Impacts of forage legumes on intake, digestion and methane emissions in ruminants

Cécile Martin, Giuseppe Copani, Vincent Niderkorn

LEGUME PERSPECTIVES

For animals, humans and environment

Legumes in ruminant feeding

The journal of the International Legume Society

Issue 12 • April 2016

IMPRESSUM

ISSN
2340-1559 (electronic issue)

Quarterly publication
January, April, July and October
(additional issues possible)

Published by
International Legume Society (ILS)

Co-published by
CSIC, Institute for Sustainable Agriculture, Córdoba, Spain
Instituto de Tecnologia Química e Biológica António Xavier
(Universidade Nova de Lisboa), Oeiras, Portugal
Institute of Field and Vegetable Crops, Novi Sad, Serbia

Office and subscriptions
CSIC, Institute for Sustainable Agriculture
International Legume Society
Apdo. 4084, 14080 Córdoba, Spain
Phone: +34957499215 • Fax: +34957499252
diego.rubiales@ias.csic.es

Front cover photo
A beef cow grazing alfalfa-grass pasture
by Emma McGeough

EDITORIAL

Thank you for visiting this issue of Legume Perspectives. *The over-riding objective has been to assemble a suite of papers that summarise the considered viewpoints of researchers who are active in diverse aspects of ruminant production systems where forage and/or grain legumes contribute meaningfully to the diet. These authors come from tropical, Mediterranean, temperate and boreal climates, and have active connectivity with farming and ranching practices in their countries. We thank them for their enthusiastic and generous commitment to providing papers for this issue, and hope that you find their contributions to be informative and thought-provoking.*

Pádraig O'Kiely and Emma McGeough
Managing Editors of Legume Perspectives *Issue 12*

CONTENTS

CARTE BLANCHE

RESEARCH

EVENTS

Carte blanche to…

…Pádraig O'Kiely[1] and

Emma McGeough[2]

Demonstrate legumes boosting farm profits!

An ever growing quantity of literature shows potential ecological, environmental, feed production and animal productivity benefits from leguminous crops, and generations of researchers have been convinced of and enthusiastic about including legumes in ruminant production systems. However, farmers and ranchers involved in ruminant production systems in many parts of the world have not been as positive in integrating locally-produced forage or grain legumes into their systems as might have been anticipated. This apparent disconnect is a major challenge - its causes need to be understood and effective remedies actioned if the disconnect is to be overcome.

There is a requirement for agricultural knowledge transfer activities to include the farm-scale demonstration of more profitable meat and milk production systems where forage and/or grain legumes make a long-term and meaningful contribution to the economic, environmental and social sustainability of the farm. Ultimately, the inclusion of legumes on farms operating ruminant production systems will primarily hinge on farmers being convinced of the economic merit of that strategy. Improved profits may derive from reducing the cost of or risks associated with providing feed for livestock, improving the nutritional, health or reproductive efficiency of the animals or the quality of their produce, or becoming eligible for financial or other incentives. It should not be underestimated, however, that in many cases farmers will require an enlarged agronomic and animal-based skill-set if they are to successfully increase the role of legumes in their livestock production systems.

[1]Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Ireland (padraig.okiely@teagasc.ie)
[2]University of Manitoba, Department of Animal Science, Winnipeg, Canada (emma.mcgeough@ad.umanitoba.ca)

Legume traits for selection to benefit ruminant production

by Garry WAGHORN[1]* and John CARADUS[2]

Abstract: Optimising legume traits for animal production depends on the feeding system, diet, physical environment, climate and animal productivity. Legumes are valuable because they form a symbiosis with rhizobia which fix atmospheric nitrogen (N) for the plant to use in growth. In many situations, especially in the tropics, insufficient dietary N can limit animal production. This is especially important in young or lactating individuals, and legumes are usually able to meet their requirements. However, some legumes produce compounds that can be toxic to ruminants and these must be reduced in breeding programmes. Legumes without toxins are nutritious and complement other components of ruminant diets, so selection should improve yield, persistence and ease of management. Future focus should be on substantive markets that support breeding investment.

Key words: breeding, legume, ruminant production, selection, trait

Introduction

The high proportion of protein and soluble (non-structural) carbohydrates in legume leaves enables digestion by ruminant and monogastric species alike. Unfortunately this foliage is also attractive to insects, fungi and is sought after by many animals. Wild type (unselected) legumes often synthesise secondary compounds that deter predation; isoflavones, condensed tannins, saponins, coumestans, cyanogenic glycosides, etc. Breeding has increased dry matter (DM) yields and reduced the concentration of anti-nutritional components, but vulnerability to predation is increased. Management of pure stands of legumes requires more specialist skills and investment than most grasses, and their contribution in mixed swards often declines after establishment, especially when N fertiliser is applied to boost grass growth.

Public concern about intensive agriculture, the routine use of herbicides and pesticides, and irrigation is justified, especially when the nitrogen applied to boost grass growth pollutes ground water and rivers. Legumes allay some of these concerns; they fix nitrogen naturally (although they contribute to N loss in urine) and those with deep root systems tolerate dry conditions better than shallow rooted species. The quality of well-managed legumes ensures high intakes of nutritious material and a high feeding value (= intake × quality). Benefits of legumes for nutrition will be most evident with young stock and lactating animals, because their requirements for crude protein are higher than for mature (non-lactating) ruminants. Unfortunately legume DM yields can be lower than many other forages (temperate and tropical grasses, grains and root crops), and this affects farmer choice for inclusion in pastures, and their ability to compete in mixed swards. Legumes such as lucerne (syn. alfalfa, *Medicago sativa* L.), are often grown as monocultures because their contribution to feed quality in mixed pastures can diminish as pastures age.

Future selection

Breeding objectives for ruminant feeding will depend on the region (temperate, tropical) and also feeding systems (grazing, harvest and conserved). Above ground traits of value include seed yield, resistance to pests and diseases, grazing tolerance, persistence and presence of appropriate condensed tannins and, especially, DM yield. Attention should also be given to growth below ground: deep roots, nodulation (particularly under soil stresses), resistance to root pests and diseases, and tolerance of low pH, high aluminium and manganese, high salinity and variations in soil moisture.

Tropical environments. Unlike temperate regions, there are few species of forage legumes that can withstand grazing and compete with companion grasses in tropical environments. This limits productivity, because C4 grasses in tropical regions have a low feeding value; they have insufficient crude protein for ruminants and their fibre is tough and slowly (and poorly) digested. Increased grass growth is dependent on nitrogen fertiliser applications in tropical regions, and skilled management is needed to maintain forage quality. Compatible legumes could provide very significant advantages in tropical regions and contribute an improved standard of living for farmers.

Should investment in forage legume improvement be directed toward tropical environments? Morally, a definite 'yes'; but gains in productivity of legumes have been substantially lower in tropical regions (4), especially under grazing (8). Development of truly competitive forages in tropical regions is dependent on investment (6) and requires evaluation under local farming conditions. Species from the genera *Aeschynomene* L., *Arachis* L., *Centrosema* (DC.) Benth., *Desmodium* Desv., *Macroptilium* (Benth.) Urb. and *Stylosanthes* Sw. can benefit tropical pasture systems and have undergone selection and evaluation. One unintended consequence of selection to lower condensed tannin concentration and increase digestibility (2) of the perennial herb sericea lespedeza (*Lespedeza cuneata* (Dum. Cours.) G. Don), was recognition of its anthelmintic properties (7). There is a renewed interest in sericea lespedeza for sheep and goat farmers in the southern United States, where parasite resistance to propriety anthelmintics is common.

[1]DairyNZ, Hamilton, New Zealand (garry.waghorn@dairynz.co.nz)
[2]Grasslanz Technology Ltd, Palmerston North, New Zealand

Temperate environments. The real successes with temperate forage legumes are lucerne, white clover (*Trifolium repens* L.; Fig. 1, first and second from above), subterranean clover (*T. subterraneum* L.), and to a lesser extent red clover (*T. pratense* L., 'cow grass'; Fig. 1, third from above), but there are other legumes that warrant attention because they have good growth potential and feeding value for ruminants. These include sainfoin (*Onobrychus viciifolia* Scop.), the lotuses (*Lotus corniculatus* L. and *L. pedunculatus* Cav.) which have received support from EU projects (HealthyHay, LegumePlus), but also sulla (*Hedysarum coronarium* L.; Fig. 1, fourth from above). If these forages had received the funding given to lucerne breeding, would they be as 'good'? In low fertility and dry environments any legume growth adds appreciable value for animal production. Therefore, the inclusion of annual legumes in dryland environments (e.g. Australia) provides a substantial advantage for ruminants, but the legumes need to have good seed production and hard seededness to maintain populations and increase opportunities for survival.

The nutritional attributes of legumes such as red clover, lucerne, sainfoin and sulla for ruminants are associated with the irrapidly digested leaf, together with a tougher stem. The leaf provides a rapid release of nutrients to the rumen, whereas chewing required to process the stem encourages salivation and pH buffering in the rumen. A healthy rumen pH (for the microflora and the host) provides an opportunity for readily fermentable carbohydrates (root crops or grains) to be fed with reduced risks of acidosis. Stem structure differs between forages, and warrants more investigation. Stems from sainfoin and lucerne tend to be brittle, perhaps facilitating breakdown and clearance from the rumen. In contrast, mature lotus stems are very tough and avoided by livestock (3). Chopped stems of sulla are eaten (1), but are avoided when mature.

Figure 1. Some temperate perennial forage legumes; from the top down: white clover, white clover, red clover, sulla

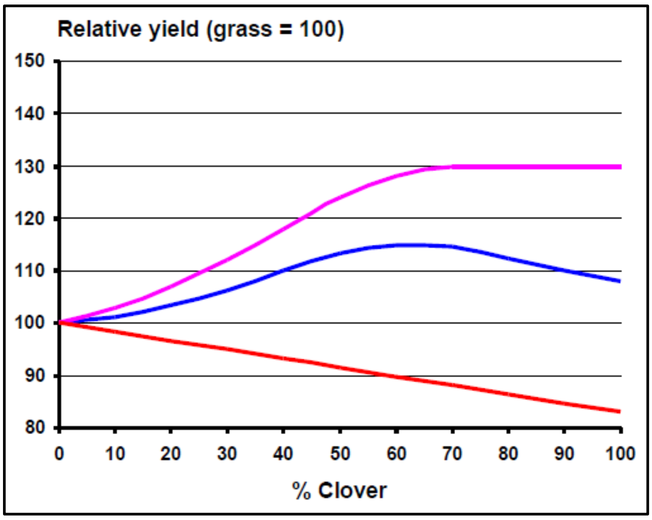

Figure 2. Effect of increasing percentages of white clover in ryegrass pasture on production (ha^{-1}) of dry matter (red line), milk (blue) and milk fat + protein (purple) (5)

Secondary compounds

Certain secondary compounds (e.g. condensed tannins) can benefit nutritive value by protecting plant protein from digestion in the rumen and increasing amino acid absorption from the intestine (9). Condensed tannins can provide real benefits for productive animals (young growing, or lactating) because more amino acids can be absorbed, but benefits only apply when dietary protein concentrations are not limiting production. The tannins divert more of the surplus dietary nitrogen from urine to faeces and this will lower nitrate leaching and emissions of nitrous oxide - a potent greenhouse gas. Perhaps the greatest benefits of some legumes with tannins are their anti-parasitic effects, especially when livestock have developed resistance to anthelmintics; efficacy is determined by the type of tannin, and legumes are ideal for delivering "nutritional anthelmintics". Unfortunately the most commonly used legumes in temperate pastures, white clover, red clover and lucerne, do not contain sufficient appropriate condensed tannins to provide added benefits.

Summary

Legumes are usually highly acceptable to ruminants, and animal production is often greater when legumes *vs.* grasses are fed. The problem for farmers is that most legumes are less productive than grasses when grown as a monoculture (Fig. 2), and in a sward grasses tend to dominate, especially in fertile environments. Both legumes and grasses require specialist management to achieve high levels of growth, and agriculture needs legumes now more than ever before because they can help protect our environment. Plant breeders need to make legumes more competitive and higher yielding so they will be included into pastures for grazing livestock, and replace urea fertiliser. The need may be greatest in tropical regions, but the challenges are also greater and opportunities may be fewer.

References

(1) Burke JL, Waghorn GC, Brookes IM (2002) An evaluation of sulla (*Hedysarum coronarium*) with pasture, white clover and lucerne for lambs. Proc N Z Soc Anim Prod 62:152-156

(2) Donnelly ED, Anthony WB (1970) Effects of genotype and tannin on dry matter digestibility in *Sericea lespedeza*. Crop Sci 10:200-202

(3) Douglas GB, Wang Y, Waghorn GC, Barry TN, Purchas RW, Foote AG, Wilson GF (1995) Liveweight gain and wool production of sheep grazing *Lotus corniculatus* and lucerne (*Medicago sativa*). N Z J Agric Res 38:95-104

(4) Graham PH, Vance CP (2003) Legumes: importance and constraints to greater use. Plant Physiol 131:872-877

(5) Harris SL, Clark DA, Auldist MJ, Waugh CD, Laboyrie PG (1997) Optimal white clover content for dairy pastures. Proc N Z Grassl Assoc 59:29-33

(6) Jank L, Valle CB, Resende RMS (2011) Breeding tropical forages. Crop Breed Biotechnol S1:27-34

(7) Mechineni A, Kommuru DS, Gujja S, Mosjidis JA, Miller JE, Burke JM, Ramsay A, Mueller-Harvey I, Kannan G, Lee JH, Kouakou B, Terrill TH (2014) Effect of fall-grazed sericea lespedeza (*Lespedeza cuneata*) on gastrointestinal nematode infections of growing goats.Vet Parasitol 204:221-228

(8) Valle CB (2002) Forage genetic resources for tropical areas. Proceedings, First Virtual Global Conference on Organic Beef Cattle Production, Embrapa, Brazil, 2 September - 15 October 2002, 1-14

(9) Waghorn GC (2008) Beneficial and detrimental effects of dietary condensed tannins for sustainable sheep and goat production - progress and challenges. Anim Feed Sci Technol 147:116-139

Legumes and grasses in mixtures complement each other ideally for sustainable forage production

by Andreas LÜSCHER[1]*, Matthias SUTER[1] and John A. FINN[2]

Abstract: Forage legumes offer great potential to cope with a major challenge for modern agriculture: to produce more food and feed with less resources. They are most effective in grass-legume mixtures. The resulting benefits are strongly linked to special features of the legumes, such as symbiotic N_2 fixation and plant secondary metabolites, but also to positive interactions between legumes and grasses within mixed swards, leading to enhanced resource utilization. The use of legumes in grassland livestock systems constitutes one of the pillars for sustainable and competitive ruminant production systems, and it can be expected that forage legumes will become more important in the future.
Key words: climate change, plant secondary metabolites, sustainable intensification, symbiotic N_2 fixation, yield

Figure 1. Detailed view of a grass-clover mixture (above); plots of the pan-European Agrodiversity experiment at the Swiss site (below): swards are (from the left to the right) *Trifolium pratense* (Tp), *Dactylis glomerata* (Dg), four-species mixture (Tp, Dg, Tr and *Lolium perenne*), and *Trifolium repens* (Tr)

Legume-grass mixtures: A key to increased forage yield

Agriculture is challenged by an increasing demand for food and feed combined with a decreasing availability of resources. The pan-European Agrodiversity experiment (Fig. 1), conducted across 31 sites in 17 countries, found that grass-legume mixtures containing four species (two legumes and two grasses) achieved a 77% yield advantage compared to the average of the four monocultures (Fig. 2; 1). Greatest yield benefits were observed in equilibrated grass-legume mixtures, but mixtures outperformed monocultures over a wide range of legume proportions (5, 8; Fig. 2). Yield advantages of grass-legume mixtures were surprisingly robust: they persisted over three experimental years and across the large climatic gradient covered by the experimental sites, spanning a latitudinal range from 40°44' N (Sardinia, Italy) to 69°40' N (Tromsø, Norway). Using species appropriate to the regional conditions across the climatic gradient of the experiment, the legume species examined were *Trifolium pratense* L. (red clover), *T. repens* L. (white clover), *Medicago sativa* L. (lucerne), *M. polymorpha* L. (burr medic), and *T. ambiguum* M. Bieb. (Caucasian clover). Grass-legume mixtures outperformed both grass and legume monocultures (1, 8). This proves that positive interactions were occurring in such mixtures which are extremely important for the performance of the mixed system. Because all swards at a specific site (all monocultures and mixtures) grew under the same conditions and thus had comparable access to growth resources (e.g. fertilizer input), an increased yield ultimately signifies an increased resource use efficiency. Grass-legume mixtures therefore help to address the prominent challenge of improving resource use efficiency in agricultural production.

[1]Agroscope, Institute for Sustainability Sciences, Zurich, Switzerland
(andreas.luescher@agroscope.admin.ch)
[2]Teagasc, Environment Research Centre, Johnstown Castle, Ireland

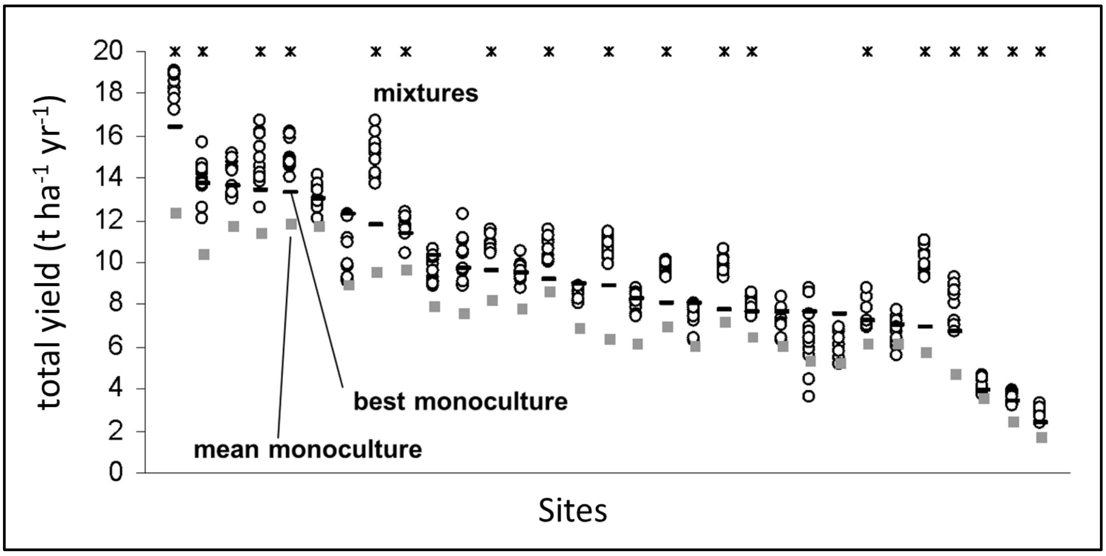

Figure 2. Four-species mixtures of two grasses and two legumes generally outperformed the best-performing monoculture, based on annual yield (dry matter) from experimental grassland field trials at each of 31 sites of the pan-European Agrodiversity experiment; open circles represent each of eleven mixture communities of widely varying legume proportions (from 20% to 80% of legumes in seed mixture); horizontal bars represent the yield of the best-performing monoculture; boxes represent the mean monoculture performance; sites where the yield of mixtures was significantly greater than that of the best monoculture are indicated by asterisks (1)

Special feature: Symbiotic N_2 fixation

Current agricultural production is highly N limited, while the provision of industrial N is largely based on fossil energy with its associated emission of greenhouse gases. Thus, substitution of industrial N-fertilizer with N derived from legumes' symbiotic N_2 fixation is an important contribution to more environmental-friendly and resource-efficient agricultural systems. In grassland, symbiotically fixed N_2 by legumes can range from 100 kg N ha^{-1} $year^{-1}$ to 380 kg N ha^{-1} $year^{-1}$ and, in addition, 10 kg N ha^{-1} $year^{-1}$ to 70 kg N ha^{-1} $year^{-1}$ can be transferred from the legume to the grass component of the mixed sward (9, 12). In the pan-European Agrodiversity experiment (Fig. 1), total nitrogen yield in the forage acquired by grass-legume mixtures was up to 70% higher than in grass monocultures (11). Interestingly, proportions of 30% to 60% of legumes in the sward were already sufficient to fully exploit the benefit of symbiotic N_2 fixation, i.e. to achieve the same amount of fixed N as in the legume monocultures (9, 11). Similarly high proportions of N derived from symbiosis in the legume plants were evident not only in sown swards but also across a large altitudinal gradient and a wide range of legume species in permanent grassland of the Swiss Alps (*Lotus corniculatus* L., *L. alpinus* Schleicher, *Vicia sativa* L., *Trifolium pratense* L., *T. repens* L., *T. nivale* Sieber, *T. thalii* Vil., *T. badium* Schreber, and *T. alpinum* L.; 4). Finally, positive interspecific interactions were demonstrated for the N nutrition of all individual plant species in mixed swards: the grass species profited from their legume partners by an increased N-nutrition and the legume species increased their proportion of N derived from symbiosis due to their grass partners (9).

Special feature: Plant secondary metabolites

Several forage legumes possess plant secondary metabolites that include tannins and polyphenol oxidase (7). In the rumen, condensed tannins protect proteins from degradation and, consequently, ruminants excrete less urinary N but more fecal N. This is important because the urinary N is quickly converted to ammonia and nitrous oxide, a potent greenhouse gas, which induces environmental problems.

Furthermore, condensed tannins in legumes offer opportunities to manage animal health. Tanniferous legumes such as sainfoin (*Onobrychis viciifolia* Scop.), birdsfoot trefoil (*Lotus corniculatus* L.), crownvetch (*Coronilla varia* L.) and cicer milkvetch (*Astragalus cicer* L.) can prevent bloat of animals (7). Condensed tannins of legumes have proven anthelmintic bioactivity in several experiments (2). This is of high relevance because widespread resistance against all three classes of broad-spectrum anthelmintic drugs is challenging conventional treatment worldwide.

And the future?

Today legumes are a pillar for sustainable livestock production systems and they are a key component for sustainable intensification, the main challenge of modern agriculture. There is no sign that this will change in the foreseeable future given the need for greater production while facing an increasing scarcity of resources. A further increased significance of legumes in the future has to be expected from important opportunities that legumes offer regarding climate change (adaptation and mitigation; reviewed in 6). They can contribute to lower greenhouse gas emissions (methane, nitrous oxide, carbon dioxide), can increase carbon stocks in the soil, have higher temperature requirements than grasses, better sustain moderate to severe drought stress (3), and profit disproportionally from elevated atmospheric CO_2 (10). In conclusion, it can be expected that forage legumes will become even more important in the future.

References

(1) Finn JA, Kirwan L, Connolly J, Sebastià MT, Helgadóttir Á, Baadshaug OH, Bélanger G, Black A, Brophy C, Collins RP, Čop J, Dalmannsdóttir S, Delgado I, Elgersma A, Fothergill M, Frankow-Lindberg BE, Ghesquire A, Golinska B, Golinski P, Grieu P, Gustavsson AM, Höglind M, Huguenin-Elie O, Jørgensen M, Kadžiulienė Ž, Kurki P, Llurba R, Lunnan T, Porqueddu C, Suter M, Thumm U, 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. J Appl Ecol 50:365-375

(2) Häring DA, Scharenberg A, Heckendorn F, Dohme F, Lüscher A, Maurer V, Suter D, Hertzberg H (2008) Tanniferous forage plants: agronomic performance, palatability and efficacy against parasitic nematodes in sheep. Renew Agric Food Syst 23:19-29

(3) Hofer D, Suter M, Hoekstra NJ, Haughey E, Eickhoff B, Finn JA, Buchmann N, Lüscher A (2014) Important differences in yield responses to simulated drought among four species and across three sites. Grassl Sci Eur 19:166-168

(4) Jacot KA, Lüscher A, Nösberger J, Hartwig UA (2000) Symbiotic N_2 fixation of various legume species along an altitudinal gradient in the Swiss Alps. Soil Biol Biochem 32:1043-1052

(5) Kirwan L, Luescher A, Sebastià MT, Finn JA, Collins RP, Porqueddu C, Helgadóttir Á, Baadshaug OH, Brophy C, Coran C, Dalmannsdóttir S, Delgado I, Elgersma A, Fothergill M, Frankow-Lindberg BE, Golinski P, Grieu P, Gustavsson AM, Höglind M, Huguenin-Elie O, Iliadis C, Jørgensen M, Kadžiulienė Ž, Karyotis T, Lunnan T, Malengier M, Maltoni S, Meyer V, Nyfeler D, Nykanen-Kurki P, Parente J, Smit HJ, Thumm U, Connolly J (2007) Evenness drives consistent diversity effects in intensive grassland systems across 28 European sites. J Ecol 95:530-539

(6) Lüscher A, Mueller-Harvey I, Soussana JF, Rees RM, Peyraud JL (2014) Potential of legume-based grassland-livestock systems in Europe: a review. Grass Forage Sci 69:206-228

(7) Mueller-Harvey I (2006) Unravelling the conundrum of tannins in animal nutrition and health. J Sci Food Agric 86:2010-2037

(8) Nyfeler D, Huguenin-Elie O, Suter M, Frossard E, Connolly J, Lüscher A (2009) Strong mixture effects among four species in fertilized agricultural grassland led to persistent and consistent transgressive overyielding. J Appl Ecol 46:683-691

(9) Nyfeler D, Huguenin-Elie O, Suter M, Frossard E, Lüscher A (2011) Grass-legume mixtures can yield more nitrogen than legume pure stands due to mutual stimulation of nitrogen uptake from symbiotic and non-symbiotic sources. Agric Ecosyst Environ 140:155-163

(10) Soussana JF, Lüscher A (2007) Temperate grasslands and global atmospheric change: a review. Grass Forage Sci 62:127-134

(11) Suter M, Connolly J, Finn JA, Loges R, Kirwan L, Sebastià MT, Lüscher A (2015) Nitrogen yield advantage from grass-legume mixtures is robust over a wide range of legume proportions and environmental conditions. Glob Change Biol 21:2424-2438

(12) Zanetti S, Hartwig UA, van Kessel C, Lüscher A, Hebeisen T, Frehner M, Fischer BU, Hendrey GR, Blum H, Nösberger J (1997) Does nitrogen nutrition restrict the CO_2 response of fertile grassland lacking legumes? Oecol 112:17-25

Estimating the nutritive value of forage and grain legumes - Requirements and considerations

by Karl-Heinz SÜDEKUM*, Katrin GERLACH and Christian BÖTTGER

Abstract: Forage and grain legumes have favorable nutritive value characteristics. Although protein is often classified as their primary nutrient, legumes provide significant amounts of energy to animals. Although legumes are sometimes difficult to ensile, appropriate wilting, rapid silo packing and sealing and, optionally, applying additives may provide high quality silage. Lucerne hay and silage are excellent sources of structural fibre. Moreover, the fibre of forage legumes contributes to ruminal buffering and rumen stability through high cation exchange capacity. Additionally, the high crude protein content of forage and grain legumes contributes to the overall buffering capacity of legumes in the rumen ecosystem.

Key words: energy, ensiling, legume, protein, rumen degradation

Table 1. Summary on nutritive value of selected temperate forage and grain legumes

Crop	Energy density	Protein value	Specific characteristics
		Forage legumes	
Lucerne	Moderate	Extensive rumen degradation	Excellent physical structure value for ruminants
Red clover	Good	Moderate rumen degradation	Polyphenol oxidase reduces rumen degradation
White clover	Excellent	Extensive rumen degradation	Enhances palatability of mixed swards when grazed
		Grain legumes	
Faba bean	Excellent	Variable rumen degradation and protein value	Varieties with coloured flowers contain tannins that can bind proteins and may affect intake
Field pea	Excellent	Moderate to extensive rumen degradation	Varieties with coloured flowers contain tannins that can bind proteins and may affect intake
Lupin	Excellent	Extensive rumen degradation	Protein value can be improved by thermal treatments

Nutritive value of forage and grain legumes

Forage and grain legumes can be successfully established and grown in contrasting environments. Their widespread utilization is often more hampered by inadequate agronomic performance (e.g., low yields of grain legumes compared with cereal grains and weak persistence of forage legumes in grass-legume mixtures) than by nutritive value characteristics which are generally favourable. Although protein is often considered as the primary nutrient of legumes, they do also deliver significant amounts of energy to animals and rumen microbes. Table 1 summarizes general characteristics of major temperate forage and grain legumes. It is obvious that all grain legumes are high-energy feeds with some limitations for non-ruminant animals, in particular poultry due to anti-nutritional factors which, in ruminants, are degraded by rumen microorganisms making the animal itself insensitive. The energy content can be estimated from the development of gas production *in vitro* under strictly standardized conditions, e.g. using a rumen fluid-buffer solution in which the test feeds are being incubated anaerobically. The results reported in Fig. 1 illustrate that grain and forage legumes compare well with ryegrass and silage maize, with some features distinctly different to C3 (ryegrass, *Lolium* spp.) and C4 (maize, *Zea mays* L.) grasses.

Pure grass and, likewise, legume forages provide an unfavourable ('asynchronous') N to energy ratio throughout the season, and the inefficient use by ruminants of N from those forages is largely attributed to the extensive ruminal degradation of crude protein (CP), resulting in excessive ammonia absorption through the ruminal wall and, after conversion of ammonia into urea in the liver, urinary excretion of urea. Attempts to improve efficiency of N use have focused on reducing the rate and extent of ruminal CP degradation. Red clover (*Trifolium pratense* L.) contains a soluble enzyme, namely polyphenol oxidase (PPO; 6) that, upon cell death, reacts with caffeic acid to yield *o*-quinones which then react with both proteases and substrate proteins rendering them inaccessible to microorganisms in the rumen (and in the silo). Broderick et al. (2)

University of Bonn, Institute of Animal Science, Bonn, Germany (ksue@itw.uni-bonn.de)

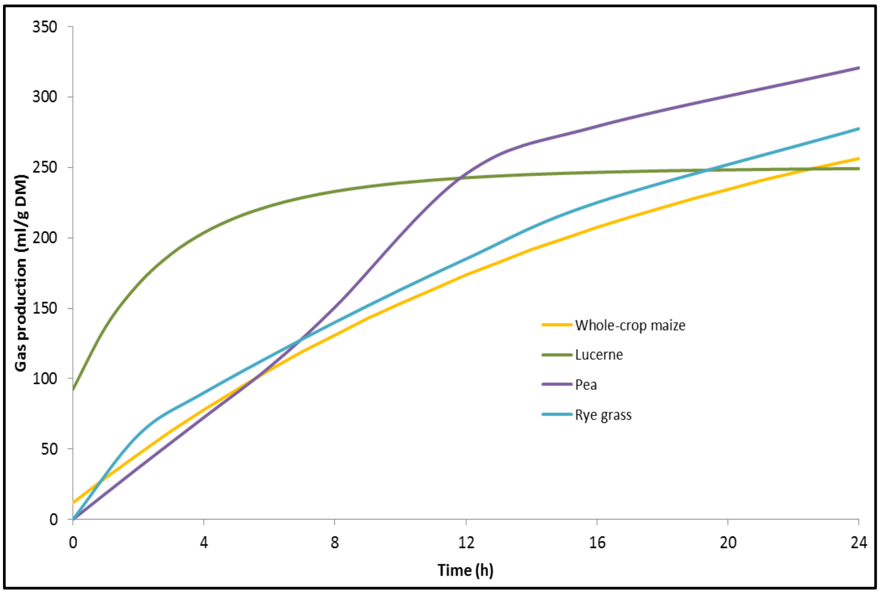

Figure 1. Exemplary evolution of gas over time when forage (lucerne) and grain (pea) legumes are incubated in an *in vitro* rumen system mimicking rumen microbial degradation; whole-crop maize at harvest and ryegrass are shown for the purpose of comparison

reported a wide range of ruminal CP degradation rates (from 0.088 h^{-1} to 0.146 h^{-1}) and rumen CP escape values (287 g kg^{-1} to 409 g kg^{-1}) among red clover entries. The assumed relationship, however, between PPO and the 'protein value' of red clover still needs to be confirmed. *Lotus* spp., particularly *L. pedunculatus* Cav. (big trefoil) and *L. corniculatus* L. (birdsfoot trefoil), contain elevated concentrations of condensed tannins (CT) that form stable complexes with proteins under ruminal conditions (pH = 6.0 - 7.0). Both proteases and substrate proteins may bind to CT. Once past the rumen, the lower pH in the abomasum (pH = 2.5 - 3.5) dissociates the CT-protein complexes, resulting in enhanced digestion and absorption of essential amino acids in the small intestine (1). Condensed tannins are restricted to *Lotus* spp. and few other legumes but are virtually absent from grasses and forage legumes such as *Trifolium* spp. (white clover, red clover) or *Medicago sativa* L. (lucerne). Both extent and rate of ruminal CP degradation can be estimated, again using strictly standardized methods, from enzymatic CP degradation or ammonia release *in vitro* using settings which are similar to the gas production methods mentioned above (3). As protein binding by tannins can result in slightly impaired post-ruminal CP digestibility, it is advisable to also estimate post-ruminal protein digestibility.

Ensilability and aerobic stability

The most important conservation methods for forage legumes are ensiling and air-drying. As they possess higher CP concentrations than most grasses and also relatively high concentrations of organic acids and cations, legumes have a high buffering capacity. In contrast, they often contain little water-soluble carbohydrates and therefore, limited substrate is available for fermentation by lactic acid bacteria. Both factors impede ensiling of forage legumes with fast pH decline and storage stability, classifying them as forages that are more difficult to ensile. The use of additives to improve the fermentation process is often recommended, also to prevent extensive CP degradation during ensiling. When legumes are wilted to an appropriate dry matter (DM) content, the silo is rapidly packed and sealed and optionally additives are being used, high quality silages can be produced. After silo opening, most legume silages have a moderate to good aerobic stability, where an increase in temperature acts as an indicator for spoilage. However, legume silages seem to react differently during oxygen exposure in comparison to grass and maize silages. The latter two are characterized by a rapid growth of yeasts and a simultaneous rise of temperature and microbial counts and a reduction in feed intake. Muck and O'Kiely (7) reported that aerobic stability of lucerne silages is difficult to predict with common models. This was recently confirmed by Gerlach et al. (4) who reported that eight days of aerobic exposure strongly influenced preference and short-time DM intake (DMI) of lucerne silages by goats (decrease of between 58% and 67%), although silage temperature, fermentation products and microbial variables changed only slightly. It was supposed that the factor responsible for the good aerobic stability of lucerne silages was unlikely one of the principal products of silage fermentation, therefore giving evidence for unidentified compounds occurring during the spoilage process that might also affect preference and DMI. Processes occurring under impact of oxygen need to be further studied, especially in legume silages; however, air contact has to be restricted as strictly as possible due to its enormous influence on DM intake.

Rumen buffering

To maintain rumen function, ruminants need adequate amounts of structural fibre which promotes rumination and saliva flow, thus buffering the acids produced during ruminal fermentation. Lucerne hay and silage are excellent sources of structural fibre. Besides this indirect, physical effect feedstuffs display traits that help buffering or neutralising acids in direct interaction with the rumen ecosystem. While being unfavourable for ensiling (see above), once the feedstuff is ingested these traits may help to stabilize the ruminal environment. The fibre of forage legumes contributes to ruminal buffering via its high cation exchange capacity, a reversible binding of H^+ ions to fibre (9). Additionally, the high CP content of forage as well as grain legumes is beneficial. Feedstuffs rich in protein display high resistance upon acid addition (5). Furthermore, H^+ ions are bound to ammonia released during fermentation of protein (9). One method to assess the intrinsic buffering properties of feedstuffs is recording pH changes during *in vitro* ruminal fermentation (8) which warrants further evaluation.

References

(1) Barry TN, McNabb WC (1999) The implications of condensed tannins on the nutritive value of temperate forages fed to ruminants. Br J Nutr 81:263-272

(2) Broderick GA, Albrecht KA, Owens VN, Smith RR (2004) Genetic variation in red clover for rumen protein degradability. Anim Feed Sci Technol 113: 157-167

(3) Edmunds B, Südekum K-H, Spiekers H, Schwarz FJ (2012) Estimating ruminal crude protein degradation of forages using i*n situ* and *in vitro* techniques. Anim Feed Sci Technol 175:95-105

(4) Gerlach K, Liao Y, Südekum K-H (2014) Aerobic exposure of lucerne silages and its impact on preference and dry matter intake by goats. Small Rumin Res 121:308-313

(5) Giger-Reverdin S, Duvaux-Ponter C, Sauvant D, Martin O, Nunes do Prado I, Müller R (2002) Intrinsic buffering capacity of feedstuffs. Anim Feed Sci Technol 96:83-102

(6) Jones BA, Hatfield RD, Muck RE (1995) Screening legume forages for soluble phenols, polyphenol oxidase and extract browning. J Sci Food Agric 67:109-112

(7) Muck RE, O'Kiely P (1992) Aerobic deterioration of lucerne (*Medicago sativa*) and maize (*Zea mays*) silages - effects of fermentation products. J Sci Food Agric 59:145-149

(8) Rustomo B, Cant JP, Fan MZ, Duffield TF, Odongo NE, McBride BW (2006) Acidogenic value of feeds. I. The relationship between the acidogenic value of feeds and *in vitro* ruminal pH changes. Can J Anim Sci 86:109-117

(9) Van Soest PJ, Robertson JB, Lewis BA (1991) Methods for dietary fiber, neutral detergent fiber, and nonstarch polysaccharides in relation to animal nutrition. J Dairy Sci 74:3583-3597

Meat and milk quality: Responses to forage legumes

by Aidan P. MOLONEY

Abstract: The diet of the animal can influence the appearance, shelf-life, nutritional and sensory characteristics of milk and meat. Substitution of grazed or ensiled ryegrass with legumes generally results in an increase in alpha-linolenic acid (18:3 n-3) in milk and meat. This can predispose milk and meat to an increase in lipid oxidation with a consequent decrease in shelf-life. There is some evidence that inclusion of legumes in the ration of cattle and sheep can alter the flavour characteristics in milk and meat. The variation in effect between studies seems to be related to the proportion of legumes in the diet and to odoriferous compounds stored in the depot fats.

Key words: fatty acids, legumes, sensory, shelf-life

The appearance, shelf-life, nutritional and sensory characteristics of milk and meat are of critical concern to consumers and to the agricultural industry. The diet of the animal can influence many of the above characteristics. The influence of forage feeding *per se* on the quality of milk and meat has been regularly reviewed (17). The focus of this paper is on the influence of substitution of forage legumes for non-legume forages in the rations of ruminants with a particular focus is on the fatty acid composition of milk and meat because of its relationship to other "quality" characteristics. There is emerging evidence that forage legumes may influence the concentrations of carotenoids, fat soluble vitamins and phytoestrogens in milk (18) but few data are available for meat.

Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Ireland
(aidan.moloney@teagasc.ie)

Fatty acid composition

In comparison with milk from cows fed grass silage, legume silages generally increase the proportion of the health-promoting n-3 fatty acid, alpha-linolenic acid (18:3 n-3). In a meta-analysis of eight published studies, Steinshamn (18) reported an average increase in milk 18:3 n-3 proportion from 0.53 to 0.91% due to feeding red clover silage compared to grass silage. They found no statistical difference between white clover (*Trifolium repens* L.) and red clover (*T. pratense* L.) silages. For grazing cows, Larsen et al. (8) found a higher 18:3 n-3 concentration in milk from cows that grazed pastures of perennial ryegrass (*Lolium perenne* L.) mixed with white clover, compared to milk from cows that grazed pastures of perennial ryegrass mixed with red clover or lucerne (*Medicago sativa* L.), which did not differ. Increasing the deposition of 18:3n-3 in milk (and meat) on legume-based rations is dependent on increasing the level of 18:3n-3 in the forage, increasing forage consumption and reducing the extent of ruminal biohydrogenation. Legumes containing tannins appear to produce milk that contains higher levels of 18:3 n-3 from sheep or cows grazing non-tanniniferous herbages. It appears that this effect is related to the reduced biohydrogenation of 18:3 n-3 in the rumen as a consequence of the action of tannins.

An increase in meat 18:3n-3 concentration is often seen when cattle or sheep graze a legume-rich pasture compared to a grass pasture (17). Replacing grass silage with a mixture of grass and red clover silage in the ration of steers or cull cows also increased the deposition of 18:3 n-3 n-3 in muscle (17). In contrast, Dierking et al. (6) observed no difference in the fatty acid composition of muscle from steers that grazed grass + red clover pasture or lucerne before slaughter. Similarly, Schmidt et al. (14) observed no difference in the fatty acid composition of muscle from steers that grazed Bermuda grass (*Cynodon dactylon* (L.) Pers.) or lucerne before slaughter. These differences are likely due to the proportion of the legume in the pasture and the duration of feeding prior to slaughter.

Shelf-life

Given the propensity of milk containing a higher concentration of polyunsaturated fatty acids to undergo increased oxidation, milk from cows fed on clover silage compared to grass silage had greater oxidative deterioration and thus a shorter shelf-life (1). This could be corrected by including additional anti-oxidants in the rations of the cows.

Meat that contains greater contents of polyunsaturated fatty acids is also more prone to lipid oxidation which can contribute to loss of redness and a decrease in shelf-life. For example, meat from red clover silage-fed animals had a lower concentration of vitamin E and a poorer colour, shelf life and increased lipid oxidation compared to grass silage-fed animals (9). This increase in lipid oxidation in meat from cattle that consumed legumes is often observed but is not always accompanied by a loss of colour stability. Differences in colour stability between studies appear to relate to the extent of lipid oxidation and the absolute difference in muscle vitamin E concentration. Turning cattle out to finish on grazed grass after a winter on red clover silage retained the increased red clover-derived n-3 polyunsaturated fatty acid concentration in the meat, but also built up the stocks of grass-derived vitamin E, resulting in meat with normal colour and lipid stability (16).

Sensory characteristics

Bertilison and Murphy (3) observed that the "taste of milk from diets containing clover, especially red clover (silage), deviated more frequently from what was expressed as "good quality milk" when compared to milk from grass silage. The findings from other studies on milk (and cheese) are summarised in Table 1. In addition, Martin et al. (10) in their review indicate that differences in the

Table 1. The effect of legume inclusion in the ration on the sensory characteristics of milk

Control	Legume	Effect of legume	Reference
Grazed grass	Lucerne	Less intense taste but similar acceptability	4
Maize silage	Lucerne silage	More yellow, "less creamy" flavour and less stale aroma	8
Grass silage	Red clover silage	More "boiled", whiter and thinner textured	12

Table 2. The effect of legume inclusion in the ration on the sensory characteristics of meat

Control	Legume	Effect of legume	Reference
		Beef	
Grass silage	Red clover silage	Less acidic, more greasy, more fishy	9
Grazed grass (*F. arundinacea*)	White clover	More greasy	7
Grass silage (*D. glomerata*)	Lucerne silage	Higher beef flavour	2
Grazed grass (*C. dactylon*)	Lucerne	More preferred	14
		Lamb	
Grazed grass	White clover / grass	Rancid, animal, strong odours	19
Grazed grass	Lucerne	Higher intensity of animal odour and flavour	5
Subterranean clover (*T. subterraneum*)	Gland clover (*T. glanduliferum*)	Less juicy, "slightly more pleasant"	11

sensory characteristics of cheese made from milk produced in the valleys or in the mountains of France are related in part to the presence of legumes in the pastures grazed by the cows.

There is little evidence that legume inclusion influences the tenderness of meat, in which case flavour and juiciness increase in relative importance to the consumer. The effects of legume inclusion in the ration on flavour characteristics of beef and lamb are equivocal but the effect of forage type on flavour appears to be more pronounced in lamb than in beef. Meat from sheep that consumed red clover or lucerne alone has been reported to give a more intense, unacceptable "sharp" and "sickly" flavour than meat from grass-fed sheep (15). Statistically significant effects are summarised in Table 2. However at least three studies on beef and five studies on lamb yielded no significant differences (13). Differences due to legume consumption have been attributed to the proportion of legumes in the diet and its consequent effect on the content of 18:3 n-3 in meat and its associated lower oxidative stability, and to odoriferous compounds stored in the depot fats.

References

(1) Al-Mabuk RM, Beck NFG, Dewhurst RJ (2004) Effects of silage species and supplemental vitamin E on the oxidative stability of milk. J Dairy Sci 87:406-412

(2) Berry BW, Leddy KF, Bond J, Rumsey TS, Hammond AC (1988) Effects of silage diets and electrical stimulation on the palatability, cooking and pH characteristics of beef loin steaks. J Anim Sci 66:892-900

(3) Bertilsson J, Murphy M (2003) Effects of feeding clover silages on feed intake, milk production and digestion in dairy cows. Grass Forage Sci 58:309-322

(4) Claps S, Sepe L, Caputo AR, Di Trana A, Paladino F, Di Napoli MA, Pizzillo M, Fedel V (2009) Influence of four single fresh forages on volatile organic compound (VOC) content and profile and sensory properties of goat Caciotta cheese. Ital J Anim Sci 8:390-393

(5) Devincenzi T, Prunier A, Meteau K, Nabinger C, Prache S (2014) Influence of fresh alfalfa supplementation on fat skatole and indole concentration and chop odour and flavour in lambs gazing a cocksfoot pasture. Meat Sci 98:607-614

(6) Dierking RM, Kallenbach RL, Grun IU (2010) Effect of forage species on fatty acid content and performance of pasture-finished steers. Meat Sci 85:597-605

(7) Larick DK, Hedrick HB, Bailey ME, Williams JE, Hancock DL, Garner GB, Marrow RE (1987) Flavor constituents of beef as influenced by forage- and grain-feeding. J. Food Sci 52:245-251

(8) Larsen MK, Kidmose U, Kristensen T, Beaumont P, Mortensen G (2013) Chemical composition and sensory quality of bovine milk as affected by type of forage and proportion of concentrate in the feed ration. J Sci Food Agric 93 93-99

(9) Lee MR, Evans PR, Nute GR, Richardson RI, Scollan ND (2009) A comparison between red clover silage and grass silage feeding on fatty acid composition, meat stability and sensory quality of the M. longissimus muscle of dairy cows. Meat Sci 81:738-744

(10) Martin B, Verdier-Metz I, Buchin S, Hurtaud C, Coulon JB (2005) How do the nature of forages and pasture diversity influence the sensory quality of dairy livestock products? Anim Sci 81:205-212

(11) Masters DG, Mata G, Revell CK, Davidson RH, Norman HC, Nutt BJ, Solah V (2006) Effects of Prima gland clover (*Trifolium glanduliferum* Boiss cv. Primas) consumption on sheep production and meat quality. Anim Prod Sci 46:291-297

(12) Moorby JM, Lee MRF, Davies DR, Kim EJ, Nute GR, Ellis NM, Scollan ND (2009) Assessment of dietary ratios of red clover and grass silages on milk production and milk quality in dairy cows. J Dairy Sci 92:1148-1160

(13) Phelan P, Moloney AP, McGeough EJ, Humphreys J, Bertilsson J, O'Riordan EG, O'Kiely P (2015) Forage legumes for grazing and conserving in ruminant production systems. Crit Rev Plant Sci 34:281-326

(14) Schmidt JR, Miller MC, Andrae JG, Ellis SE, Duckett SK (2013) Effect of summer forage species grazed during finishing on animal performance, carcass quality, and meat quality. J Anim Sci 91:4451-4461

(15) Schreurs NM, Lane GA, Tavendale MH, Barry TN, McNabb WC (2008) Pastoral flavour in meat products from ruminants fed fresh forages and its amelioration by forage condensed tannins. Anim Feed Sci Technol 146:193-221

(16) Scollan ND, Gibson K, Ball R, Richardson RI (2008) Meat quality of Charolais steers: influence of feeding grass versus red clover silage during winter followed by finishing off grass. Proc Br Soc Anim Sci 9:52-53

(17) Scollan ND, Dannenberger D, Nuernberg K, Richardson I, MacKintosh S, Hocquette JF, Moloney AP (2014) Enhancing the nutritional and health value of beef lipids and their relationship with meat quality. Meat Sci 97:384-394

(18) Steinshamn H (2010) Effect of forage legumes on feed intake, milk production and milk quality - a review. Anim Sci Pap Rep 28:195-206

(19) Young OA, Berdagué JL, Viallon C, Rousset-Akrim S, Theriez M (1997) Fat-borne volatiles and sheep meat odour. Meat Sci 45:183-200

Intake and performance with temperate forage legume-based ruminant production systems

by Aila VANHATALO* and Seija JAAKKOLA

Abstract: Forage legume-based ruminant production systems founded on biological N_2 fixation have great potential to challenge grass-only systems or to complement maize-based systems heavily reliant on inorganic N fertilizers. In temperate areas, the most important forage legumes are lucerne and red clover predominantly used as conserved forage for large ruminants, and white clover primarily used for grazing ruminants. Using forage legumes either as a pure or grass-legume mixture pastures or ensiled forages in comparison to grass, typically increases dry matter intake and performance of ruminant production animals. The extent of the positive production responses in favour of legumes largely depends on factors such as plant species used, grazing management, growth stage of the plant at harvest and success of ensiling techniques used in forage production.

Key words: dry matter intake, grass, grazing, legume, milk production

Forage legumes are often considered as an economically profitable alternative to grass and/or maize (*Zea mays* L.) based forages owing to their ability to provide biologically fixed nitrogen. Using forage legumes as feeds for high producing ruminant animals serves as an effective means to reduce dependence on synthetic N fertilizers and thus fossil energy. Other benefits of forage legumes include among others lower emissions to the environment in terms of reduced N losses and greenhouse gas emissions (9). However, the most attractive attribute of the diverse and widespread forage legumes as ruminant feed is their ability to support high dry matter (DM) intakes even with high-producing dairy cows fed high-forage diets (2, 6, 10). This is of major importance because feed intake is the most important factor determining animal performance. In temperate areas, the economically most important forage legumes used for conservation are lucerne (*Medicago sativa* L.) in warmer areas such as North America and red clover (*Trifolium pratense* L.) in cooler areas such as Northern Europe while white clover (*T. repens* L.) is predominantly used for grazing. Forage legumes are more often grown in mixtures with grasses or other plants than as pure stands, as mixtures give higher annual herbage yields than monocultures (9). This paper focuses on intake and animal performance properties of forage legumes and forage legume-grass mixtures, with particular emphasis being on conserved forages and high-producing large ruminants.

Composition and ensilability of forage legumes

Generally, forage legumes are lower in neutral detergent fibre (NDF) and sugar, and higher in crude protein, minerals, ash and indigestible fibre than grasses and maize. Though, there are differences in composition between legumes such that lucerne is higher in crude protein and white clover is lower in fibre than other legumes. The low sugar content together with high content of crude protein and other constituents contributing to high buffering capacity of forage legumes makes them more difficult to ensile than grass species or maize. With good ensiling technique, including wilting and use of additive, a high fermentation quality of legume silage can be achieved. Choice of forage maturity at harvest has a major effect on the nutritive value and ensilability of all forages regardless of plant species used, with advancing maturity increasing fibre and decreasing crude protein contents of the forage. However, the decline in rate of digestibility due to advancing maturity is slower with legumes than grasses (6) extending the time span for harvesting especially in the first cut when these plant species are grown in mixtures.

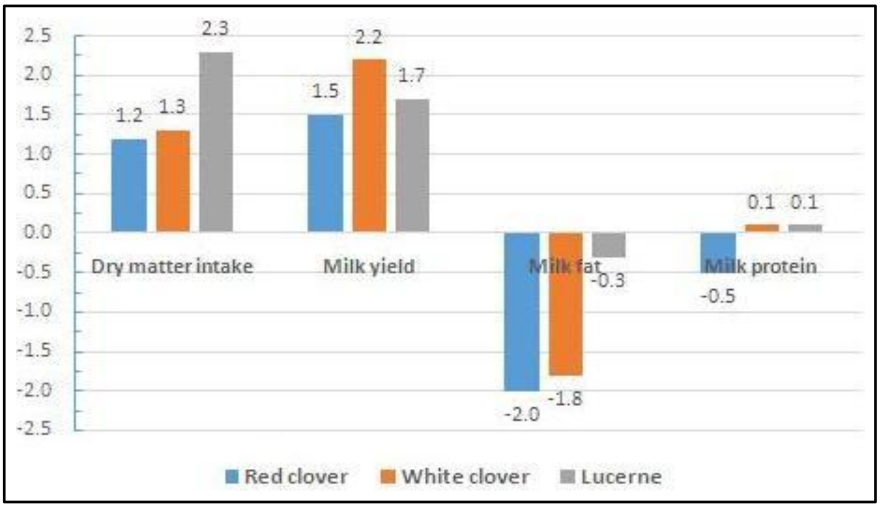

Figure 1. Average production responses of forage legume silage based diets (red clover, white clover and lucerne) in terms of dry matter intake (kg d^{-1}), milk yield (kg d^{-1}), and milk fat and protein contents (g kg^{-1}) in comparison to grass silage based diets (10)

University of Helsinki, Department of Agricultural Sciences, Helsinki, Finland
(aila.vanhatalo@helsinki.fi)

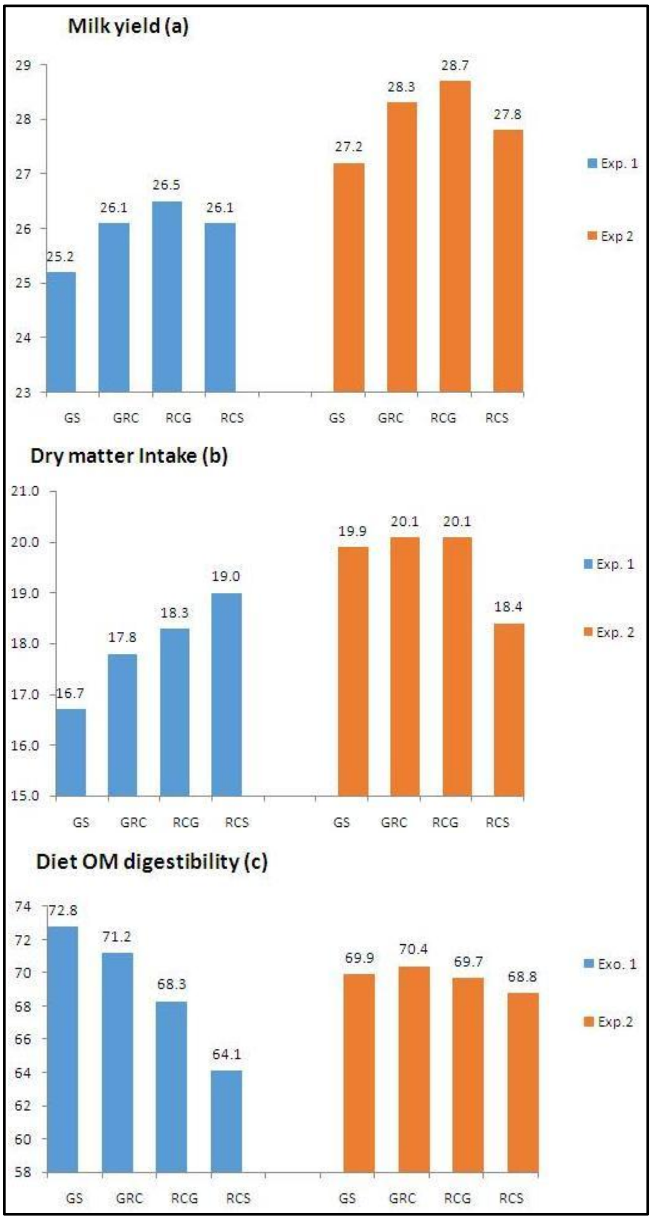

Figure 2. Effect of altering the forage ratio of grass and red clover silages on milk yield (a, kg d^{-1}), dry matter intake (b, kg d^{-1}) and diet organic matter (OM) digestibility (c, %) in experiments 1 and 2, respectively (8, 3); GS = grass silage, RCS = red clover silage, and GRC and RCG = 2:1 and 1:2 mixtures of GS and RCS, respectively

Intake and production potential of forage legume diets

Results from a recent literature review (10) comparing forage legume and grass silage based diets (Fig. 1) demonstrate the superior DM intake (DMI) and production potential of forage legumes over grasses. On average, forage legume silage diets increased both DMI and milk yield of cows by 1.6 kg d^{-1} in comparison to grass silage diets. However, the concomitant decreases in milk fat and protein contents of 1.2 g kg^{-1} and 0.4 g kg^{-1}, respectively, reduced the benefit to some extent. Even so, the net benefits from higher legume diet DMI remain positive. In another review (6), red clover silage diets (proportion of red clover in the forage varying in range of 0.3-1.0) produced on average 0.4 kg d^{-1} - 1.3 kg d^{-1} higher DMI and 0.8 kg d^{-1} more energy corrected milk compared with grass silage diets. The generally higher intake characteristics of legume than grass silages despite lower digestibility have been attributed to their lower fibre content, more rapid fermentation and particle breakdown in the rumen, and higher rate of passage from the rumen (2, 6, 7). Among the legume silages, lucerne increased DMI much more than other legumes while the highest milk yield was achieved with white clover (Fig 1.) owing to its inherently low fibre content and high organic matter digestibility (2, 10). Lucerne and red clover silages were equal in milk yields despite higher lucerne DMI. This was attributed to lower digestibility and net energy content of lucerne as compared to red clover (10).

As found with conserved forages fed to dairy cows feeding lucerne or red clover silages to beef cattle and small ruminants such as lambs has generally increased or maintained their DMI and live weight gain in comparison to ryegrass silage fed animals (5). Also, white clover-based pastures have great potential to support high DMI and production performance of all grazing ruminant production animals (9). However, full production potential of forage legume pasture, be it grown as monoculture or grass-legume mixture, is rarely realized because production of livestock per ha and per animal is very much subject to the grazing management and the balance between forage production and stocking rate in particular (9). For this reason livestock production per hectare from grass-legume swards has generally been found to be approximately only 0.7-0.8 of that obtained from grass monocultures receiving high inputs of fertilizer N (9).

Positive interactions from mixed legume forages

Feeding mixed legume-grass or legume-maize forages in dairy cow rations may induce positive associative effects on dairy cow performance i.e. the DMI and/or milk yields may be higher with the mixture forage feeding than with either of the forages fed alone. Inclusion of maize silage in lucerne-based diets was strongly recommended because of the positive interactions of these forages on DMI, milk yield and N utilization (1). Positive interactions of legume-grass mixtures are illustrated with research results (3, 8) presented in Fig. 2. In these studies, red clover silage replaced high-digestible grass silage made either of ryegrass (*Lolium* *perenne* L.) (8) or timothy grass (*Phleum pratense* L.) - meadow fescue (*Festuca pratensis* Huds.) (3) in the ratio of 0:100, 33:67, 67:33 and 100:0 on a DM basis. In both studies, the highest milk yield was achieved with 2:1 mixture of red clover and grass silage (Fig. 2a). The beneficial combination seemed to be attributed either to high DMI of low-digestible red clover silage (Fig.2b, NDF = 461 g kg^{-1} DM) in the first study or to high-digestible red clover silage (Fig. 2c, NDF = 339 g kg^{-1} DM) used in the second study. It may be understandable that the low-digestible red clover silage fed as sole forage led to compromised milk yield despite the high DMI. However, why was the DMI of cows fed high-digestible red clover silage as sole forage clearly limited in the second study? This phenomenon was shown earlier in a study, where DMI of early cut red clover silage despite higher digestibility was clearly lower than that of late cut red clover silage (7). The low DMI was probably attributable to metabolic factors regulating DMI because physical constrains in terms of measured rumen pool sizes of DM and NDF did not explain the results obtained (7). It seems that intake characteristics of forage legumes are not yet fully understood. This was also reflected in developing relative silage DMI index such that the intake of mixed silages could be predicted with reasonable accuracy only when the proportion of legume or whole-crop silage was less than 0.50 of silage DM (4).

Forage legumes an integral part of future ruminant production systems

Animal production studies conducted for comparing legume forages or legume-grass mixtures with grass-only or maize-based forages vary a lot in terms of the assortment of forage legume and grass species used, arising from their suitability to the farming conditions in question. In addition, variation in maturity of the plants during harvest and number of cuts as well as forage preservation method used cause confounding variation in results between the experiments. Therefore, it is most challenging to draw definitive conclusions on the superiority of using forage legumes in all possible ruminant production systems. The effects of feeding forage legumes in mixtures with other forages such as grasses on forage DMI clearly warrants further research for optimizing harvesting and use of forage legumes in the diets of ruminants. This is of importance because forage legumes are primarily cultivated and harvested in mixtures with other forages owing to the higher herbage production potential of such mixtures in comparison to monocultures (9). With increasing pressure to reduce use of inorganic N fertilizers the utilization of forage legumes will be an integral part of the future ruminant production systems.

References

(1) Brito AF, Broderick GA (2006) Effect of varying dietary ratios of alfalfa silage to corn silage on production and nitrogen utilization in lactating dairy cows. J Dairy Sci 89:3924-3938

(2) Dewhurst RJ (2013) Milk production from silage: comparison of grass, legume and maize silages and their mixtures. Agric Food Sci 22:57-69

(3) Halmemies-Beauchet-Filleau A, Vanhatalo A, Toivonen V, Heikkilä T, Lee MRF, Shingfield KJ (2014) Effect of replacing grass silage with red clover silage on nutrient digestion, nitrogen metabolism, and milk fatty acid composition in lactating cows fed diets containing a 60:40 forage-to-concentrate ratio. J Dairy Sci 97:3761-3776

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

(5) Keady TWJ, Hanrahan JP, Marley CL, Scollan ND (2013) Production and utilization of ensiled forages by beef cattle, dairy cows, pregnant ewes and finishing lambs: a review. Agric Food Sci 22:70-92

(6) 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 Sci 11:1-49

(7) Kuoppala K, AhvenjärviS, Rinne M, Vanhatalo A (2009) Effects of feeding grass or red clover silage cut at two maturity stages in dairy cows. 2. Dry matter intake and cell wall digestion kinetics. J Dairy Sci 92:5634-5644

(8) Moorby JM, Lee MRF, Davies DR, Kim EJ, Nute GR, Ellis NM, Scollan ND (2009) Assessment of dietary ratios of red clover and grass silages on milk production and milk quality in dairy cows. J Dairy Sci 92:1148-1160

(9) Phelan P, Moloney AP, McGeough EJ, Humphreys J, Bertilsson J, O'Riordan EG, O'Kiely P (2015) Forage legumes for grazing and conserving in ruminant production systems. Crit Rev Plant Sci 34:281-326

(10) Steinshamn H (2010) Effect of forage legumes on feed intake, milk production and milk quality - a review. Anim Sci Pap Rep 28:195-206

Ensiling temperate forage and grain legumes for ruminant feeds

by Pádraig O'KIELY

Abstract: Forage and grain legumes are important contributors to ruminant diets and their integration into ruminant production systems sometimes requires that they are conserved by ensilage. Successful ensilage necessitates rapidly storing the legume under air-free acidic conditions. The latter normally results from a rapid and sufficiently extensive lactic acid dominant fermentation and, for forage legumes, this can be difficult to achieve due to their relatively low fermentable substrate content and high buffering capacity. However, forage legume silages are generally more stable during the aerobic conditions at feedout than are graminoid silages. Grain legumes, particularly pulses, are relatively straightforward to preserve by ensilage provided they are processed (e.g. rolled) at ensiling and that air-free conditions are achieved and maintained.

Key words: forage legume, grain legume, losses, ruminant, silage

Introduction

Temperate forage and grain legumes can be conserved dry (hay, dry grain) or moist (silage, haylage; high moisture grain) to facilitate their efficient storage and subsequent feeding to livestock over an extended duration. In all cases the primary objective is to limit quantitative and qualitative losses so as to 'save' as much feedstuff and feed value as feasible. These losses can occur during the harvesting process in the field or, for ensiled feeds, during subsequent storage in or feedout from the silo (including baled silage).The conservation process can, in some cases, reduce challenges posed by anti-nutritional secondary metabolites in the feedstuff.

Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Ireland (padraig.okiely@teagasc.ie)

The major forage legumes conserved by ensilage include lucerne (*Medicago sativa* L.), red clover (*Trifolium pratense* L.) and birdsfoot trefoil (*Lotus corniculatus* L.), with lesser quantities of vetch (*Vicia* spp.), forage pea (*Pisum sativum* L.), sainfoin (*Onobrychis viciifolia* Scop.), sulla (*Hedysarum coronarium* L.), galega (*Galega orientalis* Lam.) and white clover (*Trifolium repens* L.). Their relatively low concentration of water-soluble carbohydrates and high buffering capacity can make many of these forages difficult to successfully preserve as silage unless they are field wilted or treated with an effective preservative at ensiling (1, 8).

Important grain legumes included in ruminant diets are soybean (*Glycine max* (L.)Merr.), field pea, lupin (*Lupinus* spp.) and faba bean (*Vicia faba* L.), as well as chickpea (*Cicer arietinum* L.), mung bean (*Vigna radiata* L.), peanut (*Arachis hypogaea* L.) and lentil (*Lens culinaris* Medik.). Whereas these are most commonly stored at sufficiently low moisture contents to prevent plant enzyme or fungal activity there can be circumstances where their moist anaerobic storage can have logistical or economic attractions.

Field losses

Field losses can be a concern with forage legumes. The main sources of loss are due to continued plant or microbial respiration (a particular problem if attempting to wilt under poor drying conditions), leaching of plant nutrients during rainfall (more severe if the plant was already partially wilted), leaf shatter when extensively wilted herbage is mechanically tedded or windrowed, and incomplete pick-up of the crop at harvesting. In addition, contamination of the mown crop with soil needs to be avoided as this could predispose the affected herbage to undergo an undesirable clostridial fermentation in the silo.

Silo losses

The main storage losses are associated with fermentation, effluent outflow and respiration.

A rapid, lactic acid dominant silage fermentation will greatly restrict forage legume protein breakdown and contribute to a minimal decline in its nutritive value during ensilage. In addition to requiring anaerobic conditions, a successful fermentation also requires the presence of sufficient water-soluble carbohydrates (WSC) and efficient lactic acid bacteria to produce enough lactic acid to reduce the pH of the ensiled legume from approximately 6.0 to 3.8-4.5 (the exact value depending on the crop dry matter (DM) concentration achieved by wilting). Forage species differ in their buffering capacity and, since this alters the amount of lactic acid required to bring about the required reduction in pH, it therefore alters the amount of WSC needed. The silage fermentation challenge posed by many forage legumes compared to grass was shown by Halling et al. (2) who reported lucerne, red clover, birdsfoot trefoil, galega and white clover to have relatively low WSC concentrations of between 65 g kg^{-1} DM and 92 g kg^{-1} DM and high buffering capacities of between 610 g lactic acid kg^{-1} DM and 710 g lactic acid kg^{-1} DM. Under comparable circumstance grass that received 0 kg N ha^{-1} or 200 kg N ha^{-1} had higher WSC (124 g kg^{-1} DM and 112 g kg^{-1} DM) and lower buffering capacity (430 g kg^{-1} DM and 520 g kg^{-1} DM) values. These differences would be expected to result in it being more difficult to achieve a lactic acid dominant fermentation with the forage legumes compared to the grasses. However, some legumes can undergo a better fermentation than would be predicted from ensilability indices, and this is shown in Table 1 where despite red clover having poorer ensilability characteristics than timothy grass (*Phleum pratense* L.) it still showed much less evidence of clostridial

Table 1. Herbage ensilability and silage preservation characteristics (adapted from 3 and 5)

	Perennial ryegrass	Timothy	Red clover
	Pre-ensilage		
DM (g kg^{-1})	232	234	169
WSC (g kg^{-1} DM)	184	115	86
Buffering capacity (mEq kg^{-1} DM)	395	398	620
	Post-ensilage		
pH	3.88	4.56	4.52
Lactic acid (g kg^{-1} FP)	730	449	557
Butyric acid (g kg^{-1} DM)	3	10	3
Ammonia-N (g kg^{-1} N)	76	130	81

DM - dry matter; WSC - Water-soluble carbohydrate; FP - Fermentation products

Table 2. Conservation characteristics of ensiled high-moisture blue-flowering lupin grains

	Intact grain	Rolled grain
DM (g kg^{-1})	598	587
DM digestibility (g kg^{-1})	923	932
Crude protein (g kg^{-1} DM)	352	351
pH	5.1	4.3
Lactic acid (g kg^{-1} DM)	20	57
Lactic acid (g kg^{-1} FP)	636	774
Ammonia-N (g kg^{-1} N)	16	28
In-silo DM loss (g kg^{-1})	35	51
Aerobic stability (days)	2.0	8.3
Aerobic deterioration (°C)	36	4

DM - dry matter; FP - Fermentation products

activity during the ensilage process as indicated by lower butyric acid and ammonia-N values. Proteolysis rates during ensilage can differ among legume species, with the lower rates associated with sulla and sainfoin compared to lucerne, for example, being associated with their higher content of condensed tannins (1) and with polyphenol oxidase in red clover also being associated with reduced proteolysis (4). Preservation is aided in legumes by their lower water activity than grasses at the same dry matter content.

The volume of effluent produced by an ensiled legume depends mainly on the wetness of the crop harvested, and in the case of the red clover in Table 1 it produced 207 litres effluent t^{-1} herbage ensiled. Wilting such crops to 250 g kg^{-1} DM -350 g kg^{-1} DM (the extent of wilting required depends on silage storage height) will usually eliminate effluent production and thus avoid the associated losses.

Respiration losses can occur during silo filling until the ensiled legume is sealed from air and during storage if air ingresses past the plastic film. However, the primary cause of respiration losses in horizontal silos usually occurs during feedout when the silage feed face can be exposed to air for several days and DM losses in excess of 100 g kg^{-1} sometimes occur. This latter process is usually initiated by yeast and continued by bacteria and, in particular, mould in the silage. Besides reducing the nutritive value and palatability of silage, extensive aerobic deterioration can also expose livestock to mould spores and mycotoxins. Silages differ in their susceptibility to aerobic deterioration during feedout and, in general, silages produced from forage legumes tend to be more aerobically stable than silages made from grass and these, in turn, tend to be more stable than silages made from small, e.g. wheat (*Triticum aestivum* L.), barley (*Hordeum vulgare* L.), or large, e.g. maize (*Zea mays* L.), grain whole-crop cereals.

Grain legumes such as peas, beans and lupins (i.e. pulses) can be successfully ensiled, and the same principles that govern the successful ensilage of forage legumes apply to the ensilage of pulse grains. They would normally be rolled or crushed at ensiling as this stimulates fermentation, facilitates removal of air spaces during consolidation in the silo, and obviates the requirement for further processing during feedout. A study with moist faba bean grains of 751 g DM kg^{-1} showed them to possess good ensilability characteristics, having a relatively high concentration of WSC (130 g DM kg^{-1}) and low buffering capacity (209 mEq kg^{-1} DM). When rolled at ensiling, they resulted in an ensiled product of similar digestibility to the pre-ensiled grains. The fermentation was quite restricted and little breakdown of protein occurred. In-silo losses of DM were 38 g kg^{-1} and the ensiled beans were relatively stable when exposed to air during feedout (6). A similar outcome occurred when lupin grains of 612 g DM kg^{-1}, 173 g WSC kg^{-1} DM and a buffering capacity of 257 mEq kg^{-1} DM were ensiled. As shown in Table 2, rolling these grains at ensiling resulted in a more extensive fermentation, and the small increase in in-silo losses due to rolling were compensated by a major reduction in aerobic deterioration during feedout (7).

References

(1) Cavallarin L, Tabacco E, Borreani G (2007) Forage and grain legume silages as a valuable source of proteins for dairy cows. Ital J Anim Sci, 6S:282-284

(2) Halling MA, Hopkins A, Nissinen O, Paul C, Tuori M, Soelter U (2002) Forage legumes - productivity and composition. LandbauforschVoelkenrode Sonderh 234:5-15

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

(4) Lee MRF, Scott MB, Tweed JKS, Minchin FR, Davies DR (2008) Effects of polyphenol oxidase on lipolysis and proteolysis of red clover silage with and without a silage inoculant (*Lacobacillus plantarum* L54). Anim Feed Sci Technol 144:125-136

(5) McEniry J, King C, O'Kiely P (2013) Silage fermentation characteristics of three common grassland species in response to advancing stage of maturity and additive application. Grass Forage Sci 69:393-404

(6) O'Kiely P, Stacey P, Hackett R. (2014) Conserving high moisture spring field bean (*Vicia faba* L.) grains. Grassl Sci Eur 19:583-586

(7) O'Kiely P, Stacey P, Hackett R (2014) Conserving high moisture lupin grains. Proceedings, Agricultural Research Forum, Tullamore, Ireland, 10-11 March 2014, 109

(8) Pahlow G, Rammer C, Slottner D, Tuori M (2002) Ensiling of legumes. LandbauforschVoelkenrode Sonderh 234:27-31

Animal health - potential and strategies to reduce bloat with forage legumes

by Surya N. ACHARYA[1]*, Edmund T. SOTTIE[2], Yuxi WANG[1] and Tim A. McALLISTER[1]

Abstract: Alfalfa is well-known for maximizing beef production on pastures, but its propensity to cause bloat discourages its inclusion at high levels in pastures. Sainfoin is bloat-safe as it contains condensed tannins (CT) which prevent bloat, improve N utilization and control parasites. Agriculture and Agri-Food Canada has undertaken a program to develop new lines of sainfoin with high yield and persistence in mixed pastures with alfalfa. New populations persisted for 3-4 years, with yields comparable to alfalfa, supporting gains in beef cattle of > 1.0 kg day^{-1} with a 95% reduction in pasture bloat.

Key words: alfalfa, bloat, cattle, lucerne, sainfoin

In North America, beef production has been enhanced through the widespread use of alfalfa (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.).Other important forage legumes include alsike clover (*Trifolium hybridum* L.), kura clover (*Trifolium ambiguum* Bieb.), sweet clover (*Melilotus officinalis* L.),white clover (*Trifolium repens* L.), birdsfoot trefoil (*Lotus corniculatus* L.), cicer milkvetch (*Astragalus cicer* L.) and sainfoin (*Onobrychis viciifolia* Scop.).

The inherent agronomic characteristics and superior feed value of alfalfa make it the 'Queen of forages' in western Canada. Alfalfa has been bred since the turn of the 20th century for improved productivity, quality and adaptation to the agronomic conditions in North America (5).However, alfalfa's propensity to cause bloat discourages livestock producers from including it in pastures. Furthermore, the full value of alfalfa's protein is often unrealized due to extensive proteolysis in the rumen and during ensiling (9). Legumes that contain condensed tannins do not cause bloat and exhibit superior protein utilization in ruminants and mitigating bloat through genetic improvement of these CT containing species could be the solution for bloat-safe, high performance legume grazing systems.

Among CT containing legumes, sainfoin is perhaps the most suited for such a goal, owing to its bloat-safe nature, high nutritive value, winter hardiness, drought tolerance and resistance to pests of alfalfa (6). It is comparable to alfalfa in forage quality and results in average daily gains in ruminants that are similar to alfalfa (12) and superior to most other CT containing legumes (16). As with all legumes, sainfoin fixes nitrogen enabling it to produce high yields without nitrogen fertiliser. Dry matter yields of sainfoin range from 7 t ha^{-1} DM to 15 t ha^{-1} DM (8), but yields of old cultivars are often 20% less than alfalfa (8). Sainfoin retains its leaves longer than alfalfa and can be harvested at greater maturity with little loss in quality. Older sainfoin cultivars such as Nova or Melrose may tolerate light grazing in budding and still regrow, but if grazed after full bloom regrowth is minimal.

Incorporation of as little as 10% sainfoin DM in alfalfa pastures reduces the risk of pasture bloat (11, 15). Unfortunately, older sainfoin cultivars such as Melrose and Nova fail to persist in mixtures with alfalfa and exhibit poor regrowth after grazing (1).

Development of new sainfoin cultivars to control bloat in mixed alfalfa/sainfoin pastures

Development of sainfoin cultivars capable of producing high yield and persisting in mixed alfalfa stands was seen as an approach to solving the bloat problem. A sainfoin variety with these characteristics could prevent bloat and improve protein utilization in mixed legume pastures. Several new sainfoin populations were developed from clones selected for rapid growth/regrowth and high biomass production in competition with alfalfa (2).

Recent studies in western Canada showed that growing these new sainfoin populations in alternate rows with alfalfa prevented bloat in cattle rotationally grazing mixed legume pastures (4, 14). Pasture DM yield decreased over time for both new and old sainfoin populations, but the yield of the mixed three year old stands with new sainfoin populations was higher than those with the old variety, Nova (14). The incidence of bloat in the alfalfa-sainfoin stands with new sainfoin population was ~95% less than with Nova. Neither the nutritional quality nor levels of CT differed among new and old sainfoin populations. These studies indicated that the ability of sainfoin populations to persist at 25-30% of the pasture biomass over three years, dramatically reduced bloat risk.

In studies at Lethbridge, Alberta and Swift Current, Saskatchewan, the proportions of sainfoin in all mixtures at Lethbridge were 25% or higher over all three cuts even though there were reductions from cut to cut in the amount of Nova and the sainfoin cultivar, 3401 in pastures (Table 1; 13). In 2010, all mixtures had over 40% sainfoin before grazing, but after grazing DM proportions of Nova and 3401 dropped to 8 and 13%, respectively. For mixtures with the new cultivars 3432 and 3519, the proportion of sainfoin was 30 and 28%, respectively. In 2011 and 2012, only mixed pastures with 3432 and 3519 retained more than 25% sainfoin after regrowth.

At Swift Current, proportions of Nova and 3401 sainfoin DM in the regrowth were 11% and 17% respectively, whilst 3423 (42%) and 3519 (30%) accounted for a higher proportion of pasture DM (Table 1). The proportion of 3432 (39%) of pasture DM in primary growth in 2011 was higher than Nova (25%), 3401 (26%) and 3519 (26%).

[1]Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Canada (surya.acharya@agr.gc.ca)
[2]Agriculture and Agri-Food Canada, Semiarid Prairie Agriculture Research Centre, Swift Current, Canada

Table 1. Botanical composition (% DM basis) of sainfoin in alfalfa/sainfoin mixed pastures under rotational grazing in Lethbridge, Alberta, and Swift Current, Saskatchewan, Canada

Lethbridge, Alberta					
Year and cut	Nova/BJ*	3401/BJ	3432/BJ	3519/BJ	*P*-value
2009					
1st cut (June 11)	55	52	54	55	0.724
2nd cut (July 19)	44	45	52	52	0.214
3rd cut (September15)	25a	30a	48b	45b	0.025
2010					
Primary growth (June 28)	43a	40a	50b	53b	0.041
Regrowth (August 6)	8a	13a	30b	28b	0.001
2011					
Primary growth (June 19)	30a	40ab	52c	49bc	0.038
Regrowth (August 2)	5a	13a	43c	30b	0.001
2012					
Primary growth (June 19)	28a	30a	47b	44b	0.032
Regrowth (July 27)	5a	11a	40c	29b	0.001

Swift Current, Saskatchewan					
Year and cut	Nova/Br*	3401/Br	3432/Br	3519/Br	*P*-value
2010					
Primary growth (July 14)	33ab	27a	39b	30a	0.042
Regrowth (Sept 21)	11a	17a	42c	30b	0.001
2011					
Primary growth (July 4)	25a	26a	39b	26a	0.001

*BJ: AC Blue J alfalfa, Br: Beaver alfalfa; forage regrowth in 2010 but no regrowth in 2011 in Swift Current due to poor precipitation; no regrowth in continuous grazing pastures in Lethbridge as steers were retained on pasture throughout the grazing season; in 2009, there was no grazing in Lethbridge but the paddocks were cut and baled three times; means in the same row with different letters differ significantly ($P < 0.05$)

Table 2. Population designation, parentage, country of origin, selection method used and clonal composition of sainfoin populations used for development of AAC Mountainview

Population designation	Parent population	Origin	Selection method used and number of selected clones from populations
Melrose	Cultivar	Western Canada	Original population (Hanna and Cooke, 1970)
Nova	Cultivar	Western Canada	Original population (Hanna 1980)
LRC 3401[y]	Emyr	England	300 individual plants selected after 3 spring applications of 0.5 l ac^{-1} of glyphosate and mowing the crop 3-times per year.
LRC 3402	Perly	Switzerland	Original population (Boller et al. 2012)
LRC 3422	Kazakhstan	Kazakhstan	Original population
LRC 3432[y]	Remont	Montana, USA (Carlton and Delaney 1972)	300 individual plants selected after 3 spring applications of 0.5 l ac^{-1} of glyphosate and mowing the crop 3-times per year.
LRC 3506	CN 45635	PGRC[x] (China)	Original population
LRC 3507	CN 31800	PGRC (China)	Original population
LRC 3511	Eski	Montana, USA	Original population (Eslick et al. 1967)
LRC 3519[y]	Splendid	Romania (Savatti et al. 994)	300 individual plants selected after 3 spring applications of 0.5 l ac^{-1} of glyphosate and mowing the crop 3-times per year.
LRC 3902[w]	200 clone synthetic	Alberta, Canada	LRC: 3519 (90); 3432 (28); 3511 (20); 3401 (14); 3506 & 3507 (14); Nova (10); Melrose (10); 3402 (10); and 3422 (4)

All populations and cultivars are *Onobrychis viciifoila* subsp. *viciifolia*;
[y]the components of LRC 3401, 3432 and 3519 were selected from nurseries (30 m × 30 m) planted in rows with 1m spacing and clones from 300 selected plants were planted in 3 separate isolated breeding nurseries from which seed was harvested in bulk;
[w]the components of the 3902 (AAC Mountainview) were seeded in alternate rows with AC Longview alfalfa in 2001 spring, these (6 m × 18 m) plots were cut in the fall of 2001 and 3 times each year in 2002 to 2004, in 2005 spring the best of the survivors were selected and their clones were transplanted to a separate breeding nursery for seed production in the proportion noted above and seed for LRC 3902 was harvested for the first time in 2006;
[x]Plant Gene Resources of Canada

This work resulted in the release of 'AAC Mountainview' in western Canada (3) which was derived from defined crosses (Table 2). Selection criteria included an ability to survive in mixed alfalfa stands, high yield and rapid regrowth after cutting. When grown under irrigated and rain-fed conditions in western Canada, Mountainview out yielded Nova by 22% to 42% in pure stands and 30% to 39% in mixed stands with alfalfa. Mountainview should be well suited for preventing pasture bloat in mixed alfalfa stands without a loss in animal productivity.

Summary and concluding remarks

Sainfoin is comparable to alfalfa in forage quality and when mixed in low proportions (10% - 12%) with alfalfa it prevents pasture bloat. New sainfoin populations persist in mixed alfalfa stands and exhibit regrowth after grazing that is comparable to alfalfa. Mixed stands out yielded pure stands of sainfoin or alfalfa in tests under rain-fed and irrigated conditions. Sustained efforts in developing mixed legume pastures through improved sainfoin populations will benefit western Canada producers in terms of forage and cattle productivity. Enhanced levels of alfalfa/sainfoin mixed pasture grazing will not only reduce production costs, but also help alleviate public concern over beef production practices that use high grain diets in intensively managed feedlots.

References

(1) Acharya SN (2007) Advances in forage legume breeding. Proceedings, Foothills Forage Association Conference *Grazing Legumes for a Sustainable and Secure Future*, Lethbridge, Canada, 28-29 November 2007

(2) Acharya S (2012) Newly developed sainfoin populations can do more than prevent alfalfa pasture bloat. Proceedings, Alberta Forage Industry Network Annual General Meeting, Olds, Canada, 28 March 2012

(3) Acharya SN (2015) AAC Mountainview sainfoin (*Onobrychis viciifoila* subsp. *viciifolia*). Can J Plant Sci 95:1-5

(4) Acharya SN, Sottie E, Coulman BE, Iwaasa A, McAllister T, Wang Y, Liu J (2013) New sainfoin population for bloat-free alfalfa pasture mixture grazing in western Canada. Crop Sci 53:2283-2293

(5) Berg BP, Majak W, McAllister TA, Hall JW, McCartney D, Coulman BE, Goplen BP, Acharya SN, Tait RM, Cheng K-J (2000) Bloat in cattle: grazing alfalfa cultivars selected for a low initial rate of digestion: A Review. Can J Plant Sci 80:493-502

(6) Bolger TP, Matches AG (1990) Water-use efficiency and yield of sainfoin and alfalfa. Crop Sci 30:143-148

(7) Coulman B, Goplen B, Majak W, McAllister T, Cheng K-J, Berg B, Hall J, McCartney D, Acharya S (2000) A review of the development of a bloat-reduced alfalfa cultivar. Can J Plant Sci 80:487-491

(8) Frame J (2005) Forage Legumes for Temperate Grasslands. Food and Agriculture Organization of United Nations, Rome / Science Publishers, Enfield

(9) McDonald P, Henderson AR, Heron SJE (1991) The Biochemistry of Silage. Chalcombe Publications, Marlow

(10) McMahon LR, Majak W, McAllister TA, Hall JW, Jones GA, Popp JD, Cheng K-J (1999) Effect of sainfoin on *in vitro* digestion of fresh alfalfa and bloat in steers. Can J Plant Sci 79:203-212

(11) McMahon LR, McAllister TA, Berg B, Majak W, Acharya SN, Popp JD, Coulman B, Cheng K-J (2000) A review of the effects of forage condensed tannins on ruminal fermentation and bloat in grazing cattle. Can J Plant Sci 80:469-485

(12) Parker RJ, Moss BR (1981) Nutritional value of sainfoin hay compared with alfalfa hay. J Dairy Sci 64:206-210

(13) Sottie E, Acharya S, Iwaasa AD, McAllister T, Wang Y, Thomas J (2013) Effect of a new sainfoin population selected for persistence in alfalfa pastures on bloat incidence in cattle grazing alfalfa/sainfoin mixed pastures. Proceedings, Canadian Forage and Grassland Association Conference and AGM, Olds, Canada, 9-11 December 2013

(14) Sottie ET, Acharya SN, McAllister TA, Thomas JE, Wang Y, Iwaasa AD (2014) Alfalfa pasture bloat can be eliminated by intermixing with newly-developed sainfoin population. Agron J 106:1470-1478

(15) Wang Y, Berg BP, Baribieri LR, Veira DM, McAllister TA (2006) Feed intake, ruminal fermentation and development of bloat in steers grazing pastures of alfalfa or mixed alfalfa-sainfoin. Can J Anim Sci 86:383-392

(16) Wang Y, Acharya S, McAllister T (2015) Condensed tannins in sainfoin: composition, concentration and effects on nutritive and feeding value of sainfoin forage. Crop Sci 55:13-22

Impacts of forage legumes on intake, digestion and methane emissions in ruminants

by Cécile MARTIN*, Giuseppe COPANI and Vincent NIDERKORN

Abstract: Positive associative effects can be observed on daily intake with some grass-legume mixtures, likely due to a greater motivation of animals to eat mixtures than pure forage. Plant secondary metabolites are a key features of legumes. Legumes rich in condensed tannins modify ruminal protein degradation, resulting in a shift from urinary N to faecal N losses which may prove environmentally positive. In the same way when animals eat tanniniferous diets, enteric methane emissions per unit of intake decreases. Using grass-legume mixtures in ruminants' diets can be beneficial for animals in addition to their known agronomic benefits for increasing biomass yield and reducing the use of fertilizer.

Key words: digestion, legumes, methanogenesis, plant secondary metabolites, ruminants

Introduction

There is evidence that forage legumes, as components of mixed grass-legume swards, can provide multiple benefits to agriculture by acting at different stages in the soil-plant-animal- atmosphere system (4). This paper focuses on the impact of forage legume species - poor (lucerne, *Medicago* sativa L., and clover, *Trifolium* spp.) or rich in secondary metabolites such as tannins (lotus, *Lotus* spp., sainfoin, *Onobrychis viciifolia* Scop., sulla, *Hedysarum coronarium* L.) - in ruminants' diets on animal intake, digestion parameters and methane emissions.

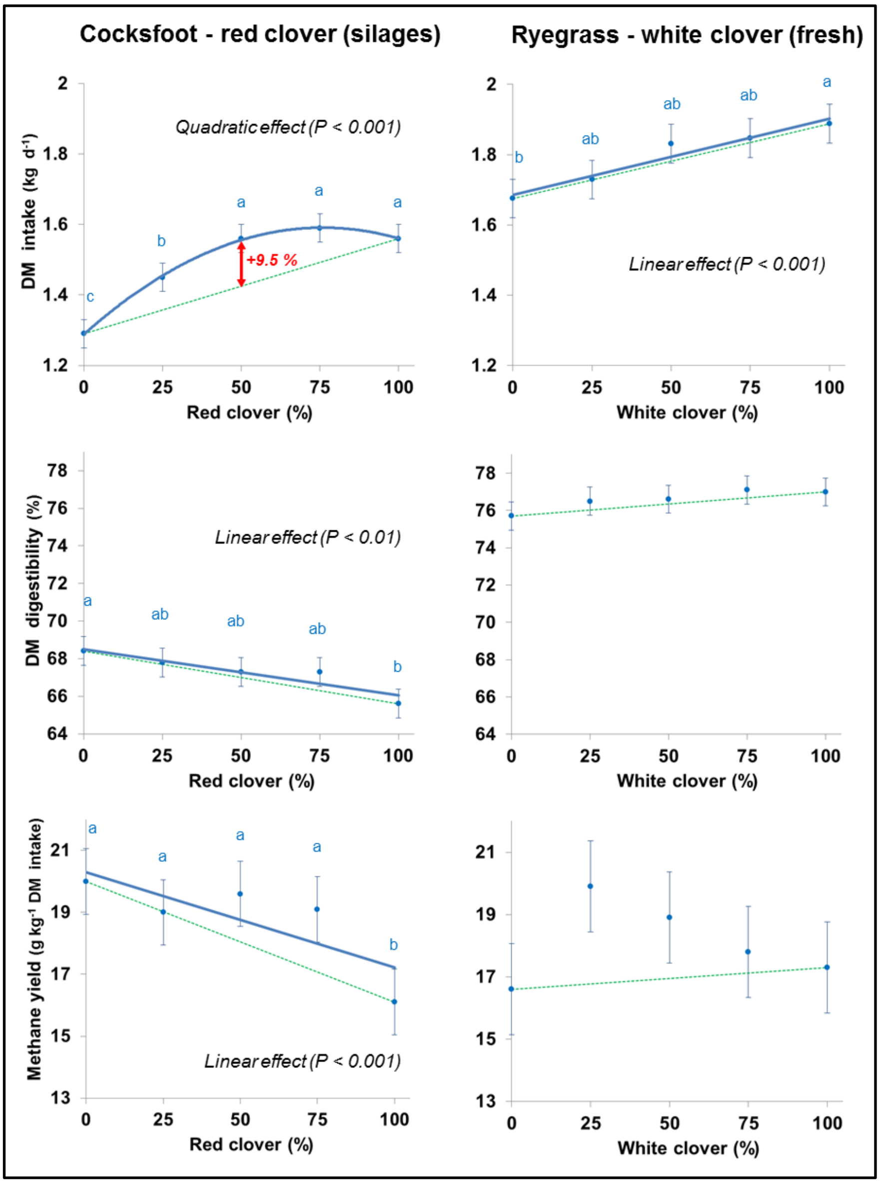

Figure 1. Voluntary dry matter (DM) intake, DM digestibility and methane yield in sheep fed with different proportions of cocksfoot and red clover silages, and ryegrass and white clover (fresh); full lines represent smoothed linear or quadratic responses, and dotted lines represent theoretical responses calculated from values obtained from pure forages (10)

INRA, UMR1213 Herbivores, Saint-Genès-Champanelle / Clermont Université, VetAgro Sup, UMR Herbivores, Clermont-Ferrand, France (cecile.martin@clermont.inra.fr)

Positive associative effects occur between grasses and legumes on voluntary intake

Associative effects between plants on intake and digestive parameters can occur when values recorded with a combination of forages differ from the balanced median values calculated from these plants considered separately (8). Feeding experiments recently conducted using models of simple forage mixtures in the form of fresh forage or silage have shown that synergies between cocksfoot (*dactylis glomerata* L.) silage and red clover (*T. pratense* L.) silage can be observed on dry matter (DM) intake and eating rate, with optimum for the proportion 50:50 (Fig. 1; 10). Positive associative effects on intake appeared more related to a greater motivation of animals to eat mixtures rather than a synergy on digestive efficiency. For this association, the synergy was also observed on daily intake of the digestible fraction and this can be expected to be reflected in improved animal performance. No associative effect was observed on daily intake and DM digestibility with mixtures of fresh ryegrass and fresh white clover, indicating that associative effects between grasses and legumes cannot be generalized to all species and all modes of forage use.

Forage legumes can modulate efficiency of ruminal protein digestion in the rumen and N excretion

Legumes forages typically have a high protein content compared to ryegrass. Losses of ruminal N in legumes-fed ruminants are always high due to an imbalance between degradable N and fermentable energy in the forage. The rumen degradability of protein is higher for forage legumes in comparison with grasses. This leads to inefficient utilization of forage N in the rumen and high urinary N excretion (4). However, legumes rich in plant secondary components such as condensed tannins protect dietary protein from ruminal degradation by forming insoluble complexes with them (7). However, although the amount of duodenal N flow increases, this is rarely matched by a greater utilization of amino acids in the intestine (1). As a consequence, when ruminants eat legumes rich in tannins, there is a shift from urinary to faecal N compared with other isonitrogenous diets which may prove environmentally positive. Indeed, urinary N is quickly converted to ammonia and nitrous oxide which has implication for environmental pollution whereas faecal N is more likely to contribute to soil organic matter.

Forage legumes can mitigate methane emissions

The general effect of legumes on ruminal methane production per unit of intake (CH_4 yield) is inconsistent probably because of differences in forage composition (stage of maturity, preservation mode) and animal genotypes between studies. No change in CH_4 yield has been found comparing mixtures of clovers and grasses (see 12 in dairy cows, 3 in heifers and 10 in sheep) and in the meta-analysis by Archimède et al. (1). In contrast, a decrease in enteric CH_4 production was reported for pure red clover in sheep (10) or for 70% lucerne in grazing beef cows (6). This effect was explained by the higher intake level and ruminal passage rate of dietary particles with legumes than with grasses.

The specific effect of condensed tannins in legumes mitigating methane has been highlighted *in vitro* when mixing cocksfoot and sainfoin (9) and *in vivo* with sainfoin, lotus or sulla (5). Antimethanogenic properties of condensed tannins depend on their polymer size and chemical structure (11). This CH_4-mitigating effect of tannins may be related from indirect effects on rumen protozoa (hydrogen producers) and/or from direct effects on methanogens (hydrogen users). However, some bacteria are tannins-tolerant and are able to inhibit the activity of these molecules in the rumen.

References

(1) Archimède H, Eugène M, Marie-Magdeleine C, Boval M, Martin C, Morgavi DP, Lecomte P, Doreau M (2011) Comparison of methane production between temperate and tropical forages: A quantitative review. Anim Feed Sci Technol 166-167:59-64

(2) Aufrère J, Dudilieu M, Poncet C (2008) *In vivo* and *in situ* measurements of the digestive characteristics of sainfoin in comparison with lucerne fed to sheep as fresh forages at two growth stages and as hay. Anim 2:1331-1339

(3) Hammond KJ, Hoskin SO, Burke JL, Waghorn GC, Koolard JP, Muetzel S (2011) Effects of feeding fresh white clover (*Trifolium repens*) or perennial ryegrass (*Lolium perenne*) on enteric methane emissions from sheep. Anim Feed Sci Technol 166:398-404

(4) Lüscher A, Mueller-Harvey I, Soussana JF, Rees RM, Peyraud JL (2014) Potential of legume-based grassland-livestock systems in Europe: a review. Grass Forage Sci 69:206-228

(5) Martin C, Morgavi DP, Doreau M (2010) Methane mitigation in ruminants : from microbes to farm scale. Anim 4:351-365

(6) McCaughey WP, Wittenberg K, Corrigan D (1999) Impact of pasture type on methane production by lactating beef cows. Can J Anim Sci 79:221-226

(7) Min BR, Barry TN, Attwood GT, McNabb WC (2003) The effect of condensed tannins on the nutrition and health of ruminants fed fresh temperate forages: a review. Anim Feed Sci Technol 106:3-19

(8) Niderkorn V, Baumont R (2009) Associative effects between forages on feed intake and digestion in ruminants. Anim 3:951-960

(9) Niderkorn V, Mueller-Harvey I, Le Morvan A, Aufrère J (2012) Synergistic effects of mixing cocksfoot and sainfoin on *in vitro* rumen fermentation. Role of condensed tannins. Anim Feed Sci Technol 178:48-56

(10) Niderkorn V, Martin C, Baumont R (2014) Associative effects between forage species on intake and digestive efficiency in sheep. Grassl Sci Eur 19:734-736

(11) Tavendale MH, Lane GA, Schreurs NM, Fraser K, Meagher LP (2005) The effects of condensed tannins from *Dorycnium rectum* on skatole and indole ruminal biogenesis for grazing sheep. Crop Pasture Sci 56:1331-1337

(12) Van Dorland HA, Wettstein HR, Leuenberger H, Kreuzer M (2007) Effect of supplementation of fresh and ensiled clovers to ryegrass on nitrogen loss and methane emissions in dairy cows. Livest Sci 111:57-69

Impact of forage legumes on greenhouse gas output and carbon footprint of meat and milk

by Michael UNDI[1]*, Karin WITTENBERG[2], Emma J. McGEOUGH[2] and Kim H. OMINSKI[2]

Abstract: The benefits of forage legumes as a source of good quality feed for livestock are well-recognized; of equal merit is the value of including forage legumes in pastures to improve soil health and reduce net greenhouse gas emissions from animal agriculture. Beneficial attributes of forage legumes include increased efficiency of nitrogen use, thereby increasing ruminal fermentation efficiency leading to reduced enteric methane (CH_4) emissions and decreasing nitrous oxide (N_2O) emissions from soils and animal manures. Interestingly, attributes such as the presence of condensed tannins (CT) that are perceived to be a stumbling block in the use of forage legumes as livestock feeds, may serve as a strategy for greenhouse gas emissions (GHG) mitigation. Inclusion of forage legumes in ruminant diets may reduce CH_4 emissions due to a combination of high CT levels, lower fiber levels and higher passage rates when compared to grasses. This paper will examine the impact of forage legumes on GHG emissions mitigation in meat and dairy production systems.

Key words: carbon, carbon footprint, enteric methane, forage legumes, nitrous oxide

[1]North Dakota State University, Central Grasslands Research Extension Center, Streeter, USA (michael.undi@ndsu.edu)

[2]University of Manitoba, Department of Animal Science and National Centre for Livestock and the Environment (NCLE), Winnipeg, Canada

Introduction

Livestock production is a significant source of GHG emissions, generating carbon dioxide (CO_2), CH_4, and N_2O from enteric fermentation, manure management and other production activities (7). Thus, meat and milk production contribute significantly to the global carbon (C) footprint associated with agricultural systems. The C footprint, expressed in terms of CO_2 equivalents (CO_2e), estimates all direct and indirect sources and sinks of GHG associated with a product or service (5). An assessment of meat production in 27 EU countries (13) estimated that beef has the highest production of net GHG on a per kg product basis (22.6 kg CO_2-eq kg^{-1}) compared to other livestock commodities including pork (3.5 kg CO_2-eq kg^{-1}), poultry (1.6 kg CO_2-eq kg^{-1}), milk (1.3 kg CO_2-eq kg^{-1}) and eggs (1.7 kg CO_2-eq kg^{-1}). In Canada, where the C footprint of beef production was estimated at 22 kg CO_2e kg^{-1} carcass, 63% of the total emissions were associated with enteric CH_4 emissions while 27% were associated with N_2O from soil and manure (1). In the Canadian dairy sector, methane accounted for 56% (of which 86% originated from enteric fermentation) and N_2O for 40% of total GHG emissions (15). Loss of CH_4 and N_2O in these production systems represent production inefficiencies as the energy losses may otherwise be used for milk and meat production. Inclusion of forage legumes in ruminant diets can potentially improve productivity while at the same time reducing the C footprint of meat and milk production through reduced CH_4 and N_2O emissions as well as enhanced C sequestration. Therefore, improved rumen fermentation efficiency and a reduction in GHG emissions are worthy goals for the global cattle industry.

Feeding strategies to reduce enteric methane

On a global scale, enteric fermentation by ruminants produces approximately 21% - 25% of total anthropogenic CH_4 emissions (12). Strategies to reduce enteric CH_4 emissions have been discussed in several reviews (6, 7). Several studies have reported that improved forage quality can reduce enteric CH_4 emissions (4, 7). In Canada, much of the forage for beef production is harvested after full head or full bloom (17) and, if fed alone, may not be sufficient to meet the nutrient requirements of cows in the last trimester of pregnancy or backgrounding steers. Improved animal productivity has been associated with the lower fiber content and higher ruminal rates of passage which are characteristic of legume forages compared to grasses (7). Increased animal productivity leading to fewer days on feed will serve to reduce enteric emissions as fewer animals are needed for the same level of production. Reduced emissions can be attributed to a lower proportion of structural carbohydrates and faster rate of passage which shifts fermentation toward high propionic acidic production (10). Enteric emissions were reduced by 25% in beef cows grazing alfalfa (*Medicago sativa* L.) grass pastures (Fig. 1, Fig. 2) compared to grass only pastures (14). Selecting regionally appropriate forage types, harvesting at optimum maturity and maximum digestible energy has been proposed to reduce emissions by 5% - 10% while inclusion of legume forages have been proposed to reduce enteric emissions by 5% (9).

Figure 1. Beef cows grazing alfalfa-grass pasture

Another well-recognized strategy to reduce enteric emissions is the inclusion of forages which contain tannins. These naturally-occurring plant compounds influence methanogenesis in the rumen by reducing rumen hydrogen production or by inhibiting the growth of methanogens (18). Reduction of enteric CH_4 emissions is more dramatic with tropical forage legumes which tend to have higher CT concentrations (3, 19). New Zealand dairy cows fed CT-containing forages such as sulla (*Hedysarum coronarium* L.) and birdfoot trefoil (*Lotus corniculatus* L.) produced 13% - 25% less CH_4 kg^{-1} DMI compared to cows fed ryegrass (*Lolium perenne* L.) (20). However, in temperate climates, feeding tannin-containing forage legumes has been less effective in reducing enteric CH_4 emissions (2, 4) as the CT concentration tends to be considerably lower. Further, the mitigation potential of tannins could be constrained by the limited area sown to tannin-containing forages in livestock-producing regions of the world (12).

Nitrous oxide (N_2O) mitigation

Sources of N_2O in cattle production systems include nitrogen fertilization and animal excreta. Improved N management in ruminant diets will not only reduce the amount of manure N excreted but also the portion excreted as more volatile urinary urea N (16), which has important implications in GHG losses, as N_2O losses are higher from urine than from feces (6). Inclusion of legumes may lead to a more appropriate dietary energy to protein ratio (17), particularly when cattle graze nitrogen-deficient native or naturalized range land. Inclusion of diversified pasture species that includes deep-rooted legumes not only decreases the need for N fertilizers but also lowers nitrate leaching and N_2O emissions (6, 10). In addition to the direct benefits of CT-containing forages in the rumen, legumes such as sainfoin (*Onobrychis viciifolia* Scop.) shift N excretion from urine to feces (4), potentially reducing N_2O emissions.

Carbon sequestration

Carbon sequestration refers to the natural process whereby atmospheric CO_2 is transferred into the soil carbon pool through conversion of plant residue into stable humus (11). Increasing soil C improves crop productivity, restores degraded soils and improves quality of surface water by reducing erosions and sedimentation. Many practices that increase forage biomass yields, including improved pasture management, fertilization, irrigation, intercropping of grasses and forage legumes, conservation tillage and crop rotation, are associated with soil organic carbon level accumulation (8). Although rates of C sequestration are highly variable, management strategies such as conversion of crop land to perennial forage, addition of legumes or N inputs and managing grazing to restore degraded grasslands can sequester 100 C ha^{-1} $year^{-1}$ - 800 C ha^{-1} $year^{-1}$ (10).

Perspectives

Inclusion of regionally appropriate legume forage types, harvesting at optimum maturity and maximum digestible energy play an important role in mitigating GHG from livestock production systems. Development of new cultivars and expansion of existing legume cultivars into new regions as a consequence of changes in environmental conditions may offer new opportunities to livestock producers in forage selection, improving both animal productivity and GHG mitigation. It is evident that forage legumes will continue to be an important livestock feed as the demand for global protein increases. In addition, inclusion of forages will play an increasingly important role in reducing GHG emissions thereby enhancing the sustainability of ruminant production systems.

Figure 2. Cattle wearing the methane collection devices

References

(1) Beauchemin KA, Janzen HH, Little SM, McAllister TA, McGinn SM (2010) Life cycle assessment of greenhouse gas emissions from beef production in western Canada: A case study. Agric Syst 103:371-379

(2) Bouchard K, Wittenberg KM, Legesse G, Krause DO, Khafipour E, Buckley KE, Ominski KH (2013) Comparison of feed intake, body weight gain, enteric methane emission and relative abundance of rumen microbes in steers fed sainfoin and alfalfa silages under western Canadian conditions. Grass Forage Sci 70:116-129

(3) Berard NC, Wang Y, Wittenberg KM, Krause DO, Coulman BE, McAllister TA, Ominski KH (2011) Condensed tannin concentrations found in vegetative and mature forage legumes grown in western Canada. Can J Plant Sci 91:669-675

(4) Chung YH, McGeough EJ, Acharya S, McAllister TA, McGinn SM, Harstad OM, Beauchemin KA (2013) Enteric methane emission, diet digestibility, and nitrogen excretion from beef heifers fed sainfoin or alfalfa. J Anim Sci 91:4861-4874

(5) Desjardins RL, Worth DE, Xavier PC, Vergé XPC, Maxime D, Dyer J, Cerkowniak D (2012) Carbon Footprint of Beef Cattle. Sustain 4:3279-3301

(6) Eckard RJ, Grainger C, de Klein CAM (2010) Options for the abatement of methane and nitrous oxide from ruminant production: A review. Livest Sci 130:47-56

(7) Hristov AN, Oh J, Firkins JL, Dijkstra J, Kebreab E, Waghorn G, Makkar HPS, Adesogan AT, Yang W, Lee C, Gerber PJ, Henderson B, Tricarico JM (2013) Mitigation of methane and nitrous oxide emissions from animal operations: I. A review of enteric methane mitigation options. J AnimSci 91:5045-5069

(8) Hutchinson JJ, Campbell CA, Desjardins RL (2007) Some perspectives on carbon sequestration in agriculture. Agric Forest Met142:288-302

(9) Irresco Solutions (2015) Summary Report - Dairy AGGP Science Coordination and Implementation Workshop. Ottawa

(10) Iwaasa A, Lemke R (2014) Reducing greenhouse gases from ruminants on perennial pastures. In: Bittman S, Hunt D (eds) Cool Forages: Advanced Management of Temperate Forages. Pacific Field Corn Association, Agassiz, 201-204

(11) Lal R (2006) Carbon dynamics in agricultural soils. In: Bhatti JS, Lal R, Apps MJ, Price MA (eds) Climate Change and Managed Ecosystems. CRC Press, Boca Raton, 127-148

(12) Lascano CE, Cárdenas E (2010) Alternatives for methane emission mitigation in livestock systems. Rev Bras Zootec 39:175-182

(13) Lesschen JP, van den Berg M, Westhoek HJ, Witzke HP, Oenema O (2011) Greenhouse gas emission profiles of European livestock sectors. Anim Feed Sci Technol 166-167:16-28

(14) McCaughey WP, Wittenberg K, Corrigan D (1997) Methane production by steers on pasture. Can J Anim Sci 77:519-524

(15) McGeough E, Little JSM, Janzen HH, McAllister TA, McGinn SM, Beauchemin KA (2012) Life-cycle assessment of greenhouse gas emissions from dairy production in Eastern Canada: A case study. J Dairy Sci 95:5164-5175

(16) Reynolds CK, Kristensen NB (2008) Nitrogen cycling through the gut and the nitrogen economy of ruminants: An asynchronous symbiosis. J Anim Sci 86S:E293-E305

(17) Sheppard SC, Bittman, S, Donohoe G, Flaten F, Wittenberg KM, Small JA, Berthiaume R, McAllister TA, Beauchemin KA, McKinnon J, Amiro BD, MacDonald D, MattosF, Ominski KH (2014) Beef cattle husbandry practices across Ecoregions of Canada in 2011. Can J Sci 95:305-321

(18) Tavendale MH, Meagher LP, Pacheco D, Walker N, Attwood GT, Sivakumaran S (2005) Methane production from in vitro rumen incubations with *Lotus pedunculatus* and *Medicago sativa*, and effects of extractable condensed tannin fractions on methanogenesis. Anim Feed Sci Technol 123-124:403–419

(19) Tiemann TT, Lascano CE, Wettstein HR, Mayer AC, Kreuzer M, Hess HD (2008) Effect of the tropical tannin-rich shrub legumes *Calliandra calothyrsus* and *Flemingia macrophylla* on methane emissionand nitrogen and energy balance in growing lambs. Anim 2:790-799

(20) Waghorn GC, Woodward SL (2006). Ruminant contributions to methane and global warming - A New Zealand perspective.In: Bhatti JS, Lal R, Apps MJ, Price MA (eds) Climate Change and Managed Ecosystems. CRC Press, Boca Raton, 233-260

Opportunities and risks of combining high inputs of inorganic N with forage legumes

by Brian McCARTHY*, Michael EGAN and Deirdre HENNESSY

Abstract: Increased global food production to meet the demands of a growing world population must be achieved in an environmentally sustainable manner. There is increased awareness of the multifunctional benefits of grass-based production systems. Combining forage legumes such as white clover with N fertilised grass swards could increase the productivity of grass-based production systems. White clover can increase herbage production, feed quality, animal performance and biodiversity in grass-based systems. Risks associated with incorporating white clover into grass-based systems include lack of persistency, reduced spring herbage production, bloat and N loss. Recent experiments in Ireland show milk solids production (30 kg cow^{-1} - 60 kg cow^{-1}) and herbage production (from 0 t ha^{-1} DM to 2.5 t ha^{-1} DM) benefits when white clover is incorporated into N fertilised grass swards compared with N fertilised grass only swards.
Key words: grass-based production system, inorganic fertiliser, legumes, white clover

Introduction

The demand for high quality food (in particular, dairy products) is increasing worldwide, due to population growth, urbanization and increases in disposable per capita income (1) and it is anticipated that continuing population and consumption growth will further increase global food demand. Although it is acknowledged that increased global food production is required, it is also acknowledged that this increase in global food production must be achieved through environmentally sustainable production systems. Consequently, there is an increasing awareness of the multi-functional character and benefits of grass-based production systems due to their capability to be both highly productive and economically profitable (2) and environmentally benign (5). Grass-based production systems, such as those practiced in North-West Europe, New Zealand and South-East Australia rely on highly productive perennial ryegrass (*Lolium perenne* L.) swards to achieve long grazing seasons in order to meet animal feed requirements from a predominantly grazed grass diet. Forage legumes offer the opportunity to increase the performance of these grass-based production systems and consequently there is renewed interest in forage legumes, such as white clover (*Trifolium repens* L.), red clover (*Trifolium pratense* L.) and lucerne (*Medicago sativa* L.) (4). Traditionally, in mixed perennial ryegrass-legume swards, inorganic nitrogen (N) fertiliser inputs are reduced, due to the ability of legumes to replace inorganic N with symbiotic N fixation and reduce overall production costs. However, there may be opportunities to combine high inputs of inorganic N with forage legumes to increase the productivity of grass-based production systems. This paper will look at these opportunities and also at the risks of combining high inputs of organic N with forage legumes.

Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Ireland
(brian.mccarthy@teagasc.ie)

Opportunities

The inclusion of forage legumes, and white clover in particular, in grass-based production systems have been shown to have benefits in terms of increased herbage nutritive value (3) and increased animal performance in terms of both dry matter (DM) intake and milk production (6). Legume inclusion in grass-based systems will increase the levels of biodiversity at farm level by incorporating multiple species into swards which may also lead to increased herbage DM production and improved soil structure. Legumes are also a source of protein that can be grown on farms and can be an alternative to imported soya bean (*Glycine max* (L.) Merr.) as a source of feed protein. Forage legumes also have a role to play in mitigating and facilitating adaption to climate change (4). As stated previously forage legumes offer positive benefits in terms of individual animal performance but the overall system performance (in terms of milk production) may be reduced due to reduced stocking rates and levels of inorganic N input. The potential benefit of combining high levels of inorganic N fertiliser with grass legume swards lies in the opportunity to realise the benefits of increased animal performance and also increased stocking rate to increase overall system performance. In Europe there is a limit to the amount of inorganic N that can be applied to grassland so rather than using legumes to reduce or replace inorganic N input, including legumes into N fertilised grass swards could supply extra N (from N fixation) to the system to support increased herbage DM production and therefore increase stock carrying capacity and overall system performance.

Risks

There are, however, a number of risks associated with including forage legumes into grass-based systems. The lack of persistency of legumes in grazing systems is a major concern in terms of feed supply as reduced levels of herbage production will lead to increased production costs. Spring herbage production may be reduced and there are also issues with bloat and silage preservation with some legumes which can cause problems and economic losses. However, the biggest risk of combining high levels of inorganic N with forage legumes is the risk of N loss. The main environmental benefit of forage legumes is through the reduction of inorganic N use and if high levels of inorganic N are combined with forage legumes there may be surplus N in a system which, if not used by herbage, may be lost through nitrate leaching or denitrification.

Table 1. Herbage production results from both the Moorepark (2013 and 2014) and Clonakilty (2014) experiments

Moorepark experiment	Treatment[1]				SE[2]	Significance[3]		
	Cl150	Cl250	Gr250	-		T	-	-
Clover content (%)	26.6	22.5	-		0.07	***		
Herbage production (t DM ha^{-1})	14.4	14.3	14.2		0.43	NS		
Clonakilty experiment	**Treatment[1]**				**SE[2]**	**Significance[3]**		
	TO	DO	TC	DC		P	C	P*C
Clover content (%)	-	-	39.1	40.3	1.76	NS	-	-
Herbage production (t DM ha^{-1})	14.9	14.8	17.5	17.2	0.49	NS	***	NS

[1]Cl150 = grass white clover 150 kg N ha^{-1}, Cl250 = grass white clover 250 kg N ha^{-1}, Gr250 = grass only 250 kg N ha^{-1}, TO = tetraploid only, DO = diploid only, TC = tetraploid + clover, DC = diploid + clover; [2]SE: Standard Error; [3]Significance: *** = $P < 0.001$, NS = not significant, T = treatment, P = ploidy, C = clover

Table 2. Milk production results from both the Moorepark (2013 and 2014) and Clonakilty (2014) experiments

Moorepark experiment	Treatment[1]				SE[2]	Significance[3]		
	Cl150	Cl250	Gr250	-		T	-	-
Milk yield (kg cow^{-1})	5649	6016	5900		156.5	NS	-	-
Milk solids yield (kg cow^{-1})	447	477	476		12.6	NS	-	-
Milk yield (kg ha^{-1})	15478	16485	16167		529.7	NS	-	-
Milk solids yield (kg ha^{-1})	1226	1305	1304		40.4	NS	-	-
Clonakilty experiment	**Treatment[1]**				**SE[2]**	**Significance[3]**		
	TO	DO	TC	DC		P	C	P*C
Milk yield (kg cow^{-1})	4895	4848	5532	5506	202.7	NS	***	NS
Milk solids yield (kg cow^{-1})	414	403	464	463	16.0	NS	***	NS
Milk yield (kg ha^{-1})	13473	13366	15284	15118	940.9	NS	***	NS
Milk solids yield (kg ha^{-1})	1140	1109	1279	1273	78.1	NS	***	NS

[1]Cl150 = grass white clover 150 N kg ha^{-1}, Cl250 = grass white clover kg N ha^{-1}, Gr250 = grass only kg N ha^{-1}, TO = tetraploid only, DO = diploid only, TC = tetraploid + clover, DC = diploid + clover; [2]SE: Standard Error; [3]Significance: *** = $P < 0.001$, NS = not significant, T = treatment, P = ploidy, C = clover

Recent experiments in Ireland

Two recent experiments have been undertaken in Ireland investigating the use of forage legumes (namely, white clover, which is the most important forage legume in temperate grazing systems worldwide) in intensive grazing systems. The first experiment was established at Teagasc, Animal and Grassland Research and Innovation Centre, Moorepark, Fermoy, Co. Cork, Ireland, in January 2013. The experiment was a systems experiment with three treatments, a grass only sward receiving 250 kg N ha^{-1} (Gr250), a grass white clover sward receiving 250 kg N ha^{-1} (Cl250) and a grass white clover sward receiving 150 kg N ha^{-1} (Cl150). Treatments were stocked at 2.74 cows ha^{-1} and rotationally grazed in 2013 and 2014. The second experiment was established at Teagasc Agricultural College, Clonakilty, Co. Cork, Ireland, in January 2014. The experiment was also a systems experiment, with four treatments, a tetraploid grass sward (TO), a diploid grass sward (DO), a tetraploid grass with white clover sward (TC) and a diploid grass with white clover sward (DC). Treatments were stocked at 2.75 cows ha^{-1}, rotationally grazed and received 250 kg N ha^{-1} in 2014.

Herbage production results from both experiments are presented in Table 1. Sward clover content ranged between 24% and 40% on the clover treatments. Including clover into perennial ryegrass swards increased herbage DM production in the Clonakilty experiment by 2.5 t DM ha^{-1} in 2014, regardless of grass ploidy. Although there was no difference in herbage DM production between the three treatments in the Moorepark experiment over two years, it is interesting to note that the Cl150 treatment had the same herbage DM production as the Gr250 and Cl250 treatments despite receiving 100 kg N ha^{-1} less than Gr250 and Cl250. Milk production results from both experiments are presented in Table 2. The average increase in milk solids yield for cows grazing grass clover swards compared with grass only swards was 30 kg cow^{-1} and 55 kg cow^{-1} in the Moorepark and Clonakilty experiments, respectively.

In conclusion, incorporating white clover into grass-based milk production systems in conjunction with high levels of inorganic N offers an opportunity to increase animal performance and in some circumstances increase herbage DM production in high stocking rate grass-based milk production systems. White clover may also offer the opportunity to strategically reduce inorganic N input to high stocking rate grass-based systems. The presented experimental results are in their infancy and must be undertaken for 5 to 6 years to allow a comprehensive analysis of the impact and role of white clover in grazing systems.

References

(1) Delgado CL (2005) Rising demand for meat and milk in developing countries: implications for grasslands-based livestock production. In: McGilloway DA (ed) Grassland: A Global Resource. Wageningen Academic Publishers, Wageningen, 29-39

(2) Dillon P, Hennessy T, Shalloo L, Thorne F, Horan B (2008) Future outlook for the Irish dairy industry: a study of international competitiveness, influence of international trade reform and requirement for change. Int J Dairy Technol 61:16-29

(3) Harris SL, Clark DA, Auldist MJ, Waugh CD, Laboyrie PG (1997) Optimum white clover content for dairy pastures. Proc N Z Grassl Assoc 59:29-33

(4) Lüscher A, Mueller-Harvey I, Soussana JF, Rees RM, Peyraud JL (2014) Potential of legume-based grassland-livestock systems in Europe: a review. Grass Forage Sci 69:208-226

(5) Peyraud JL, Van den Pol-van Dasselaar A, Dillon P, Delaby L (2010) Producing milk from grazing to reconcile economic and environmental performances. Grassl Sci Eur 15:865-879

(6) Riberio Filho HMN, Delagarde R, Peyraud JL (2005) Herbage intake and milk yield of dairy cows grazing perennial ryegrass swards or white clover/perennial ryegrass swards at low- and medium-herbage allowances. Anim Feed Sci Technol 119:13-27

Economics of temperate forage legumes for beef and dairy production systems

by Paul CROSSON

Abstract: The ability of legumes to biologically fix nitrogen and improve animal performance when compared to alternative perennial forages makes them a potentially attractive feed source for ruminants. A number of beef and dairy production studies, primarily based on grazed grass systems, were reviewed to assess the economics of utilizing forage legumes for these systems. For beef systems, animal live weight performance benefits were modest and stocking rates were mostly assumed to be constant. Therefore, benefits obtained were primarily cost reductions which led to higher gross margins for legume based beef production systems. Effects on dairy systems were influenced to a large extent by the impact on milk output with stocking rate and milk yield per cow having a substantial impact. Legume-based dairy systems operated at a lower stocking rate and, on average, milk yield per cow was lower and, therefore, economic returns were also lower for these systems.

Key words: beef, clover, dairy, economics, grazing, legumes

Introduction

Increasing competitiveness in ruminant production systems has led to a greater focus on improving cost efficiencies within these production systems. Feed costs represent the greatest cost in ruminant production systems (7) and therefore, management strategies to reduce the cost of feed provision are key for improving profitability. Fertilizer costs in particular represent an important component of total ruminant feed costs with global nitrogen (N) fertilizer inputs increasing by 25% between 2005 and 2012 (6). Legumes provide an opportunity to lower production costs for ruminant production systems owing to their ability to biologically fix atmospheric nitrogen (N) and thus, replace or reduce inorganic N inputs (10). A further advantage of some legumes is their higher digestibility when compared to alternative perennial forages (10). A number of studies have explored the opportunity to improve the economic returns of beef and dairy production systems.

Beef systems

Five beef production systems studies were retrieved from the scientific literature of which one was a research farm study (9) and the remaining four were farm systems modelling studies (Fig. 1). Doyle et al. (5) compared beef systems grazing swards with or without white clover (*Trifolium pratense* L.) for calf to 18-month beef production in two UK regions. Animal performance was modelled as a function of stocking rate, the quantity of concentrates fed and the proportion of clover in the sward. Thus, the grass/clover system resulted in higher intakes and live weight performance and correspondingly, gross margin was greater. However, it was noted that the level of variability was also greater with the coefficient of variation for live weight gain and gross margin being 50% and 23%, respectively, greater for the grass/clover system.

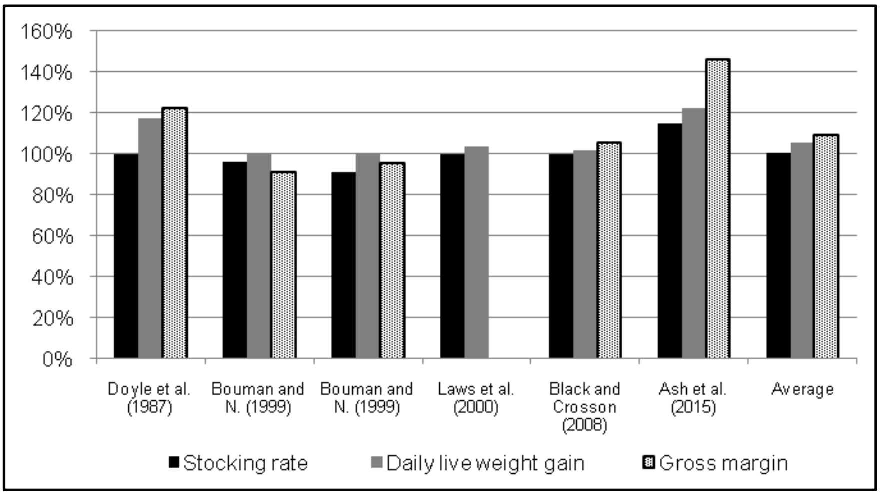

Figure 1. Relative stocking rate, daily live weight gain and gross margin of beef production systems based on grass/legume pastures compared to grass pastures with no legume

Teagasc, Animal and Grassland Research and Innovation Centre, Grange, Ireland
(paul.crosson@teagasc.ie)

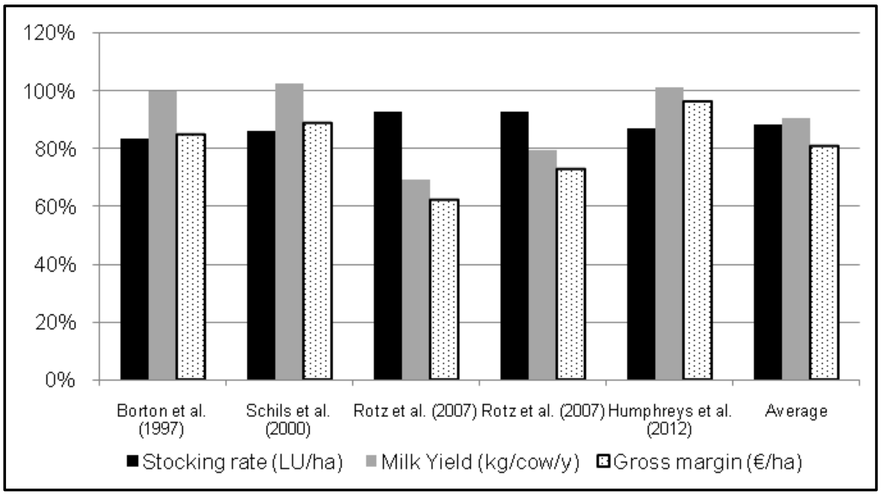

Figure 2. Relative stocking rate, milk yield and gross margin of dairy production systems based on grass/legume pastures compared to grass pastures with no legume

Bouman and Nieuwenhuyse (4) explored options for suckler cow calf and beef fattening systems for the Atlantic Zone of Costa Rica. This study involved a range of scenarios representing the soil and pasture types that prevail in the region, N fertilization strategies and animal production strategies. Beef fattening systems were much more profitable than suckler cow systems. With respect to the effect of legumes, no difference in animal performance between grass only or grass/legume forages was assumed. Grass only pastures were capable of sustaining marginally higher stocking rates and combined with differences in supplementary feed requirements, gross margins were greater for the grass only production systems. It was noted however, that the grass only pastures resulted in "N-mining" and that the longer term sustainability of these systems was questionable.

Black and Crosson (2) modelled the profitability of sucker cow-calf systems in Ireland taking progeny through to slaughter and assumed improvements in live weight gain and reductions in inorganic N fertilizer application for the perennial ryegrass (*Lolium perenne* L.) / white clover (*Trifolium repens* L.) swards. Improvements in live weight performance were assumed to occur only in the June to September period when clover growth is greatest and accordingly, across the full animals' life cycle live weight gain benefits to the grass/clover system was relatively modest. Overall, gross margin was 6% greater for the grass/clover system. Similarly, Ash et al. (1) compared the productivity and profitability of Australian pasture-based suckler beef production systems. In this analysis, a simulation model was used to evaluate alternative production strategies for three regions representing different production systems in northern Australia. A number of scenarios were evaluated to explore options to increase productivity of beef herds, including oversowing legumes with native pasture, a strategy which led to higher carrying capacity (+13%) and improved live weight performance (+22%). Overall, gross margin was 43% greater for the grass/ legume pasture.

Laws et al. (9) compared the performance of steers grazing either a grass monoculture receiving 280 kg ha^{-1} inorganic fertilizer N or a grass/white clover sward receiving no fertilizer at two sites with different soil types in south west England. The experiment was replicated across two sites. Herbage yield was 65% greater for the N fertilized pastures. Stocking rate was fixed with both pastures providing sufficient herbage for the grazing season; however, it was estimated that winter forage requirements were not adequately provided for in the grass/clover treatments with a shortfall of 7%. In contrast, the N-fertilized treatment had a winter feed surplus of 77%. Animal performance was similar for both treatments with the exception of one year where the grass/cover treatment was greater than the N-fertilized treatment on one of the sites.

Dairy systems

Four dairy based studies are summarised; two describe research farm experiments and two describe simulation modelling studies (Fig. 2). In the research farm studies, Schils et al. (12) and Humphreys et al. (8) evaluated grazing-based dairy production systems for the Netherlands and Ireland, respectively. Schils et al. (12) compared a grass/white clover system with a grass system supplemented with fertilizer N. Calving occurred from October to April so that much of the period of lactation occurred while cows were on conserved grass diets. The grass only system had a higher stocking rate but also higher costs. The authors also reported on challenges with bloat on the grass/clover system with incidences occurring in each of the three years of the study. The overall effect was an eleven per cent lower gross margin for the grass/clover system. Similarly, Humphreys et al. (8) quantified the economic benefits of grass/white clover feeding systems by comparing spring-calving dairy production systems using either 246 kg ha^{-1} N with no clover or 90 kg ha^{-1} N with clover. Although stocking density and milk sales was lower for the clover-based systems, fertilizer N and total costs were also lower such that gross and net margins were similar. Sensitivity analysis showed that the milk price/fertilizer price ratio was an important determinant of the relative profitability of the systems with margins for the grass/clover system being lower where milk price was high and/or fertilizer N price was low.

Grazing-based dairy systems for north eastern United States of America were also evaluated by Rotz et al. (11) in a simulation modelling study based on organic or conventional farming production principles whereby grazing was on grass only or grass/legume swards, respectively. Calving was either in spring (organic) or all-year (conventional) which limits the capacity to make a valid comparison between the production systems. Stocking rate was similar for both systems although productivity per cow was assumed to be forty-four per cent higher for the conventional system. Although fertilizer use rates were not specified, the combined cost of seed, fertilizers and chemicals was 38% greater for the conventional system. Gross and net margin was substantially lower for the organic legume-based system with much lower output per cow more than offsetting the lower input costs. An important consideration regarding these data is that the production systems were based on a comparison of organic and conventional production systems; although price data were adjusted to remove organic market premia, the production systems themselves were optimised to maximise returns in the context of organic markets.

Confinement based dairy production systems in the United States of America were modelled by Borton et al. (3) and Rotz et al. (11). Borton et al. (3) modelled dairy systems using either maize or alfalfa silage as the forage source. Although fertilizer N application rates were not specified, seed and chemical costs (which included fertilizer N) were 83% greater for the maize silage system. Stocking rate was lower for the alfalfa system due to the lower yields (35% lower) when compared to the maize silage system. No differences in milk yields were assumed. Gross margin per cow was similar for both systems (1,507 EUR and 1,570 EUR for the maize and alfalfa systems, respectively), however, as a result of differences in stocking rate, gross margin per hectare was higher for the maize system. Rotz et al. (11) modelled organic and conventional confinement dairy production systems using legumes or inorganic fertilizer as the source of N. Stocking rate was similar for both systems, however, milk yield per cow was much greater for the conventional system and therefore, gross and net margins were greater for the conventional system.

Summary

For beef production systems, gross margin was 10% greater for temperate forage legume (mainly white clover) systems when compared to grass systems without legumes. Only two systems presented net margin and these showed an average benefit of 50% in favour of grass/legume systems. The effect of grass/legume systems on stocking rate and live weight performance was highly variable among studies; on average, no advantage was assumed in stocking rate and a modest 6% advantage in live weight gain. The capacity to reduce production costs (lower inorganic fertilizer N costs) was more consistent. In the case of dairy production systems, the opposite effect emerges whereby the average gross margin was 19% lower for the grass/legume systems. The comparison of organic and conventional production in the study of Rotz et al. (11) has important implications for the cow-type and associated yield potential differences in this system; overall, milk yield was 25% lower for the organic systems. Stocking rates were typically lower (-12%) across the four studies for the grass/legume system reducing output and margin per hectare considerably. These effects have the overriding impact of reducing output value and thus, gross (and net) margin. These data would suggest that for systems where the margin between production costs and product value is low, legume-based pastures can have a particularly important role.

References

(1) Ash A, Hunt L, McDonald C, Scanlan J, Bell L, Cowley R, Watson I, McIvor J, MacLeod N (2015) Boosting the productivity and profitability of northern Australian beef enterprises: Exploring innovation options using simulation modelling and systems analysis, Agric Syst 139:50-65

(2) Black A, Crosson P (2008) Technical and economic considerations concerning the use of clover for beef farmers. Proceedings, Irish Grassland Association Beef Farm Study Tour and Conference, 8 July 2008, Tipperary, Ireland, 10-13

(3) Borton LR, Rotz CA, Black JR, Allen MS, Lloyd JW (1997) Alfalfa and corn silage systems compared on Michigan dairy farms. J Dairy Sci 80:1813-1826

(4) Bouman BAM, Nieuwenhuyse A (1999) Exploring options for sustainable beef cattle ranching in the humid tropics: a case study for the Atlantic Zone of Costa Rica. Agric Syst 59:145-161

(5) Doyle CJ, Morrison J, Peel S (1987) Prospects for grass-clover swards in beef production systems: A computer simulation of the practical and economic implications, Agric Syst 24:119-148

(6) FAO (2015) Global Fertilizer Statistics. Food and Agriculture Organization of United Nations, Rome, http://faostat.fao.org/site/575/DesktopDefault.aspx?PageID=575#ancor

(7) Finneran E, Crosson P, O'Kiely P, Shalloo L, Forristal PD, Wallace M (2012) Economic modelling of an integrated grazed and conserved perennial ryegrass forage production system. Grass Forage Sci 67:162-176

(8) Humphreys J, Mihailescu E, Casey IA (2012) An economic comparison of systems of dairy production based on N-fertilized grass and grass-white clover grassland in a moist maritime environment. Grass Forage Sci 67:519-525

(9) Laws JA, Pain BF, Jarvis SC, Scholefield D (2000) Comparison of grassland management systems for beef cattle using self-contained farmlets: effects of contrasting nitrogen inputs and management strategies on nitrogen budgets, and herbage and animal production, Agric Ecosyst Environ 80:243-254

(10) Phelan P, Moloney AP, McGeough EJ, Humphreys J, Bertilsson J, O'Riordan EG, O'Kiely P (2014) Forage legumes for grazing and conserving in ruminant production systems. Crit Rev Plant Sci 34:281-326

(11) Rotz CA, Kamphuis GH, Karsten HD, Weaver RD (2007) Organic dairy production systems in Pennsylvania: A case study evaluation. J Dairy Sci 90:3961-3979

(12) Schils RLM, Boxem TJ, Jagtenberg CJ, Verboon MC (2000) The performance of a white clover based dairy system in comparison with a grass/fertiliser-N system. II. Animal production, economics and environment. NJAS - Wagening J Life Sci 48:305-318

Legumes in ruminant production systems in European cold climates - Limitations and opportunities

by Kirsi JÄRVENRANTA*, Kaisa KUOPPALA, Marketta RINNE and Perttu VIRKAJÄRVI

Abstract: Use of legumes in ruminant systems in areas within Europe with a cold climate is mostly dependent on forage legumes and peas or faba beans. Organic production leans strongly on grass-clover mixtures, red clover being the most important forage legume. The growing season is short, which limits the choice of grain legumes to the earliest types. Winters are cold, snowy and wet and this causes challenges to the overwintering of forage legumes. However, there is a large capacity to increase protein production from both forage and grain legumes as currently their production area is minor. The expected climate changes will enhance the possibilities to grow legumes in the very north of Europe.

Key words: cold climate, forage legume, grain legume, ruminant production

Introduction

The use of legumes in ruminant systems in areas of Europe with a cold climate is mostly dependent on forage legumes and pea (*Pisum sativum* L.) or faba bean (*Vicia faba* L.), as the most important grain legume, soya bean (*Glycine max* (L.) Merr.), does not thrive in such a climate (3). Ruminant diets are strongly based on grass silage and cereals, and supplemental protein comes in the form of either domestic or imported rapeseed (*Brassica napus* L.) or imported soya bean. The role of on-farm produced grain legumes is minor. Organic production leans strongly on grass-clover mixtures together with some home-produced grain legumes and whole-crop mixtures. According to recent estimations, there is a large capacity to increase domestic protein production in areas with a cold climate (3, 6).

Natural Resources Institute Finland, Helsinki, Finland (kirsi.jarvenranta@luke.fi)

Climate and soil limit the production of both forage and grain legumes

The growing season in cold climates in the north of Europe is short but intensive. This limits the choice of available grain legumes to the earliest types. Winters are cold, snowy and wet and this causes challenges to overwintering forage legumes. Nitrogen fixation may be decreased by cool springs. In general, the climate is better suited for forage than grain legume production. Perennial grasses and legumes are able to utilize the solar radiation, temperature and water supply of the early summer. Night frosts occur frequently in the beginning of the growing season, which is hazardous to grain legumes. Summer droughts are not rare. Legumes are also more demanding regarding soil quality than grasses and cereals. In northern areas, soils are typically slightly acidic (unsuitable for lucerne, *Medicago sativa* L.) and the proportion of organic soils is high, which reduces the land area suitable for N fixing legume production (4).

Overwintering of forage legumes is affected by occasionally occurring warm, wet autumns, mid-winter freeze-thaw cycles, freezing, frost heave, flooding, ice encasement and low temperature fungal attack. Overwintering of red clover (*Trifolium pratense* L.) is better in mixed swards with grasses, but the benefits may be lost during the growing season, when grasses compete for the resources (4).

Legume species in a cold climate

Red clover, white clover (*T. repens* L.) and alsike clover (*T. hybridum* L.) can be cultivated throughout the Nordic area. The production of lucerne is limited to southern parts of Scandinavia. However, in the future climate change will probably enable lucerne production further north on well drained non-acidic soil. Common vetch (*Vicia sativa* L.), hairy vetch (*V. villosa* Roth), birdsfoot trefoil (*Lotus corniculatus* L.) and fodder galega (*Galega orientalis* Lam.) have been assessed in experiments with variable success.

Of the grain legumes, pea and faba bean are the most important. In addition blue lupin (*Lupinus angustifolius* L.) has been tested for seed production in southernmost areas with variable success, while white lupin (*L. albus* L.) does typically not ripen (3, 6).

Red clover - the most important forage legume

Red clover is well suited for dairy cow feeding in intensive silage-based systems (2). Including red clover in the grass mixtures in silage production (optimal amount 30% - 50%) has several advantages. The most compatible companion grass for red clover is timothy (*Phleum pratense* L.), but also tall fescue (*Festuca arundinacea* Schreb.) seems to be a feasible alternative. Biological nitrogen (N) fixation, up to 250 kg ha^{-1} y^{-1} N (4), provides a N source into organic farming systems and saves on fertilization costs in conventional farming. The decline in digestibility during the primary growth is slower compared to the companion grasses. This provides flexibility into the timing of the harvest of first cut forage (2). Red clover mixtures are cut twice a year producing up to 10,000 kg $year^{-1}$ dry matter (DM). The proportion of clover is typically lower in the primary growth than in the regrowth, and declines as the ley gets older. High N fertilization favors the competitiveness of grasses compared to clovers. Red clover compared to grasses has a lower digestibility and cell wall concentration, but higher crude protein (CP) and indigestible neutral detergent fiber (iNDF) concentrations. Red clover is characterized by having a good intake potential by ruminants (2). Ensiling of legumes is more challenging than for grasses due to typically lower DM concentration and higher buffering capacity of the herbage. Using appropriate silage additives decreases the risks of poor fermentation quality (4).

Red clover is vulnerable to clover rot (*Sclerotinia trifoliorum* Erikss.) and root rots (*Fusarium* spp.). A grass-clover mixture is slow to establish, and this causes problems with weeds as there is a lack of efficient herbicides for clover mixtures. In cattle production, slurry is commonly used as a fertilizer and this causes problems to clover stands as they are sensitive to soil compaction and physical damage (6).

Grain legumes in ruminant production

In northern areas the late harvest time of legumes causes a risk both for the ripening of the crop and for the harvesting circumstances. Less than 1% of crop land in the Nordic-Baltic region is covered by grain legumes. Grain legumes have a low competitive ability against weeds and diseases and they can be included in crop rotations only every 3-6 years (6). For grain harvesting in cold climates, field pea and faba bean are the only available crops, with the DM yields of 2000 kg ha^{-1} year^{-1} - 4000 kg ha^{-1} year^{-1} and 400 kg ha^{-1} year^{-1} - 700 kg ha^{-1} year^{-1} protein (1). Even though the yield is limited, the grain samples show that relatively typical seed composition could be obtained (5).

Grain legumes (peas, faba beans and lupins) are used as mixtures with cereals and harvested as whole-crop silage. The CP concentration and energy value of the leguminous part of the crop are high, which improves their usability in ruminant rations (2). Some early varieties of blue lupin are suitable for seed production. White lupin temperature sum requirement is too high for grain production in cold climates, but it may be used in mixtures for silage (6).

Future possibilities

In ruminant production, it would be possible to markedly increase protein production by supplementing or replacing fertilized grass stands with forage and grain legumes and mixtures (3, 6). However, as the overwintering and yield stability are not consistent, plant breeding programs are essential in developing varieties with sufficiently cold tolerant rhizobia, over-wintering capability and disease resistance. For spring-sown grain legumes, earliness is a vital trait. In the future, climate change will increase the possibilities to grow more grain legumes in areas that currently have a relatively cold winter.

References

(1) Känkänen H, Suokannas A, Tiilikkala K, Nykänen A (2012) Reducing of fossil energy by biological N fixation. MTT Rep 76:1-60

(2) 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 11:1-50

(3) Peltonen-Sainio P, Niemi JK (2012) Protein crop production at the northern margin of farming: to boost or not to boost. Agric Food Sci 21:370-383

(4) Riesinger P (2010) Agronomic challenges for organic crop husbandry. PhD Thesis. Department of Agricultural Sciences, University of Helsinki, Helsinki

(5) Rinne M, Dragomir C, Kuoppala K, Smith J, Yáñez-Ruiz D (2014) Novel feeds for organic dairy chains. Org Agric 4:275-284

(6) Stoddard FL, Hovinen S, Kontturi M, Lindström K, Nykänen A (2009) Legumes in Finnish agriculture: history, present status and future prospects. Agric Food Sci 18:191-205

Legumes for rainfed Mediterranean farming systems

by Rita MELIS[1]*, Luciano PECETTI[2], Paolo ANNICCHIARICO[2] and Claudio PORQUEDDU[1]

Abstract: A wide range of legumes is traditionally used in Mediterranean regions, owing to the extreme variability of environmental conditions and farming systems. Annual forage legumes are cultivated as short-term forage crops, usually in mixture with cereals or grasses. Self-reseeding annual legumes are sown to improve permanent pastures in extensive agro-pastoral systems. Breeding programs are carried out on alfalfa to select varieties with high tolerance to summer drought, grazing, and attitude, to grow in mixtures with summer dormant perennial grasses. Other perennial legumes are also under study for their flexible utilization. Nonetheless, some critical aspects concern the legume seed production in Mediterranean Europe and the rhizobia-legume symbiosis.

Key words: mixtures, pasture and forage legumes, rainfed systems, sustainability

Introduction

The rising cost of inputs and the foreseen water scarcity due to climate change can impact negatively on forage production. Nitrogen-fixing legumes tolerant to drought may play a crucial role in strategies of adaptation to climate changes and mitigation of their effects, while enhancing the sustainability of Mediterranean farming systems, by: i) reducing GHG emissions and energy consumption associated with the industrial synthesis of nitrogen fertilizer, ii) increasing the resilience and water use efficiency of grasslands, iii) reducing the amount of methane emitted per unit of animal product, by means of better feed quality, more balanced diets and more productive animals (5), iv) contributing to the diversification and flexibility of farming systems, and v) reducing the marked deficit of high-protein feedstuff and the related feed insecurity and exposure to feed price volatility. This last aspect is particularly important for organic and typical animal products.

A wide range of annual and, to a lesser extent, perennial legumes can be adopted in Mediterranean environments, owing to their wide variation of soil, climatic and crop management characteristics.

Annual forage legumes

Annual forage legumes are re-seeded every year (Table 1). They can be grazed in winter, harvested in the following spring for hay, or harvested for grain and straw at maturity (2). Largely-grown species are *Trifolium incarnatum*, *T. alexandrinum* L., *T. resupinatum* L., *Vicia sativa* L. and *V. villosa* Roth. Less common species such as *Pisum sativum* L. and *V. narbonensis* L. are under study in drought-prone areas, also because of their flexibility of utilization (Fig. 1). Most species are usually grown in mixture with winter cereals (oat, *Avena sativa* L., or barley, *Hordeum vulgare* L.) or grasses (Italian ryegrass, *Lolium perenne* L.), to achieve better weed and disease control and/or higher yields.

Table 1. Environmental requirements of annual and perennial legumes suitable or used in Mediterranean areas

Species	Mean annual rainfall (mm)	pH	Soil requirements
Annual forage legumes			
Trifolium resupinatum	> 400	5.0 - 8.0	Tolerant to alkaline soils and salinity
T. incarnatum	> 450	5.0 - 7.5	Not tolerant to alkaline soils
T. alexandrinum	> 400	6.5 - 8.0	Adapted to saline and alkaline soils
T. squarrosum	> 450	6.0 - 8.0	It prefers alkaline soils
Vicia sativa	> 350	6.0 - 8.0	It prefers moderately fertile soils
V. villosa	> 350	6.0 - 8.0	Sensible to alluminum
V. narbonensis	> 300	6.5 - 8.5	Adapted to alkaline soils
Pisum sativum	> 400	5.5 -7.5	Sensible to salinity
Annual pasture legumes			
Trifolium brachycalycinum	> 450	6.0 - 8.0	Adapted to clay-rich soils
T. subterraneum	> 450	5.0 - 7.5	Adapted to sandy soils
T. yanninicum	> 400	5.5 - 7.5	Tolerant to water logging
T. michaelianum	> 350	5.0 - 7.5	Tolerant to water logging
T. hirtum	> 250	5.5 - 7.5	Adapted to well-drained soils
T. glanduliferum	> 350	4.5 - 7.5	Tolerant to water logging
T. vesiculosum	> 400	5.0 - 7.5	Adapted to sandy soils
Biserrula pelecinus	> 400	5.0 - 7.5	Adapted to sandy soils
Ornithopus compressus	> 350	4.5 - 7.0	It prefers sandy soils
O. sativus	> 350	4.5 - 7.0	It prefers sandy soils
Medicago polymorpha	> 300	5.5 - 8.5	Suitable for all types of soils
M. truncatula	> 250	6.5 - 8.0	It prefers clay soils
M. scutellata	> 400	6.5 - 8.5	It prefers not too fertile soils
M. rugosa	> 350	6.5 - 8.0	It prefers clay soils
Perennial legumes			
Medicago sativa	> 450	6.5 - 8.0	Sensible to water logging
Trifolium pratense	> 400	5.5 - 7.5	Tolerant to aluminum-rich soils
Sulla coronaria	> 350	6.5 - 8.5	Not suitable to coarse-textured soils
Onobrychis viciifolia	> 400	6.5 - 8.5	Not adapted to fine-textured soils
Bituminaria bituminosa	> 300	5.0 - 8.5	Broad adaptation to soils

[1]CNR, Institute for Animal Production System in Mediterranean Environment, Sassari, Italy (rita.melis@ispaam.cnr.it)
[2]CREA, Centre for Fodder Crops and Dairy Productions, Lodi, Italy

Figure 1. Experimental field of annual forage legumes (peas and vetches) in pure stand and in mixture with winter cereals under evaluation within the REFORMA Project

Figure 2. Flowering stage of *Bituminaria bituminosa*, a perennial legume with high drought tolerance able to grow and remain green all-year-round even during summer

Annual pasture legumes

Pasture legumes are widespread in Mediterranean natural and semi-natural grasslands. Species survival during summer droughts relies on seed dormancy (hard seeds) mediated by the presence of a water-impermeable coat. Proper management of the seed bank is fundamental for the preservation of annual species in permanent pastures. The most-grown species for pasture improvement are subterranean clover (*T. subterranuem* L.) and medics (*Medicago* spp.) (Table 1). When grown in suitable soils, they achieve long-lasting persistence through self-reseeding, while providing high levels of N fixation and excellent weed control. Their yield response is affected by the specific growing conditions, especially rainfall during the growing season (4). On average, their dry matter yields range from 3 t ha^{-1} $year^{-1}$ to 12 t ha^{-1} $year^{-1}$. The so-called second-generation alternative pasture legumes (e.g. *Biserrula pelecinus* L., *T. glanduliferum* Boiss.) are commercially available for pasture improvement. Most of them are imported from Australia, where they have been selected for the local management systems (ley farming, which requires high levels of hard seeds). When sown in Mediterranean permanent pastures, varieties of these species often show a difficult re-establishment in autumn, because of an unsuitable breakdown pattern of hardseededness that prevents a ready germination of seeds (8).

Perennial legumes

The most-known perennial legume is alfalfa (*Medicago sativa* L.). Its ability to respond to summer irrigation makes it suitable for forage production in Mediterranean environments with water availability. Under severe stress in rainfed conditions it frequently shows reduced persistence and yield. Breeding programs are exploiting landraces that evolved in rainfed Mediterranean environments to select new varieties with high tolerance to summer drought and grazing (2). The ERANet project REFORMA is investigating ecological and molecular strategies to improve alfalfa tolerance to drought, salinity and grazing, as well the potential to grow alfalfa in mixtures with summer-dormant perennial grasses (cocksfoot, *Dactylis glomerata* L., or tall fescue, *Festuca arundunacea* Schreb.).

Yet, other perennial legumes such as sulla (*Hedysarum coronarium* L.) and sainfoin (*Onobrychis viciifolia* Scop.) are able to survive summer drought and regrow after the first autumn rain, offering the opportunity to stabilize production and improve forage quality. An important trait of these two species is their flexibility of use, by direct grazing or hay production. In addition, they show moderate concentrations of condensed tannins that enhance their nutritive value by promoting amino-acid absorption in the intestine, decreasing nitrogen excretion and reduced loads of gastro-intestinal parasites (6). Studies on deep-rooted clover species (Caucasian clover, stoloniferous red clover, tallish clover) are being carried out in Tasmania and elsewhere. Another perennial legume with potential as a forage legume for Mediterranean areas is the native *Bituminaria bituminosa* (L.) C.H. Stirt (Fig. 2). This legume has deep roots and physiological traits conferring drought tolerance. It grows and remains green all-year-round, even during summer. It is assumed to be tolerant of heavy grazing and some accessions are being selected in Spain and Sardinia (9).

Higher yield gains, better seasonal distribution and better forage quality can be obtained through perennial and annual legume-grass mixtures of species belonging to different functional groups (i.e. fast and slow establishing grasses and legumes) (6). Moreover, the concurrent use of plants using different adaptation strategies might be one of the tools to overcome drought and improve the adaptation to climate change and the ecosystem stability.

Grain legumes

Pea (*Pisum sativum* L.) is the main feed grain legume along with faba bean (*Vicia faba* L.) in southern Europe. It has remarkable flexibility of utilization, as it may be harvested at crop maturity for grain and straw (whose nutritive value is slightly lower than an average lucerne hay), or harvested earlier for hay or silage production. In addition, it may be grazed at maturity when unfavorable climatic conditions lead to poor grain yield. The grain of modern pea varieties is valuable as a concentrate for livestock feeding, because of its high protein and energy value, lack of antinutritional factors, and ease of conservation. A traditional drawback of pea, namely its poor standing ability, has been improved remarkably by recent plant breeding. Novel varieties, however, have hardly ever targeted regions of the Mediterranean basin. Nevertheless, pea has showed higher grain yield than faba bean or lupins (*Lupinus* spp.) in southern Europe (1).

Legume-rhizobia symbiosis

Rhizobia are usually widespread in soils of the Mediterranean basin, leading to little artificial inoculation of legume seeds. Only sulla is frequently inoculated with a specific strain to guarantee plant establishment. In contrast, commercial seed of pasture legumes imported from Australia is often inoculated with specific strains selected in Australia from wild rhizobia populations collected in the Mediterranean basin. However, there is poor scientific knowledge on the interactions with natural populations of rhizobia and the fate of the introduced strains in Mediterranean soils (10).

Future challenges

The increasing interest in legume use for Mediterranean farming systems finds a bottleneck in the lack of a European seed industry that produces well-adapted Mediterranean forage and pasture legume species. This situation has prevented the full exploitation of the results of successful breeding programs for Mediterranean environmental condition carried out by public research institutions. Concurrently with breeding and marketing of improved and well-adapted varieties, it is essential to allocate more efforts to on-farm experimentation and knowledge transfer to farmers, with emphasis on the optimal management of legumes in different target environments and farming systems.

Acknowledgements

This article is an outcome of the REFORMA project (http://reforma.entecra.it/)funded by the ERANet-ARIMNet, Coordination of the Agricultural Research in the Mediterranean Area.

References

(1) Annicchiarico P (2008) Adaptation of cool-season grain legume species across climatically-contrasting environments of southern Europe. Agron J 100:1647-1654

(2) Annicchiarico P, Pecetti L, Abdelguerfi A, Bouizgaren A, Carroni AM, Hayek T, M'Hammadi Bouzina M, Mezni M (2011) Adaptation of landrace and variety germplasm and selection strategies for lucerne in the Mediterranean basin. Field Crop Res 120:283-291

(3) Ates S, Feindel D, El Moneim A, Ryan J (2014) Annual forage legumes in dryland agricultural systems of the West Asia and North Africa Regions: research achievements and future perspective. Grass Forage Sci 69:17-31

(4) Bolger TP, Turner NC, Leach BJ (1993) Water use and productivity of annual legume-based pasture systems in the south-west of Western Australia. Proceedings, XVII International Grassland Congress I, Palmerston North, New Zealand, 8-21 February 1993, 274-275

(5) FAO (2010) The State of Food and Agriculture. Livestock in the Balance. Food and Agriculture Organization of United Nations, Rome

(6) Finn JA, Kirwan L, Connolly J, Sebastià MT, Helgadottir A, Baadshaug OH, Bélanger G, Black A, Brophy C, Collins RP, Čop J, Dalmannsdóttir S, Delgado I, Elgersma A, Fothergill M, Frankow-Lindberg BE, 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, 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. J Appl Ecol 50:365-375

(7) Piluzza G, Sulas L, Bullitta S (2014) Tannins in forage plants and their role in animal husbandry and environmental sustainability: a review. Grass Forage Sci 69:32-48

(8) Porqueddu C, Gonzales F (2006) Role and potential of annual pasture legumes in Mediterranean farming systems. Pastos 36:125-142

(9) Porqueddu C, Melis RAM, Re GA, Usai M, Marchetti M (2012) Bio-agronomic traits of *Psoralea bituminosa* and *P. morisiana* accessions collected in Sardinia. Option Mediterr A 102:139-143

(10) Sulas L (2005) The future role of forage legumes in Mediterranean-climate areas. In: Reynolds S, Frame J (eds) Grasslands: Developments, Opportunities, Perspectives. Food and Agriculture Organization of United Nations, Rome / Science Publishers, Enfield, 29-54

Annual forage legumes in temperate South-East Europe

by Vojislav MIHAILOVIĆ[1], Aleksandar MIKIĆ[1]*, Pero ERIĆ[2], Branko ĆUPINA[2], Sanja VASILJEVIĆ[1], Đura KARAGIĆ[1], Lana ZORIĆ[3], Vuk ĐORĐEVIĆ[1], Dragan MILIĆ[1], Đorđe KRSTIĆ[2], Snežana Anđelković[4], Bojan ZLATKOVIĆ[5], Mirjana SREBRIĆ[6], Marina Tomičić[1], Branko ĐURIĆ[7], Vesna PERIĆ[6], Snežana KATANSKI[1], Branko MILOŠEVIĆ[1], Svetlana VUJIĆ[2], Dalibor ŽIVANOV[1] and Anja DOLAPČEV[1]

Abstract: Pea and common vetch are the most important annual forage legumes in South-East Europe, providing quality hay, silage and haylage in ruminant feeding, either as sole crops or in intercropping with cereals. A complex evaluation of the Novi Sad annual legume collection identified currently wild, neglected and unknown species and crops as new sources of quality plant protein.
Key words: annual legumes, crude protein, forage dry matter, South-East Europe

Introduction

Forage legumes are one of the most important sources of ruminant feed in many countries of temperate South-East Europe, with lucerne (*Medicago sativa* L.) and red clover (*Trifolium pratense* L.) being the most widely cultivated and commonly researched (9, 11). Annual legumes are less commonly grown, but, due to many environmental and other benefits, have a specific place in numerous farming systems (1, 10). They may be used as fresh forage, hay, forage meal, silage, haylage, dry grain and straw, while some are also suitable for grazing (12).

[1]Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikic@ifvcns.ns.ac.rs)
[2]University of Novi Sad, Faculty of Agriculture, Department of Field and Vegetable Crops, Novi Sad, Serbia
[3]University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Novi Sad, Serbia
[4]Institute for Forage Crops, Kruševac, Serbia
[5]University of Niš, Faculty of Sciences and Mathematics, Department of Biology and Ecology, Niš, Serbia
[6]Maize Research Institute Zemun Polje, Belgrade, Serbia
[7]University of Banja Luka, Faculty of Agriculture, Banja Luka, Republic of Srpska, Bosnia and Herzegovina

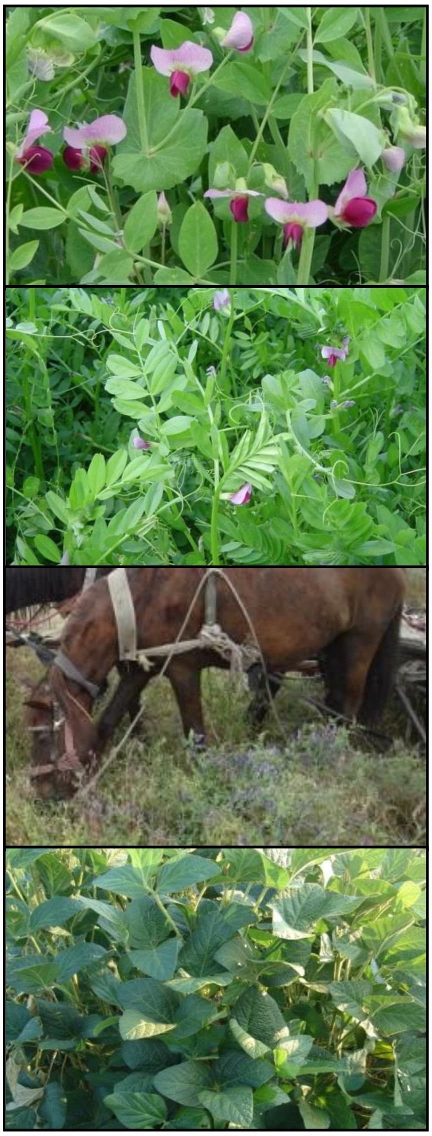

Figure 1. Some annual forage crops: (from above) 1) field pea and 2) common vetch are common in South-East Europe, with advanced breeding programmes, 3) hairy vetch, omnipresent in tilled land, rich in local landraces and grown sporadically, and 4) soya bean, with a great potential for using in other forms than grain

A long-term evaluation of more than 1,000 accessions of numerous annual legume taxa, including several institutions and comprising botanical, anatomical, morphological, bio-chemical and genetic analyses, assessed their potential for forage production (Table 1).

Traditional and most grown

It is estimated that, in Serbia, peas are cultivated on up to 40,000 ha in total, with forage pea (Fig. 1) on 5,000 ha, dry pea on 22,000 ha and vegetable pea on 14,000 ha (5). Forage pea has a high biological value for ruminant feeding, with a net energy of lactation typically ranging from 25,000 to 29,000 MJ ha^{-1} and net energy of maintenance from 24,000 to 28,000 MJ ha^{-1}. The metabolisable energy of dry pea grain is equal to that of soya bean (*Glycine max* (L.) Merr.) meal, 11.6 MJ kg^{-1}, as well as the milk and meat forage units of 4.18 MJ kg^{-1}. If pea grain is ground more coarsely than for non-ruminants, its protein may pass through the rumen and reach the small intestines. A typical daily allocation of peas for dairy cows, producing between 25 kg and 30 kg of milk daily, is 6.5 kg (6). Pea may also be included in the diets for sheep, goats and horses. Common (*Vicia sativa* L.) and other vetches (Fig. 1) are grown in Serbia for the last century on 7,000 - 9,000 ha. Autumn- and spring-sown pea and vetch genotypes are mostly grown in mixtures with cereals (8), usually at a ratio of 75% : 25%, considered a balance between forage yield and quality. Common vetch hay and grain are also quality feed for sheep in arid climates (4).

Taming the wild, returning the forgotten and introducing the novel

There are a number of annual legume species, either currently regarded as part of the wild flora or that are under-utilised in farm practice, that have a great potential for forage production. Among those currently

Table 2. Forage dry matter and protein yield in some annual legumes (unpublished data)

Genus, species and subtaxa	Hay yield (t ha^{-1})	Forage crude protein yield (kg ha^{-1})		
		Average	Min	Max
Arachis pintoi	1.8	281	265	298
Cajanus cajan	6.5	1034	876	1345
Calopogonium mucunoides	2.8	453	431	465
Cicer arietinum	7.5	1202	1102	1567
Glycine max	15.2	2436	2134	2588
Glycine soja	3.5	565	554	571
Lablab purpureus	9.7	1558	1344	1778
Lathyrus aphaca	4.8	763	755	777
Lathyrus cicera	7.4	1177	1053	1356
Lathyrus latifolius	10.0	1594	1348	1688
Lathyrus ochrus	9.0	1444	1301	1578
Lathyrus odoratus	6.8	1084	998	1256
Lathyrus sativus	11.8	1882	1776	2178
Lathyrus sylvestris	9.9	1584	1455	1623
Lathyrus tingitanus	7.7	1238	1025	1534
Lathyrus tuberosus	5.7	907	789	1104
Lens culinaris	6.3	1004	945	1345
Lens nigricans	6.4	1026	1001	1078
Lupinus albus	8.8	1400	1256	1687
Lupinus angustifolius	7.4	1191	1098	1352
Lupinus hispanicus	5.7	907	887	1100
Lupinus luteus	6.4	1030	988	1254
Lupinus mutabilis	8.4	1346	1288	1443
Macrotyloma axillare	3.9	623	598	727
Medicago truncatula	5.7	914	902	956
Mucuna pruriens	11.0	1760	1689	1895
Ornithopus sativus	6.3	1004	924	1105
Pisum abyssinicum	7.9	1268	1178	1567
Pisum fulvum	6.0	954	932	1032
Pisum sativum var. *arvense*	10.9	1748	1654	2012
Pisum sativum var. *sativum*	11.5	1843	1744	2314
Pisum sativum subsp. *elatius*	10.8	1732	1454	1799
Stylosanthes capitata	2.6	410	402	433
Trigonella phoenum-graecum	5.8	929	901	1062
Vicia beghalensis	9.0	1432	1321	1665
Vicia ervilia	8.4	1350	1267	1789
Vicia faba	10.7	1706	1653	1974
Vicia grandiflora	8.2	1311	1221	1564
Vicia hirsuta	4.5	723	654	772
Vicia narbonensis	9.5	1518	1234	1875
Vicia noeana	8.1	1289	1089	1523
Vicia pannonica	8.3	1329	1176	1658
Vicia sativa subsp. *nigra*	7.3	1162	1034	1362
Vicia sativa subsp. *sativa*	10.5	1674	1245	2332
Vicia serratifolia	6.7	1076	978	1285
Vicia villosa	12.1	1940	1572	2455
Vigna angularis	6.3	1000	885	1276
Vigna mungo	6.1	969	834	1310
Vigna radiata	6.3	1011	923	1189
Vigna unguiculata	9.1	1450	1211	1675

found in the wild, there are those such as *Lathyrus latifolius* L., *Pisum abyssinicum* A. Braun, *Vicia grandilfora* Scop. and *V. serratifolia* Jacq. (Table 1; 7). Developing the first cultivars of such species requires a long-term breeding effort in terms of uniform maturity and reliable seed production.

Among the most underutilised annual legume crops in the Balkans, once widely cultivated all over the peninsula, it is *Lathyrus sativus* L., *Vicia ervilia* (L.) Willd., *V. faba* L., *V. pannonica* Crantz and *V. villosa* Roth (Fig. 1, Table 1) that represent the best material for potential reintroduction to the fields of Southeast Europe for using in the form of hay, silage or haylage of excellent quality, especially if intercropped with cereals (3).

Soya bean (Fig. 1), *Lablab purpureus* Sweet and *Lupinus albus* L. are the best candidates to be introduced as novel annual forage crops, being able to provide quality plant protein during the summer (2).

To Rade Matić and Thomas E. Devine.
In memory of Imre I. Pataki (1958-2014).

Acknowledgements

Projects TR-31016 and TR-31024 of the Ministry of Education, Science and Technology of the Republic of Serbia.

References

(1) Ćupina B, Manojlović M, Krstić Đ, Čabilovski R, Mikić A, Ignjatović-Ćupina A, Erić P (2011) Effect of winter cover crops on the dynamics of soil mineral nitrogen and yield and quality of Sudan grass (*Sorghum bicolor* (L.) Moench). Aust J Crop Sci 5:839-845

(2) Devine TE, Card A (2013) Forage soybeans. Legum Perspect 1:43-44

(3) Karagić Đ, Mikić A, Milosević B, Vasiljević S, Dušanić N (2012) Common vetch-wheat intercropping: Haylage yield and quality depending on sowing rates. Afr J Biotechnol 30:7637-7642

(4) Matić R, Nagel S, Robertson S, Young I, Mihailović V, Mikić A, Kirby G (2005) Vetch (*Vicia* spp) expansion and use in Australia. Biotechnol Anim Husb 21:5-6:2:203-207

(5) Mihailović V, Mikić A, Ćupina B, Erić P (2005) Field pea and vetches in Serbia and Montenegro. Grain Legum 44:25-26

(6) Mihailović V, Mikić A, Erić P, Vasiljević S, Ćupina B, Katić S (2005) Protein pea in animal feeding. Biotechnol Anim Husb 21:5-6:1:281-285

(7) Mikić A, Mihailović V (2014) Significance of genetic resources of cool season annual legumes. I. Crop wild relatives. Ratar Povrt 51:62-82

(8) Mikić A, Ćupina B, Rubiales D, Mihailović V, Šarūnaitė L, Fustec J, Antanasović S, Krstić Đ, Bedoussac L, Zorić L, Đorđević V, Perić V, Srebrić M (2015) Models, developments, and perspectives of mutual legume intercropping. Adv Agron 130:337-419

(9) Milić D, Katić S, Karagić Đ, Gvozdanović-Varga J, Petrović S, Boćanski J (2011) Genetic control of agronomic traits in alfalfa (*M. sativa* ssp. *sativa* L.). Euphytica 182:25-33

(10) Phelan P, Moloney AP, McGeough EJ, Humphreys J, Bertilsson J, O'Riordan EG, O'Kiely P (2015) Forage legumes for grazing and conserving in ruminant production systems. Crit Rev Plant Sci 34:281-326

(11) Vasiljević S, Glamočić D, Jajić I, Ćupina B, Katić S, Milić D, Mikić A (2008) Fibre fraction of red clover (*Trifolium pratense* L.) at different harvest over two seasons. Grassl Sci Eur 13:510-512

(12) Zorić L, Mikić A, Ćupina B, Luković J, Krstić Đ, Antanasović S (2014) Digestibility-related histological attributes of vegetative organs of barrel medic (*Medicago truncatula* Gaertn.) cultivars. Zemdirb Agric 101:257-264

Forage and grain legumes in ruminant production systems in Bangladesh

by Nathu Ram SARKER[1]* and Md. Omar ALI[2]

Abstract: Forage legumes and grain legumes play a significant role in dairying and cattle finishing as well as being used for human consumption in Bangladesh. The area of 748,000 ha of legumes include lentil (*Lens culinaris* Medik., with 182,000 ha), field pea (*Pisum sativum* L.), mung bean (*Vigna radiata* (L.) R. Wilczek), blackgram (*Vigna mungo* (L.) Hepper), grass pea (*Lathyrus sativus* L., with 293,000 ha), cowpea (*Vigna unguiculata* (L.) Walp.) and arhar or pigeon pea (*Cajanus cajan* (L.) Millsp.).The availability of tropical forages is mostly seasonal, being bountiful after the monsoon but meager in the dry season and during floods.

Key words: flooded areas, forage legume, grain legume, low lying, season

Introduction

Bangladesh has a population density of 976 km^{-2} and 0.05 ha cultivable land per capita (2). According to the DAE (3), legumes cover about 748,000 ha, with grass pea (*Lathyrus sativus* L., 293,000 ha) dominating, followed by lentil (*Lens culinaris* Medik., 182,000 ha). Most of the legumes are grown in Rajshahi (26%) followed by Barisal (24%), Dhaka (22%) and Khulna (17%), with the remainder in Chittagong and Sylhet. Green forage legume and grain legume availability are seasonal with good growth occurring after the monsoon. In contrast, there is a shortage of forage during the dry season and when there is flooding. The unavailability of forage is severe during July to October when most of the fields are under rice cultivation and all low lying areas are flooded. Forage shortage also occurs during late March to late April when the winter forages have been consumed. In eastern areas summer species such as cowpea (*Vigna unguiculata* (L.) Walp.) are cultivated for forage and grain to partially alleviate this shortage. Farmers in some areas grow forage legumes such as grasspea and black gram (*V. mungo* (L.) hepper) after the flood waters recede in October. These legumes supply green forage from late November to February. Their fresh output varies from 5 t ha^{-1} to 10 t ha^{-1}. Not surprisingly, in these areas both the size of the cattle herd and the level of individual animal productivity are higher than in other parts of the country.

Research accomplishment on feeding tropical forages and grain legumes

1) *Supplementing Napier grass (*Pennisetum purpureum *Schumach.) with legume forage.* A 45 day feeding trial was conducted to increase the milk butterfat content of lactating cows fed Napier grass by supplementation with legume and oils. Cows were offered T_0 (Napier silage alone as a control), T_1 (75% Napier silage + 25% grass pea hay, dry matter basis), T_2 (Napier silage + concentrate with coconut cake) and T_3 (Napier silage + concentrate with beef tallow). The three concentrate diets were iso-nitrogenous. Although milk yield was not influenced by dietary treatment, Table 1 shows that milk butterfat content was higher for T_1 than T_0, and with T_2 and T_3 being intermediate. Treatment effects also occurred with milk protein and lactose but not with minerals.

2) *Supplementing growing calves with different rates of* Vigna mungo *hay.* Hossain et al. (4) examined the effect of four rates of supplementation with *Vigna mungo* hay on feed intake, digestibility and growth rate of indigenous cattle. Groups of bull calves were offered VM0 (basal diet + 0 g vigna hay DM), VM106 (basal diet + 106g vigna hay DM), VM212 (basal diet + 212g vigna hay DM) and VM318 (basal diet + 318g vigna hay DM). The basal diet was formulated with rice (*Oryza sativa* L.) straw (*ad libitum*), wheat (*Tritivum aestivum* L.) bran, rice polishings, mustard oil cake and molasses. Straw and total DM intakes and apparent diet digestibility coefficients were increased, and live weight gain and feed conversion were improved, by adding increasing amounts of vigna hay to the diets (Table 2).

Rahman et al. (5) evaluated the effects of supplementing cowpea hay and concentrate with high yielding fodder (HYV) on the performances of growing (4-5 month old)

Table 1. Effect of supplements to Napier grass on milk composition

	Treatments				*P*
	T_0	T_1	T_2	T_3	
Fat (%)	4.03^{b}	4.85^{a}	4.41^{ab}	4.38^{ab}	< 0.01
Protein (%)	3.82^{b}	3.92^{a}	3.86^{ab}	3.79^{b}	< 0.05
Lactose (%)	5.52^{ab}	5.63^{b}	5.55^{ab}	5.46^{a}	< 0.05
SNF (%)	10.16^{a}	10.39^{b}	10.23^{ab}	10.06^{a}	< 0.05
Minerals (%)	0.65	0.64	0.63	0.66	NS

Means with different superscripts in the same row differ significantly ($P < 0.05$)

[1]Bangladesh Livestock Research Institute, Dhaka, Bangladesh (sarkernr@yahoo.com)
[2]Bangladesh Agricultural Research Institute, Pulses Research Centre, Gazipur, Bangladesh

Table 2. Feed intake, live weight gain and feed conversion efficiency responses of cattle to increasing amounts of vigna hay

	VM0	VM106	VM212	VM318	SEM	S
Initial weight (kg)	83.6	83.0	83.6	83.3	-	-
Liveweight gain (LWG, g d^{-1})	243^{c}	298^{b}	327^{ab}	358^{a}	9.8	0.005
DM intake (DMI, g d^{-1})						
Rice straw	2530^{c}	2664^{b}	2803^{a}	2913^{a}	39.0	0.005
Vigna hay	0	106	212	318	-	-
Concentrate	869	869	869	869	-	-
Total intake	3399^{d}	3633^{c}	3875^{b}	4091^{a}	36.1	0.005
Total intake (kg % liveweight)	3.7^{c}	3.9^{bc}	4.0^{ab}	4.2^{a}	0.06	0.040
Feed conversion efficiency (DMI kg^{-1} LWG)	14.0^{a}	12.2^{b}	11.8^{b}	11.4^{b}	0.36	0.005

^{a,b,c}Mean values having different superscripts in a row differ at P <0.05); SEM: standard error of the mean; S: significance; DM: dry matter

Table 3. Intake and growth of Brown Bengal goats

	T_0	T_1	T_2	T_3	S
Total DM intake (DMI, g d^{-1})	288.0	285.7	293.5	301.4	NS
Total DM intake (kg % liveweight)	4.00	3.96	4.08	4.16	NS
Total CP intake (g d^{-1})	38.68^{b}	42.08^{b}	48.31^{a}	38.77^{b}	*
Initial liveweight (kg)	5.41	5.44	5.47	5.45	NS
Liveweight gain (LWG, gday)	47.3	49.2	49.1	48.9	NS
Feed conversion efficiency (kg DMI kg^{-1} LWG)	6.18	5.90	6.02	6.29	NS

S: significance; NS = non-significant, *P > 0.05; DM: dry matter; CP: crude protein

Table 4. Yearly production of different relay pulses as vegetable for human and fodder for livestock

Treatment	First harvest of vegetable (DAE)	Last harvest of vegetable (DAE)	Vegetable harvesting duration (days)	Frequency of vegetable harvesting	Vegetable yield (t ha^{-1})	Fodder Yield (t ha^{-1})
Grass pea	53.0^{b}	101.0	48	6.5^{ab}	1.23^{b}	8.37^{b}
Chickpea	57.5^{a}	98.0	40	5.5^{b}	0.75^{c}	3.25^{c}
Field pea	53.0^{b}	101.0	48	7.5^{a}	1.63^{a}	9.50^{a}
Significance	*	NS	NS	*	*	*

Means with different letters within the same column are significantly (p < 0.05) different

Brown Bengal goats for 75 days. The goats were offered T0 (natural grazing + 101 g concentrate), T1 (*ad libitum* Napier-3 + *ad libitum* cowpea hay + 101 g concentrate), T2 (*ad libitum* Napier-4 + *ad libitum* cowpea hay + 101 g concentrate) and T3 (*ad libitum* ruzi grass (*Brachiaria ruziziensis* Germ. & C.M. Evrard) + *ad libitum* cowpea hay + 101 g concentrate). Feeding growing Brown Bengal goats with natural grass or mixed roughage of Napier-3, Napier-4 and ruzi grass with cowpea hay did not alter DM intake or animal performance (Table 3). The total CP intake was higher (p < 0.05) for T2 compared to the other treatments.

3) *Agronomic study of legume production as forage and grain.* A field experiment was conducted for two consecutive years on calcareous grey food plain soils at the Pulses Research Centre of Bangladesh Agricultural Research Institute (BARI), Ishurdi, Pabna, Bangladesh. The annual average yields for three pulses are presented in Table 4. The longest duration until the first harvest of a vegetable was 57 days after emergence (DAE) for chickpea (*Cicer arietinum* L.) while the duration until the final and/or last harvest (between 98 and 101 days) was non-significantly different among these pulses. The highest annual yield of vegetable was obtained from field pea and the lowest was from chickpea. The highest average yearly fodder yield was also produced by field pea and the lowest again was by chickpea. It was also reported that clipping of the young shoots during vegetative growth caused increase in auxiliary branches which resulted in higher by-product yields in chickpea (1, 6, 7).

Conclusion

Forage and grain legumes are important feed sources for livestock and food for human consumption in Bangladesh. In addition, the cropping system consisting of using the field pea (as a relay or cash crop) between the monsoon and a late autumn rice crop to produce a vegetable for human consumption and a forage for livestock is worthwhile. Furthermore, it will be important to utilize fallow lands for legume production and to identify legumes that can be sustainably sown and harvested between successive rice crops.

References

(1) Agrikar GP (1990) Pulse Crops of India. Indian Council of Agricultural Research New Delhi

(2) Bangladesh Bureau of Statistics (2011) Statistical Yearbook of Bangladesh. Statistics Division, Ministry of Planning, Government of People's Republic of Bangladesh, Dhaka

(3) Department of Agriculture Extension (2014) Crop Statistics. Government of People's Republic of Bangladesh, Dhaka

(4) Hossain MS, Miah MY, Khandaker ZH, Islam F (2015) Effect of different levels of matikalai (*Vigna mungo*) hay supplementation to straw-based diets on feed intake, digestibility and growth rate of indigenous cattle. Livest Res Rural Devel 27:2:27

(5) Rahman MM, Alam MA, Sarker NR (2015) Effect of feeding different high yielding fodders on growth performance of growing Brown Bengal goats. Proceedings, Bangladesh Livestock Research Institute Annual Research Review Workshop, Dhaka, Bangladesh, 2015, 25-26

(6) Saxena NP, Sheldrake AR (1979) Physiology of growth, development and yield of chickpea in India. Proceedings, International Workshop on Chickpea Improvement, Hyderabad, India, February-March 1979, 106

(7) Yadav DS, Panwar KS, Singh VK (1994) Management of pulse crop in sequential cropping. Proceedings, International Symposium on Pulses Research, New Delhi, India, 2-6 April 1994, 27

Origin and etymology of some forage legumes

by Aleksandar MIKIĆ

Abstract: Most of the annual and perennial herbaceous forage legumes originated in European Siberian, Mediterranean and Near Eastern centres of diversity. Historical linguistics may assist in assessing domestication, introduction or etymology of diverse crops, as presented in the etymologies of the genera *Lotus*, *Medicago*, *Pisum*, *Trifolium* and *Vicia*.

Key words: centres of diversity, etymology, forage legumes, historical linguistics

Forage, grazing and browsing

A vast majority of the legumes species used in ruminant feeding worldwide are herbaceous plants, especially in temperate regions. Shrubs and trees are more typical for the warmer climates. If cut and used as fresh or dry above ground biomass, especially in full bloom, it is usually referred to as *forage*. The term *grazing* is used to denote feeding ruminants directly from grasslands, while *browsing* means eating the leaves of shrubs and low trees (2).

Centres of diversity

Today, almost all economically important forage legumes are globally widespread and cultivated. Most of the annual and perennial herbaceous forage legumes originated in European Siberian, Mediterranean and Near Eastern centres of diversity (Table 1). Legumes and shrubs are mainly an important source of plant protein in their primeval homelands, such as Australia and Southeast Asia (3).

Etymology

Historical linguistics may assist in assessing domestication, introduction or etymology of diverse crops (1). Some examples of forage legume genera are presented as follows.

Table 1. Primary centres of diversity of some forage legume herbaceous plants, shrubs and trees (3)

Species	Primary centre of diversity
Acacia aneura F. Muehl. ex Benth.	Australian
Albizia lebbeck (L.) Benth.	Indochinese-Indonesian
Arachis pintoi Krapov. & W. C. Greg.	South American
Astragalus cicer L.	European Siberian
Coronilla varia L.	European Siberian
Galega officinalis L.	European Siberian
Galega orientalis Lam.	Near Eastern
Glycine max (L.) Merr.	Chinese-Japanese
Hedysarum coronarium L.	Mediterranean
Lablab purpureus Sweet	African
Lathyrus sativus L.	Mediterranean
Leucaena leucocephala (L.) de Wit	Central American and Mexican
Lotus corniculatus L.	European Siberian
Medicago lupulina L.	European Siberian
Medicago sativa L. subsp. *sativa*	Near Eastern
Melilotus albus Medik.	European Siberian
Melilotus officinalis (L.) Lam.	European Siberian
Onobrychis viciifolia Scop.	European Siberian
Ornithopus sativus Brot.	Mediterranean
Pisum sativum L.	Near Eastern
Stylosanthes spp.	South American
Trifolium alexandrinum L.	Mediterranean
Trifolium hybridum L.	European Siberian
Trifolium incarnatum L.	Mediterranean
Trifolium pratense L.	European Siberian
Trifolium repens L.	European Siberian
Trifolium resupinatum L.	Mediterranean
Trifolium subterraneum L.	Mediterranean
Trigonella foenum-graecum L.	Near Eastern
Vicia pannonica Crantz	Near Eastern
Vicia sativa L.	Near Eastern
Vicia villosa Roth	Near Eastern

- *Lotus*: derived from the Old Greek λωτός and described by Homer as a plant for feeding horses;
- *Medicago*: first cultivated in modern Iran, introduced into Greece in 5th century BC and named *medica* by Pliny and Palladius after the ancient Iranian people of Medes; the name *alfalfa* was introduced via Spanish from the Arabic فصفصة (*al-fiṣfiṣa*);
- *Pisum*: a latinised form of the Proto-Indo-European **pis-*, meaning 'to thresh';
- *Trifolium*: a complex word merging the Latin *tres* (*three*) and *folius* (*leaf*);
- *Vicia*: ultimately descending from the Proto-Indo-European **weik-, something pliable,* of an obviously descriptive nature.

Institute of Field and Vegetable Crops, Novi Sad, Serbia(aleksandar.mikic@ifvcns.ns.ac.rs)

Acknowledgements

Project TR-31024 of the Ministry of Education, Science and Technological Development of the Republic of Serbia.

References

(1) Mikić A (2012) Origin of the words denoting some of the most ancient Old World pulse crops and their diversity in modern European languages. PLoS ONE 7:e44512

(2) Skerman PJ (1977) Tropical Forage Legumes. Food and Agriculture Organization of the United Nations, Rome

(3) Zeven AC, Zhukovsky PM (1975) Dictionary of Cultivated Plants and Their Centres of Diversity. Centre for Agricultural Publishing and Documentation, Wageningen

Second International Legume Society Conference (ILS2) *2016: Legumes for a Sustainable World*

Tróia, Portugal, 12-14 October 2016

http://www.itqb.unl.pt/meetings-and-courses/legumes-for-a-sustainable-world/welcome#content

The International Legume Society and the Instituto de Tecnologia Química e Biológica of the Universidade Nova de Lisboa cordially invite you to join us at the Second International Legume Society Conference, scheduled from 12-14 October, 2016 at Tróia resort, in the vicinity of Lisbon, Portugal.

In a world urgently requiring more sustainable agriculture, food security and healthier diets the demand for legume crops is on the rise. This growth is fostered by the increasing need for plant protein and for sound agricultural practices that are more adaptable and environmentally sensitive. Food, feed, fiber and even fuel are all products that come from legumes – plants that grow with low nitrogen inputs and in harsh environmental conditions. The Second Legume Society Conference will be held during 2016 - the United Nations' International Year of Pulses. The goals of this UN International Year include: the encouragement of connections throughout the food chain that would better utilize pulse based proteins; increase global production of pulses; better utilization of crop rotations; and to address challenges in the trade of pulses.

The conference will address the following themes: Legume Quality and Nutrition; Farming Systems/Agronomy; Abiotic and Biotic Stress Responses and Breeding; Legume Genetic Resources; and New "Omics" Resources for Legumes. The health and environment benefits, as well as, the marketing of legumes will be transversal topics throughout the conference. Special attention will be given to foster the interaction of researchers and research programs with different stakeholders including farmers and farmer associations, seed/feed and food industries, and consumers. For this, the conference will also be the site of the Final Meeting of the EU-FP7 ABSTRESS project, the Annual Meeting of EU-FP7 LEGATO project; and final dissemination events of EU-FP7-ERANets MEDILEG and REFORMA. The results and conclusions from these four important research programs will be shared with conference attendees.

Please join us in beautiful Tróia, Portugal from 12-14 October, 2016! Plan now to include the Second ILS Conference in your busy agenda. Kindly share this information with any colleagues dealing with legumes.

Diego Rubiales, on behalf of the Scientific Committee
Pedro Fevereiro, Carlota Vaz Patto and Susana Araújo, on behalf of the Organizing Committee

Local Organizers

The Instituto de Tecnologia Química e Biológica / Universidade Nova de Lisboa (ITQB/UNL) will be responsible for organising the Conference, in cooperation with the International Legume Society. The official language of the Conference will be the English.

INSTITUTO DE TECNOLOGIA QUÍMICA E BIOLÓGICA ANTÓNIO XAVIER /UNL
Knowledge Creation

Conveners

Pedro Fevereiro - Universidade Nova de Lisboa (ITQB/UNL)
Carlota Vaz Patto - Universidade Nova de Lisboa (ITQB/UNL)
Susana Araújo - Universidade Nova de Lisboa (ITQB/UNL)

Scientific Coordinator

Diego Rubiales - CSIC, Córdoba, Spain

Local Organizer Committee (in alphabetic order)

Nuno Almeida - ITQB/UNL
Susana Araújo - ITQB/UNL
Ana Barradas - Fertiprado
Manuela Costa - Universidade do Minho
Isabel Duarte - Instituto Nacional de Investigação Agrária e Veterinaria (INIAV)
Sofia Duque - ITQB/UNL
Pedro Fevereiro - ITQB/UNL
Susana Leitão - ITQB/UNL
Eduardo Rosa - Universidade de Trás-os-Montes e Alto Douro
Marta Vasconcellos - Escola Superior de Biotecnologia, Universidade Católica
Carlota Vaz Patto - ITQB/UNL
Manuela Veloso - INIAV

Scientific Committee (in alphabetic order)

Michael Abberton - IITA, Nigeria
Shiv Kumar Agrawal - ICARDA, Syria
Paolo Annicchiarico - CREA-FLC, Italy
Stephen E. Beebe - CIAT, Colombia
Charles Brummer - University of California, USA
Adrian Charlton - FERA, UK
Gerard Duc - INRA, France
Noel Ellis - IYoP, New Zealand
Pedro Fevereiro - ITQB/UNL, Portugal
Judith Lichtenzveig - Curtin University, Australia
Kevin McPhee - North Dakota State University, USA
Aleksandar Mikić - Institute of Field and Vegetable Crops, Serbia
Eduardo Rosa - Universidade de Trás-os-Montes e Alto Douro, Portugal
Diego Rubiales - Institute for Sustainable Agriculture, CSIC, Spain
Fred Stoddard - University of Helsinki, Finland
Richard Thompson - INRA, France
Tom Warkentin - University of Saskatchewan, Canada

Venue

The conference will be held in Tróia in the vicinity of Lisbon, Portugal. Tróia is a beautiful sand peninsula dividing the Sado River from the Atlantic Ocean.

The nearest airport is the Lisbon International Airport, about 50 Km away. Shuttles will be made available from and to Lisbon International Airport.

During the period of Roman occupation, date from the 1st century to the 6th century AD, Tróia was an island of Sado delta, called Ácala Island.

The Sado Estuary Nature Reserve, where dolphins swim, and the Serra da Arrábida Natural Park, where a full developed Mediterranean forest can be seen, are two of the main natural attractions nearby Tróia peninsula.

The Tróia Golf Championship Course is considered the best course in Portugal in the categories of difficulty and variety. It also stands in 20th place in the list of the best golf courses in Europe drawn up by the Golf World magazine.

First tentative programme

October 10th and 11th, 2016

Ascochyta Workshop
Satellite projects meetings (to be defined)

October 11th, 2016

Evening: ILS2 Conference Registration

October 12th, 2016

08:00 Registration
09:00-09:30 Welcome addresses

09:30-10:30 Session 1, plenary: Legumes vale chain: market requirements and economic impact
09:30-10:00 Key lecture 1
10:00-10-30 Key lecture 2

10:30-11:00 Coffee break

11:00-12:00 Session 2, plenary: Legumes and environment
11:00-11:30 Key lecture 1
11:30-12:00 Key Lecture 2

12:00-13:00 Poster viewing

13:00-14:30 Lunch

14:30 – 16:00 Parallel sessions
Session 3, parallel: Session 3, parallel: Mechanisms of beneficial legume-microbe interactions
14:30-15:00 Key lecture
15:00-15:15 Oral presentation 1
15:15-15:30 Oral presentation 2
15:30-15:45 Oral presentation 3
15:45-16:00 Oral presentation 4

Session 4, parallel: Genetic resources
14:30-15:00 Key lecture
15:00-15:15 Oral presentation 1:
15:15-15:30 Oral presentation 2
15:30-15:45 Oral presentation 3
15:45-16:00 Oral presentation 4

16:00-16:30 Coffee break

16:30-17:30 Parallel sessions
Session 5, parallel: Legumes value chain: market requirements and economic impact (cont.)
16:30-16:45 Oral presentation 1
16:45-17:00 Oral presentation 2
17:00-17:15 Oral presentation 3
17:15-17:30 General discussion on Legumes value chain

Session 6, parallel: Legumes and environment (cont.)
16:30-16:45 Oral presentation 1
16:45-17:00 Oral presentation 2
17:00-17:15 Oral presentation 3
17:15-17:30 General discussion on Legumes and environment

17:30-18:30 Poster session 1
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters on the sessions of the day

20:45 Third International Legume Football Cup: semi-finals

October 13th, 2016

8:30-10:00 Session 7, plenary: Legumes in food and feed and other alternative uses
08:30-09:00 Key lecture 1
09:00-09:30 Key lecture 2
09:30-10:00 Highlighted oral presentation

10:00-10:30 Coffee break;

10:30-12:00 Session 8, plenary: Frontiers in legume genetics and genomics
10:30-11:00 Key lecture
11:00-11:30 Highlighted oral presentation
11:30-12:00 Highlighted oral presentation

12:00-13:00 Poster session 2
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters from the sessions of the day

13:00-14:30 Lunch

14:30 – 16:00 Parallel sessions
Session 9 parallel: Legumes in food and feed and other alternative uses (cont.)
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on Legumes in food and feed and other uses

Session 10 parallel: Frontiers in legume genetics and genomics (cont.)
14:30-14:45 Oral presentation 3
14:45-15:00 Oral presentation 4
15:00-15:15 Oral presentation 6
15:15-15:30 Oral presentation 7
15:30-15:45 Oral presentation 8
15:45-16:00 General discussion of genetics and genomics

16:00-16:30 Coffee break;

16:30-18:00 Parallel sessions
Session 11, parallel: Frontiers in plant and crop physiology
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3

Session 12 parallel: Integrated pest and disease management
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3

17:45-19:00 ILS General Assembly

20:45 Third International Legume Football Cup: finals

October 14th, 2016

8:30-10:00 Session 13 plenary: Frontiers in legume breeding
08:30-09:00 Key lecture
09:00-09:30 Highlighted oral presentation
09:30-10:00 Highlighted oral presentation

10:00-10:30 Coffee break;

10:30-12:00 Session 14, plenary: Frontiers in legume agronomy
10:30-11:00 Key lecture
11:00-11:30 Highlighted oral presentation
11:30-12:00 Highlighted oral presentation

12:00-13:00 Poster session 3
Slots of 3 min flash presentations (+ 2 min questions) from 12 selected posters from the sessions of the day

13:00-14:30 Lunch

14:30 – 16:00 Parallel sessions
Session 15, parallel: Advances in legume breeding (cont.)
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on advances in legume breeding

Session 16 parallel: Advances in legume agronomy (cont.)
14:30-14:45 Oral presentation 1
14:45-15:00 Oral presentation 2
15:00-15:15 Oral presentation 3
15:15-15:30 Oral presentation 4
15:30-15:45 Oral presentation 5
15:45-16:00 General discussion on advances in legume agronomy

16:00-16:30 Coffee break;

16:30-18:00 Parallel sessions
Session 17, parallel: Seed technology, marketing and knowledge-transfer
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3
17:45-18:00 Oral presentation 4

Session 18 parallel: Resistance to biotic and abiotic stresses
16:30-17:00 Key lecture
17:00-17:15 Oral presentation 1
17:15-17:30 Oral presentation 2
17:30-17:45 Oral presentation 3
17:45-18:00 Oral presentation 4

18:00-19:00 Concluding session
Posters and oral presentations awards
ILS Honorary member's awards

20:00 Farewell Dinner

North American Alfalfa Improvement Conference, Trifolium and Grass Breeders Group Joint Conference
Madison, USA, 12-14 July 2016
https://www.naaic.org/conf/currentMeeting.php

26th General Meeting of the European Grassland Federation
Trondheim, Norway, 5-8 September 2016
http://www.egf2016.no

XIV Congress of the European Society for Agronomy
Edinburgh, UK, 5-9 September 2016
http://esa14.org.uk

8th International Conference on Legume Genomics and Genetics
Siofok, Hungary, September 2017

10th World Soybean Research Conference
Savannah, USA, 10-16 September 2017
http:// www.wsrc10.com

Legume Perspectives is an international peer-reviewed journal aiming to interest and inform a worldwide multidisciplinary readership on the most diverse aspects of various research topics and use of all kinds of legume plants and crops.

The scope of *Legume Perspectives* comprises a vast number of disciplines, including biodiversity, plant evolution, crop history, genetics, genomics, breeding, human nutrition, animal feeding, non-food uses, health, agroecology, beneficial legume-microorganism interactions, agronomy, abiotic and biotic stresses, agroeconomy, sociology, scientometrics and networking.

The issues of *Legume Perspectives* are usually thematic and devoted to specific legume species or crop, research topic or some other issue. They are defined by the Editorial Board, led by the Editor-in-Chief with the help from Assistant Editors, who select and invite one or more Managing Editors for each issue. Having accepted the invitation, the Managing Editor agrees with the Editorial Board the details, such as the deadline for collecting the articles and a list of the tentative contributors, from whom he, according to his own and free choice, solicit the articles fitting into the defined theme of an issue.

There is a possibility that every member of the global legume research community, with a preference of the International Legume Society members or established authorities in their field of interest, may apply to the Editorial Board to be a Managing Editor and suggest a theme for his issue, done simply by contacting the Editor-in-Chief by e-mail, with a clearly presented idea, structure and authors of the potential issue.

The articles published in *Legume Perspectives* are usually concise, clear and up-to-date reviews on the topic solicited by the Managing Editor from each author. Managing Editor is solely responsible for collecting the articles from the authors, anonymous peer-review, communicating with the Technical Editor and providing the authors with the proofs of their manuscript prior to the publication.

Legume Perspectives prefers a clear, simple and comprehensive writing style that would make its articles interesting and useful for both academic and amateur audience.

Legume Perspectives welcomes either longer (900-1,100 words + up to 3 tables, figures or photos + up to 10 references) or shorter (400-500 words + 1 table, figure, photograph or drawing + up to 4 references) manuscripts. The Editor-in-Chief, depending on the opinion of the Managing Editor, may allow any variation in length or structure, from case to case.

The manuscripts for *Legume Perspectives* should be prepared in Microsoft Office Word, using Times New Roman font, 12 points size and single spacing. Please provide each manuscript with a 100-word abstract and 4-6 key words listed alphabetically. The references should follow the style of the published papers in this issue, be given in full and listed alphabetically. The tables may be incorporated in the manuscript, while figures, photographs or drawings should be submitted separately as jpg files with a resolution of at least 300 dpi. The authors whose native language is not English are strongly advised to have their manuscripts checked by a native English speaker prior to submission.

Publishing articles in *Legume Perspectives* is free.

LEGUME PERSPECTIVES

Sponsorship list

INTERNATIONAL LEGUME SOCIETY
CÓRDOBA, SPAIN
www.ils.nsseme.com

SPANISH MINISTRY OF SCIENCE AND INNOVATION
SPANISH NATIONAL RESEARCH COUNCIL
www.csic.es

INSTITUTO DE TECNOLOGIA QUÍMICA E BIOLÓGICA
(UNIVERSIDADE NOVA DE LISBOA)
OEIRAS, PORTUGAL
www.itqb.unl.pt

INSTITUTE OF FIELD AND
VEGETABLE CROPS
NOVI SAD, SERBIA
www.nsseme.com

TEAGASC
OAK PARK, IRELAND
http://www.teagasc.ie

UNIVERSITY OF MANITOBA
WINNIPEG, CANADA
http://umanitoba.ca

Want to help the legume research network worldwide?

Support Legume Society and its journal today!

legume.society@gmail.com