung dry matter (DM)) for each treatment are presented in Table 1. The results show that under these circumstances (peat soil and dry weather), harrowing the fresh dung pats (day 0) did not significantly increase the disappearance of dung. The combination of harrowing with watering at day 0 resulted in the most significant increased rate of disappearance of dung pats. Harrowing 7 days after deposition, with or without watering, resulted even in a significantly lower rate of dung disappearance compared with the untreated pats.

Discussion

The highest dung pat disappearance was recorded with direct harrowing and watering at the day of deposition. Direct harrowing at day 0 without watering had no additional value to the control. Watering may have had not only a washing effect but also a moistening effect on the dung pats. In the model for dung disappearance of Vadas *et al.* (2011), moisture of the dung was a very important factor. However, watering at day 7 did not increase the dry matter disappearance compared with just harrowing at day 7. Both treatments had even lower rates of disappearance than the control. Apparently, watering has little or no effect when the dung pat is no longer fresh. Harrowing a dung pat after 7 days has a negative effect on its disappearance. An explanation for this could be that after 7 days the dung pat is drier, and that harrowing the dry dung pat reduces the contact between the dung pat and the soil surface, which inhibits the decomposition processes by earthworms and other soil biota.

Conclusions

Harrowing in combination with watering dung pats at day 0 after deposition was shown to enhance the disappearance dung pats at three weeks after their deposition. Direct harrowing and harrowing after 7 days did not increase the disappearance rate of dung pats.

Table 1. Disappearance of dung (as % of dry matter (DM)) 21 days after placement.

Treatment	Disappearance of dung (as % of DM)[1]
Dung pat-untreated control	40 b
Harrowing at day 0	43 b
Harrowing + watering at day 0	61 a
Harrowing at day 7	31 c
Harrowing + watering at day 7	34 c

[1] Values followed by the same letter in a column are not statistically different at the 5% error level.

Acknowledgements

References

Barth D., Karrer M., Heinze-mutz E.M. and Elster N. (1994) Colonization and degradation of cattle dung: aspects of sampling, fecal composition, and artificially formed pats. *Environmental Entomology* 23, 571-578.

Bosker T., Hoekstra N.J., Lantinga E.A. (2002) The influence of feeding strategy on growth and rejection of herbage around dung pats and their decomposition. *Journal of Agricultural Science* 139, 213-221.

Castle M.E. and MacDaid E. (1972) The decomposition of cattle dung and its effect on pasture. *Journal of British Grassland Society* 27, 133-137.

Dickinson C.H. and Craig G. (1990) Effects of water on the decomposition and release of nutrients from cow pats. *New Phytologist* 115, 139-147.

Dohi H., Yamada A. and Entsu S. (1991) Cattle feeding deterrents emitted from cattle feces. *Journal of Chemical Ecology* 17, 1197-1203.

Vadas P.A., Aarons S.R., Butler D.M. and Dougherty W.J. (2011) A new model for dung composition and phosphorus transformations and loss in runoff. *Soil Research*, 49, 367-375.

Changes in land use resulting from diet modifications related to increasing milk yields

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Abstract

Milk yields in Germany are still increasing for economic and other reasons. Cows with higher yields need diets with higher protein and energy content. This necessitates changes in the amounts of individual feedstuffs within the diets. Accordingly, these changes result in a shift in land use from grassland to cropland. The relationship between the diets of dairy cows (including replacement) and the associated use of grassland and cropland was studied. For this purpose, the fixed amount of the annual milk production in Germany was set as a basis. The milk yield was varied from 4,000 to 12,000 kg energy corrected milk (ECM) cow^{-1} year^{-1}, in steps of 2,000 kg ECM cow^{-1} year^{-1}. The results show a decreasing use of utilised agricultural area (UAA), especially grassland, with increasing milk yield. The total use of UAA is similar for the higher milk yields. Thus, the lowest use of the resource land (UAA and grassland) associated with a defined amount of produced milk occurs at milk yields of 10,000 and 12,000 kg ECM cow^{-1} year^{-1}. The use of cropland is growing with milk yields increasing over the whole investigated scope.

Keywords: grassland, dairy cow diets, land use, milk yield

Introduction

The increasing global human population, with resulting increases in food demand accompanied by changing consumption patterns, as well as the finite availability of agricultural land, presents an urgent need for more efficient farm output. In Germany farmers are under pressure to increase the milk yield per cow for economic reasons. The number of cows is decreasing accordingly (cf. BLE, 2012, Table 138).

To ensure higher milk yields, the protein and energy contents of the diets have to be increased (cf. GfE, 2001). Achieving this dietary change means that a modification of the proportions single feedstuffs is unavoidable. This development leads to a shift from the provision of grassland-based feed to cropland-based feedstuffs, and therefore to changes in the relative land use of grassland and arable land.

This paper analyses the acreage needed to supply sufficient feed production to ensure the annual German milk production at different milk yields, divided into grassland and cropland. The aim of the study was to identify how milk yield (between 4,000 and 12,000 kg energy corrected milk (ECM) cow^{-1} year^{-1}) and pasture management are related to the extent of land use.

Materials and methods

This paper analyses the demand of utilised agricultural area (UAA), in particular grassland and cropland for production of 31,186,300 Mg ECM with 4% fat and 3.4% protein, which is equal to the level of production of Germany in 2013 (BMELV, 2014b). The system comprises a defined number of dairy cows and their replacements, which depends on the milk yield. The milk yield varies from 4,000 to 12,000 kg ECM cow^{-1} year^{-1}, in steps of 2,000 kg ECM cow^{-1} year^{-1}. For each milk yield, three diets, based on three different types of pasture management (without, half-day, and full-day pasture) are represented. The replacement rate is defined as the German average of 36.2% (KTBL, 2009) for all milk yields, as well as the loss of calves during the rearing, which is defined as 9.9% (KTBL, 2009). The rearing period for

female calves and first-calf heifers is set at 25 months (Spiekers and Potthast, 2004). No male calves are considered in this study. The lactation period is 305 days with an additional 60-day dry period.

The diets are presented as total mixed ration and based on data from Krauß *et al.* (2015). Only the composition of concentrate is slightly different. In this study it consists of 50% wheat, 26.5% soybean meal, 20% barley, 3% mineral feed and 0.5% rapeseed oil (according to mixture 170/4 from Spiekers and Potthast (2004)).

The use of grassland (corresponding feedstuffs: grass silage, pasture and hay) and cropland (corresponding feedstuffs: fieldgrass silage, maize silage, beet pulp silage, soybean meal, rapeseed meal, triticale (*Triticosecale* Wittm.) and concentrate) was calculated by the amount of feedstuff used for each diet and the corresponding crop yield based on the German average for 2013 (BMELV, 2014a). As the crops of sugar beet, rapeseed and soya produce more than one product (including products used for human nutrition), the yield was allocated to all products, according to Cederberg and Mattson (2000) and Mattson *et al.* (2000).

Results and discussion

Higher milk yields require adapted diets, because the total amount of feed intake is limited. Protein and energy contents of the diet must be raised in order to ensure that the basic needs of the animals and higher milk yields are covered. This requires a shift from grassland-based feedstuff to cropland-based feedstuff. The amount of a feedstuff is directly related to the land used for its production according to the crop yield.

Figure 1 illustrates the land use for the amount of milk produced in Germany in 2013 in relation to the milk yields of 4,000 to 12,000 kg ECM cow^{-1} year^{-1} and the associated pasture management.

The results show a decreasing use of grassland with increasing milk yield within the same pasture-management group. At the same milk yield, the diet without pasture requires the lowest use of grassland and the highest use of cropland and vice versa for the full-day pasture. Pasture management only slightly influences the total land use for the same milk yield (maximum difference 2.9% at 10,000 kg ECM
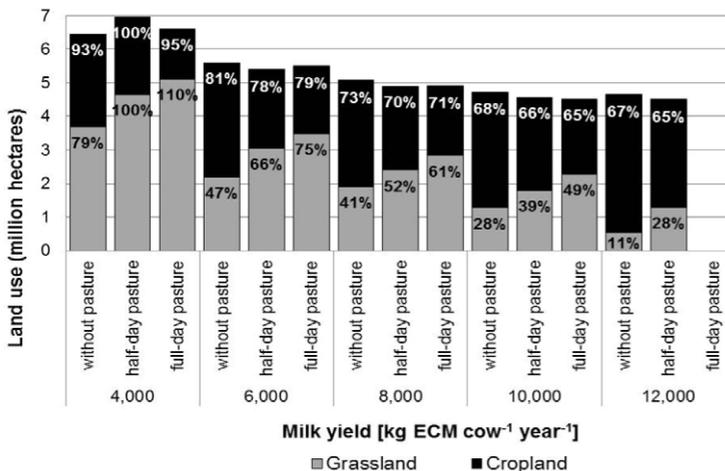
Figure 1. Land use for the production of 31,186,300 Mg ECM, related to milk yields from 4,000 to 12,000 kg ECM cow^{-1} year^{-1}, including three kinds of pasture management; upper percentages: total land use related to total land use at 4,000 kg ECM cow^{-1} year^{-1}, half-day pasture; lower percentages: total grassland use related to total grassland use at 4,000 kg ECM cow^{-1} year^{-1}, half-day pasture.

cow^{-1} year^{-1}, without pasture and full-day pasture), except for a milk yield of 4,000 kg ECM cow^{-1} year^{-1} (maximum difference 7.3%, half-day pasture and without pasture).

The cropland used to produce the diets increases with higher milk yields. However, with increasing milk yields there is a decrease in the amount of UAA needed and in the grassland area. Thus, only 65% of UAA is required if the same amount of milk is produced by cows with a milk yield of 12,000 instead of 4,000 kg ECM cow^{-1} year^{-1} (half-day pasture). While the 4,000 kg ECM cow^{-1} year^{-1} diets do not seem to be efficient regarding the land use, the difference in the use of UAA between the high milk yields of 10,000 and 12,000 kg ECM cow^{-1} year^{-1} becomes negligible (less than 1% for the same pasture management). However, a full-day pasture diet is not practicable at a milk yield of 12,000 kg ECM cow^{-1} year^{-1}. The results imply that the milk yields of 10,000 and 12,000 kg ECM cow^{-1} year^{-1} are the most efficient regarding the use of the resource land (in particular UAA).

Conclusions

The trend towards increasing milk yields results in a decrease in total UAA usage required to produce a certain amount of milk. This effect diminishes considerably at milk yields of more than 10,000 kg ECM cow^{-1} year^{-1}. Looking at the different types of land use, it is obvious that the decrease in grassland is much stronger than the decrease in the total UAA, still at higher milk yields. In contrast, diet modification leads to an increasing use of cropland with increasing milk yields. Surplus grassland would be potentially available for other purposes, e.g. bioenergy production. Further research is needed to estimate the overall environmental impact of decreasing UAA demand but increasing demand for cropland.

References

BLE [Bundesministerium für Ernährung Landwirtschaft und Verbraucherschutz] (2012) *Statistisches Jahrbuch über Ernährung, Landwirtschaft und Forsten der Bundesrepublik Deutschland 2012*, 56th edition. Landwirtschaftsverlag, Münster-Hiltrup, Germany.

BMELV [Bundesministerium für Ernährung und Landwirtschaft] (2014a) *Data & Tables: Anbau, Ertrag und Ernte der Feldfrüchte – Endgültiges Ergebnis*, table number MBT-0112090-0000. last update 07.04.2014.

BMELV [Bundesministerium für Ernährung und Landwirtschaft] (2014b) *Data & Tables: Milchwirtschaft auf einen Blick*, table number SBT-0100010-2013. last update 20.11.2014.

Cederberg C. and Mattsson B. (2000) Life cycle assessment of milk production – a comparison of conventional and organic farming. *Journal of Cleaner Production* 8, 49-60.

GfE [Ausschuss für Bedarfsnormen der Gesellschaft für Ernährungsphysiologie] (2001) *Empfehlungen zur Energie- und Nährstoffversorgung der Milchkühe und Aufzuchtrinder*. DLG Verlag, Frankfurt a. Main, Germany.

Krauß M., Kraatz S., Drastig K. and Prochnow A. (2015) The influence of dairy management strategies on water productivity of milk production. *Agricultural Water Management* 147, 175-186.

KTBL [Kuratorium für Technik und Bauwesen in der Landwirtschaft e. V.] (2009) *Faustzahlen für die Landwirtschaft*, 14th edition. KBTL, Darmstadt, Germany.

Mattsson B., Cederberg C. and Blix L. (2000). Agricultural land use in life cycle assessment (LCA): case studies of three vegetable oil crops. *Journal of Cleaner Production* 8, 283-292.

Spiekers H. and Potthast V. (2004) *Erfolgreiche Milchviehfütterung*, 4th edition. DLG Verlag, Frankfurt a. Main, Germany.

Keyword index

A

accelerometer – 166, 203
accuracy – 203
adaptation – 316
agri-environment – 116
agronomy – 116
alfalfa – 67
alternative paths – 475
AMS – 236
ANCA – 377
animal
    – health – 392
    – welfare – 51, 107
anions – 274
apparent N recovery – 331
authentication – 292
automatic milking – 125, 131, 410, 437, 452, 469
Azores – 21

B

barley – 334
barn type – 102
behaviour – 107, 203
benchmarks – 283
best management practice – 206
biodiversity – 289, 340, 431, 443
biomass – 316
    – belowground – 187
birdsfoot trefoil – 449
botanical composition – 337

C

CAP – 250
carbohydrates – 328
carbon sequestration – 431
β-carotene – 212
carryover period – 87
CASIMOD'N model – 96
catch crop – 440
cations – 274
cattle – 51, 203
    – feeding – 392
    – slurry – 245, 325
    – slurry digestate – 325

CEC – 175
cereal grain – 322
cereals – 67
change detection – 419
classification system – 224
clover-grass mixtures – 295
cocksfoot – 221
companion species – 401
competitiveness – 209
concentrates – 178
concentrate supplementation – 119, 410
continuous flowering – 319
cows – 416
cow traffic – 131
cropping systems – 139
crude protein – 250
cultivar mixture – 239
cutting
    – date – 419
    – frequency – 286
    – strategy – 319

D

dairy – 67, 84, 181, 334, 413, 472
dairy cows – 51, 90, 93, 105, 110, 122, 125, 134, 200, 259, 446, 452, 487
    – diets – 493
dairy farming – 26, 377, 428, 443
    – systems – 151, 367, 466
dairy farm network – 437
dairy farms – 40, 96, 215, 463
Dairyman sustainability index – 367
dairy production – 113
dairy sheep – 253
day length – 316
daytime – 125
DCAD – 274
decision support – 227
    – tool – 265
digestibility – 169, 250, 416
direct drilling – 218
diversity – 301
    – γ diversity – 172
DM yield – 224, 274
docks – 280

Authors index

A

Aanensen L. – 107
Aarts F. – 367
Aarts H.F.M. – 3, 377
Abbink G.W. – 78
Abraham E.M. – 449
Adolfsson N. – 277
Agruña M.J. – 292
Albrecht K.A. – 163
Alig M. – 380
Allain C. – 166
Andersson Å. – 128
Andersson S. – 125
Arranz J. – 253
Atkins N.A. – 81

B

Baert J. – 139
Bailey J. – 431
Balázsi A. – 289
Baumont R. – 416
Beare M.H. – 349
Beck C. – 166
Becker T.H. – 84
Bélanger G. – 169, 328
Belot P.-E. – 26
Berendonk C. – 178
Berg W. – 493
Berry D.P. – 383
Bleach E.C.L. – 81
Blume L. – 84
Boland T.M. – 416
Boonen J. – 367, 437
Brandsma J. – 283, 431
Breitsameter L. – 172
Brocard V. – 26, 166, 469
Buckingham S.E. – 455
Bussink D.W. – 175, 298, 392
Byrne N. – 383

C

Casey I.A. – 280
Cernoch V. – 386
Cleven M. – 178
Cloet E. – 200

Collins R.P. – 349
Cormont A. – 413, 428
Cornelissen J.M.R. – 181
Corson M.S. – 96
Coughlan F. – 113, 259
Cougnon M. – 139, 184, 187
Crespo D.G. – 431
Crotty F.V. – 218
Cummins S. – 87
Čunderlík J. – 242

D

Dachraoui M. – 389
Dagnac T. – 292
Dal Prà A. – 67
Davies J.W. – 256
De Boer J.A. – 377
De Boever J.L. – 190
Debruyne L. – 367
De Caesteker E. – 3, 139
De Campeneere S. – 190
De Cauwer B. – 139
De Haan M.H.A. – 181, 236, 377
De Haas M.J.G. – 392
Delaby L. – 90, 110, 113, 119, 151, 200, 286
Delagarde R. – 90, 166, 203
Delobel V. – 475
De Mol R.M. – 99, 134
Den Boer D.J. – 96, 392
Deru J. – 395, 398, 484
De Vliegher A. – 3, 139, 187, 190, 194, 206
De Wit J. – 197, 478, 484
D'Haene K. – 206
Dhamala N.R. – 209
D'Hose T. – 139, 194
Dillon P. – 349
Dineen M. – 259
Domhof B. – 434
Dos Passos Bernardes A. – 169
Duboc G. – 200
Dufrasne I. – 452
Dugátová Z. – 242
Dupon E. – 190
Duynisveld J. – 169
Dželetović Ž. – 481