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

Cécile Martin, Giuseppe Copani, Vincent Niderkorn

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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

Publishing Director

Diego Rubiales
CSIC, Institute for Sustainable Agriculture
Córdoba, Spain
diego.rubiales@ias.csic.es

Editor-in-Chief

Carlota Vaz Patto
Instituto de Tecnologia Química e Biológica António Xavier
(Universidade Nova de Lisboa)
Oeiras, Portugal
cpatto@itqb.unl.pt

Technical Editor

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

Front cover photo

A beef cow grazing alfalfa-grass pasture
by Emma McGeough

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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*

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Carte blanche
to...




...Pádraig
O'Kiely¹
and



Emma
McGeough²

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. 

¹Teagasc, Animal & Grassland Research and Innovation Centre, Grange, Ireland
(padraig.okiely@teagasc.ie)

²University 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 CARADUS²

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.

¹DairyNZ, Hamilton, New Zealand
(garry.waghorn@dairyNZ.co.nz)

²Grasslanz 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.

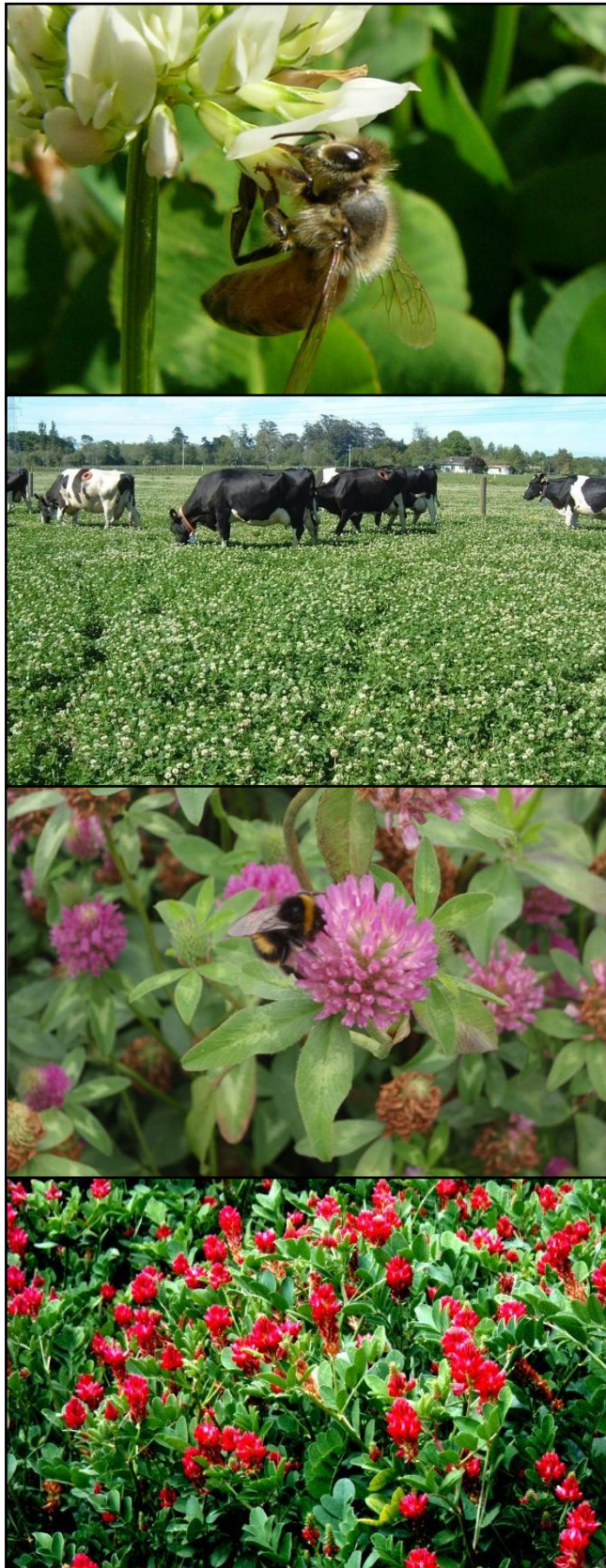


Figure 1. Some temperate perennial forage legumes; from the top down: white clover, white clover, red clover, sulla

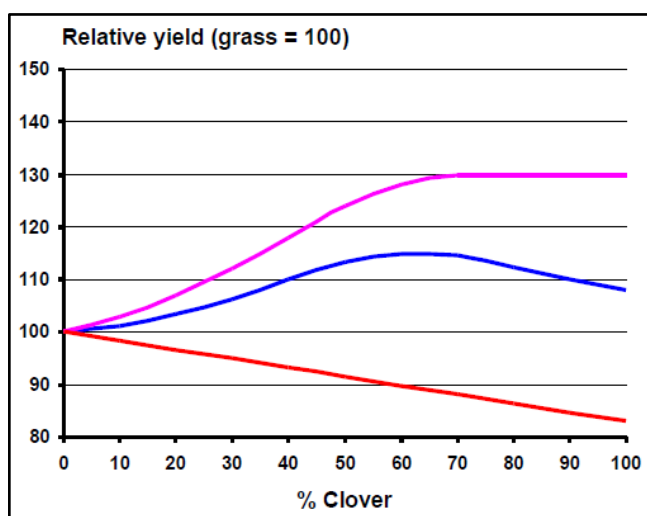


Figure 2. Effect of increasing percentages of white clover in ryegrass pasture on production (ha^{-1}) of dry matter (red line), milk (blue) and milk fat + protein (purple) (5)

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. 🌿

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

by Andreas LÜSCHER^{1*}, Matthias SUTER¹ and John A. FINN²

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 N₂ 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 N₂ fixation, yield

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



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)

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.

¹Agroscope, Institute for Sustainability Sciences, Zurich, Switzerland

(andreas.luescher@agroscope.admin.ch)

²Teagasc, Environment Research Centre, Johnstown Castle, Ireland

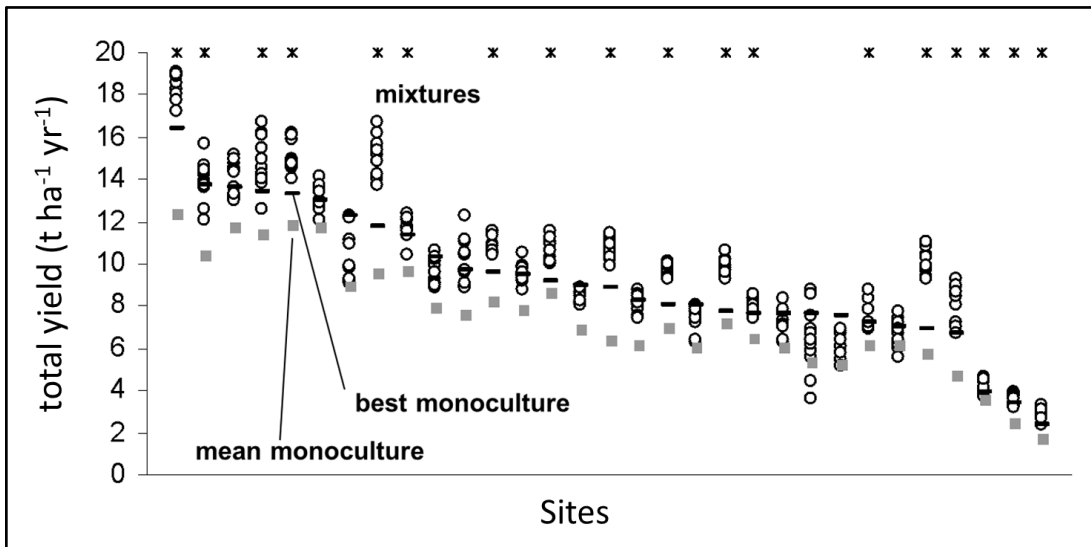


Figure 2. Four-species mixtures of two grasses and two legumes generally outperformed the best-performing monoculture, based on annual yield (dry matter) from experimental grassland field trials at each of 31 sites of the pan-European Agrodiversity experiment; open circles represent each of eleven mixture 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 N₂ 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 N₂ fixation is an important contribution to more environmental-friendly and resource-efficient agricultural systems. In grassland, symbiotically fixed N₂ 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 N₂ 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. badius* 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 disproportionately from elevated atmospheric CO₂ (10). In conclusion, it can be expected that forage legumes will become even more important in the future. 

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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 α -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)

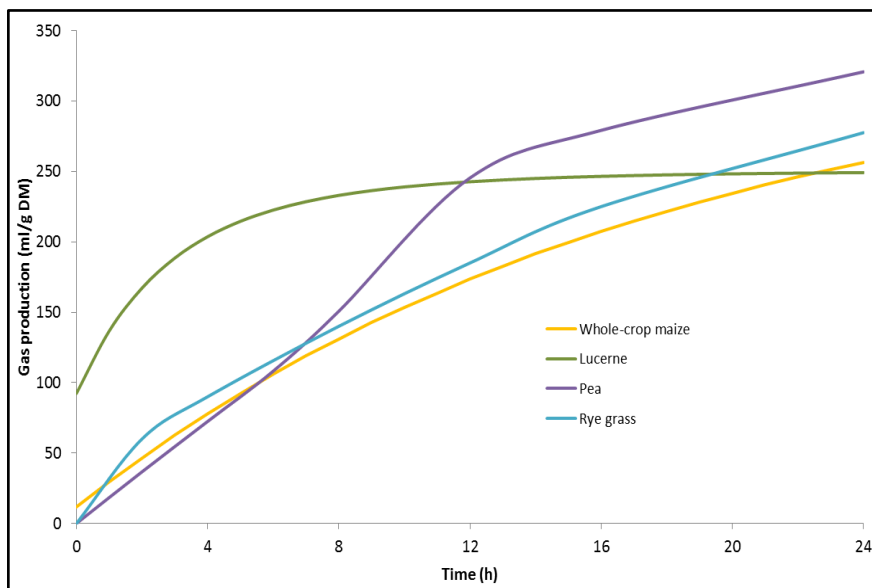


Figure 1. Exemplary evolution of gas over time when forage (lucerne) and grain (pea) legumes are incubated in an *in vitro* rumen system mimicking rumen microbial degradation; whole-crop maize at harvest and ryegrass are shown for the purpose of comparison

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. 

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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.

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 herbage. 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 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

Bertilson 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

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


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 (<i>F. arundinacea</i>)	White clover	More greasy	7
Grass silage (<i>D. glomerata</i>)	Lucerne silage	Higher beef flavour	2
Grazed grass (<i>C. dactylon</i>)	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 (<i>T. subterraneum</i>)	Gland clover (<i>T. glanduliferum</i>)	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. 

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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 N₂ 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

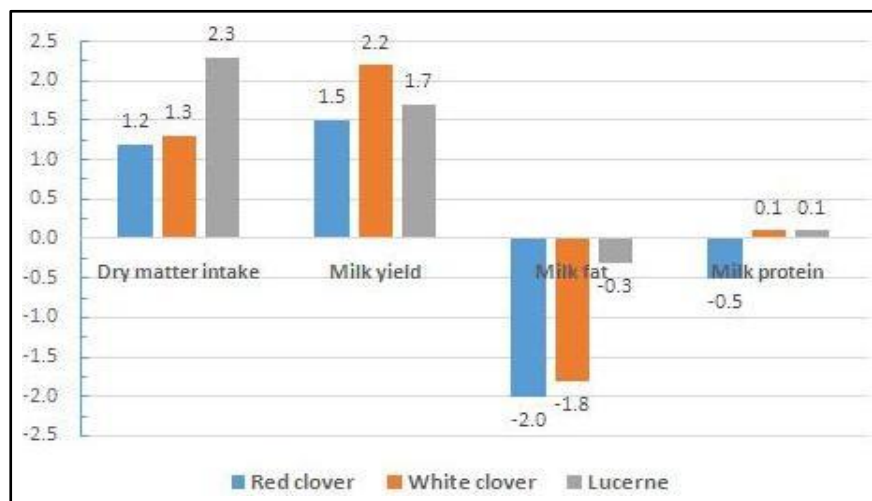
Forage legumes are often considered as an economically profitable alternative to grass and/or maize (*Zea mays* L.) based forages owing to their ability to provide biologically fixed nitrogen. Using forage legumes as feeds for high producing ruminant animals serves as an effective means to reduce dependence

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)

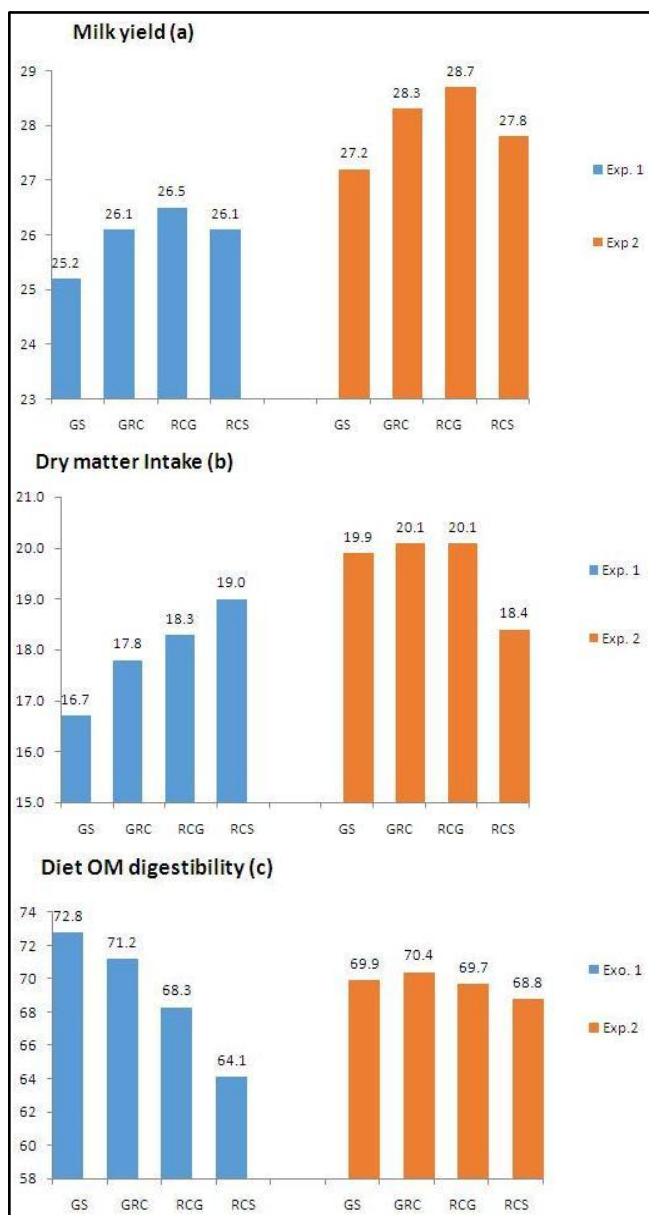


Figure 2. Effect of altering the forage ratio of grass and red clover silages on milk yield (a, kg d⁻¹), dry matter intake (b, kg d⁻¹) and diet organic matter (OM) digestibility (c, %) in experiments 1 and 2, respectively (8, 3); GS = grass silage, RCS = red clover silage, and GRC and RCG = 2:1 and 1:2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

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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.

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

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

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).

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

by Surya N. ACHARYA^{1*}, Edmund T. SOTTIE², Yuxi WANG¹ and Tim A. McALLISTER¹

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%).

¹Agriculture and Agri-Food Canada, Lethbridge Research Centre, Lethbridge, Canada (surya.acharya@agr.gc.ca)

²Agriculture 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 (September 15)	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 ^γ	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 ^γ	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 [×] (China)	Original population
LRC 3507	CN 31800	PGRC (China)	Original population
LRC 3511	Eski	Montana, USA	Original population (Eslick et al. 1967)
LRC 3519 ^γ	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 ^ω	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 viciifolia* subsp. *viciifolia*;
^γthe 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;
^ωthe 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;
[×]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. 

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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 tanniferous 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.

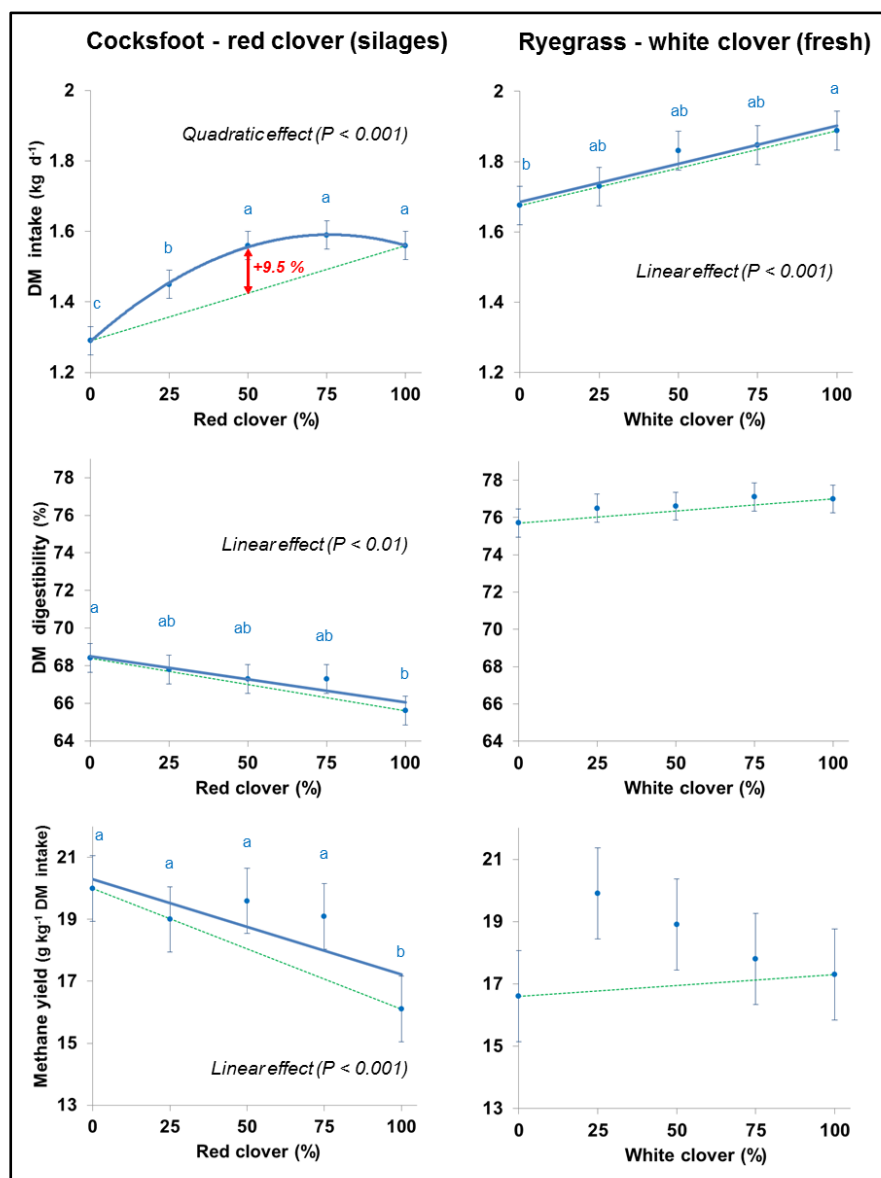


Figure 1. Voluntary dry matter (DM) intake, DM digestibility and methane yield in sheep fed with different proportions of cocksfoot and red clover silages, and ryegrass and white clover (fresh); full lines represent smoothed linear or quadratic responses, and dotted lines represent theoretical responses 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 (CH₄ yield) is inconsistent probably because of differences in forage composition (stage of maturity, preservation mode) and animal genotypes between studies. No change in CH₄ 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 CH₄ 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 CH₄-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. 

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

by Michael UNDI^{1*}, Karin WITTENBERG², Emma J. McGEOUGH² and Kim H. OMINSKI²

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 (CH₄) emissions and decreasing nitrous oxide (N₂O) 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 CH₄ 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

Introduction

Livestock production is a significant source of GHG emissions, generating carbon dioxide (CO₂), CH₄, and N₂O 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 CO₂ equivalents (CO₂e), 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 CO₂-eq kg⁻¹) compared to other livestock commodities including pork (3.5 kg CO₂-eq kg⁻¹), poultry (1.6 kg CO₂-eq kg⁻¹), milk (1.3 kg CO₂-eq kg⁻¹) and eggs (1.7 kg CO₂-eq kg⁻¹). In Canada, where the C footprint of beef production was estimated at 22 kg CO₂e kg⁻¹ carcass, 63% of the total emissions were associated with enteric CH₄ emissions while 27% were associated with N₂O from soil and manure (1). In the Canadian dairy sector, methane accounted for 56% (of which 86% originated from enteric fermentation) and N₂O for 40% of total GHG emissions (15). Loss of CH₄ and N₂O 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 CH₄ and N₂O 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 CH₄ emissions (12). Strategies to reduce enteric CH₄ emissions have been discussed in several reviews (6, 7). Several studies have reported that improved forage quality can reduce enteric CH₄ 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 acid 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).

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

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

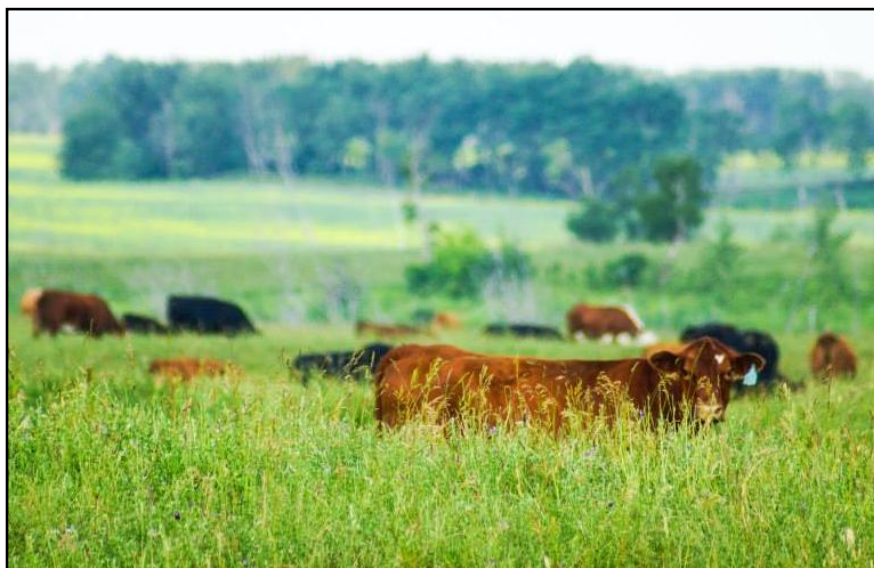


Figure 1. Beef cows grazing alfalfa-grass pasture

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

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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.

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 adaptation 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.

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

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

¹Cl150 = 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; ²SE: Standard Error; ³Significance: *** = $P < 0.001$, 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

¹Cl150 = 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; ²SE: Standard Error; ³Significance: *** = $P < 0.001$, 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. 

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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

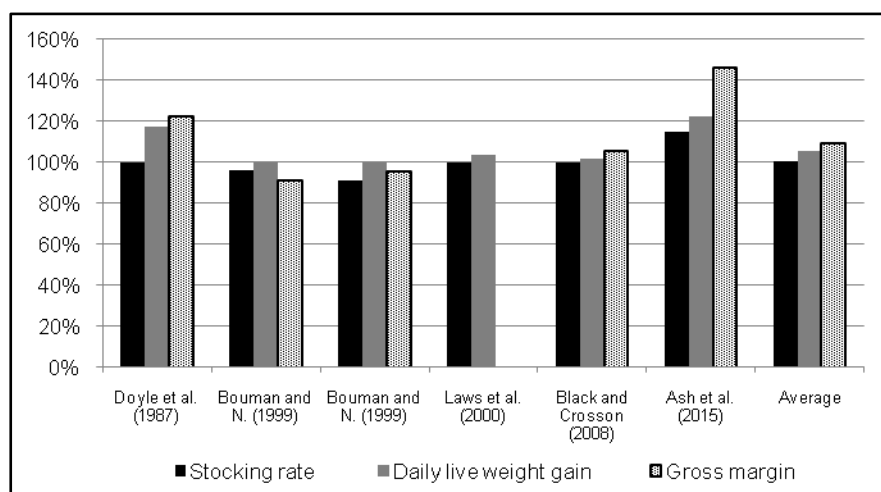
Introduction

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)

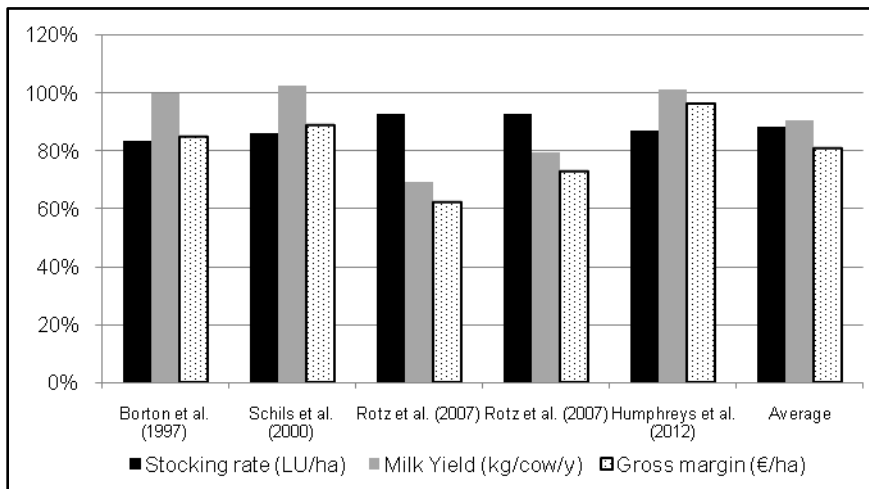


Figure 2. Relative stocking rate, milk yield and gross margin of dairy production systems based on grass/legume pastures compared to grass pastures with no legume

Bouman and Nieuwenhuys (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 suckler 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/clover 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. 

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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).

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).

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


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, overwintering 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. 

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Legumes for rainfed Mediterranean farming systems

by Rita MELIS^{1*}, Luciano PECETTI², Paolo ANNICCHIARICO² and Claudio PORQUEDDU¹

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

¹CNR, Institute for Animal Production System in Mediterranean Environment, Sassari, Italy (rita.melis@ispaam.cnr.it)

²CREA, 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. subterraneum* 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 as the potential to grow alfalfa in mixtures with summer-dormant perennial grasses (cocksfoot, *Dactylis glomerata* L., or tall fescue, *Festuca arundinacea* 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. 

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Annual forage legumes in temperate South-East Europe

by Vojislav MIHAILOVIĆ¹, Aleksandar MIKIĆ^{1*}, Pero ERIĆ², Branko ĆUPINA², Sanja VASILJEVIĆ¹, Đura KARAGIĆ¹, Lana ZORIĆ³, Vuk ĐORĐEVIĆ¹, Dragan MILIĆ¹, Đorđe KRSTIĆ², Snežana Anđelković⁴, Bojan ZLATKOVIĆ⁵, Mirjana SREBRIĆ⁶, Marina Tomičić¹, Branko ĐURIĆ⁷, Vesna PERIĆ⁶, Snežana KATANSKI¹, Branko MILOŠEVIĆ¹, Svetlana VUJIĆ², Dalibor ŽIVANOV¹ and Anja DOLAPČEV¹

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).

¹Institute of Field and Vegetable Crops, Novi Sad, Serbia (aleksandar.mikic@ifvcns.ns.ac.rs)

²University of Novi Sad, Faculty of Agriculture, Department of Field and Vegetable Crops, Novi Sad, Serbia

³University of Novi Sad, Faculty of Sciences, Department of Biology and Ecology, Novi Sad, Serbia

⁴Institute for Forage Crops, Kruševac, Serbia

⁵University of Niš, Faculty of Sciences and Mathematics, Department of Biology and Ecology, Niš, Serbia

⁶Maize Research Institute Zemun Polje, Belgrade, Serbia

⁷University of Banja Luka, Faculty of Agriculture, Banja Luka, Republic of Srpska, Bosnia and Herzegovina

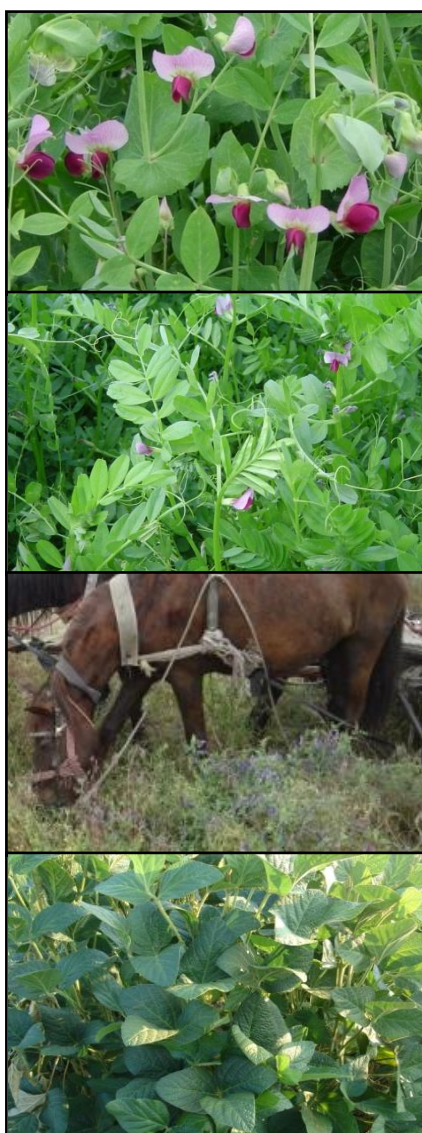


Figure 1. Some annual forage crops: (from above) 1) field pea and 2) common vetch are common in South-East Europe, with advanced breeding programmes, 3) hairy vetch, omnipresent in tilled land, rich in local landraces and grown sporadically, and 4) soya bean, with a great potential for using in other 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, biochemical 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
<i>Arachis pintoi</i>	1.8	281	265	298
<i>Cajanus cajan</i>	6.5	1034	876	1345
<i>Calopogonium mucunoides</i>	2.8	453	431	465
<i>Cicer arietinum</i>	7.5	1202	1102	1567
<i>Glycine max</i>	15.2	2436	2134	2588
<i>Glycine soja</i>	3.5	565	554	571
<i>Lablab purpureus</i>	9.7	1558	1344	1778
<i>Lathyrus aphaca</i>	4.8	763	755	777
<i>Lathyrus cicera</i>	7.4	1177	1053	1356
<i>Lathyrus latifolius</i>	10.0	1594	1348	1688
<i>Lathyrus ochrus</i>	9.0	1444	1301	1578
<i>Lathyrus odoratus</i>	6.8	1084	998	1256
<i>Lathyrus sativus</i>	11.8	1882	1776	2178
<i>Lathyrus sylvestris</i>	9.9	1584	1455	1623
<i>Lathyrus tingitanus</i>	7.7	1238	1025	1534
<i>Lathyrus tuberosus</i>	5.7	907	789	1104
<i>Lens culinaris</i>	6.3	1004	945	1345
<i>Lens nigricans</i>	6.4	1026	1001	1078
<i>Lupinus albus</i>	8.8	1400	1256	1687
<i>Lupinus angustifolius</i>	7.4	1191	1098	1352
<i>Lupinus hispanicus</i>	5.7	907	887	1100
<i>Lupinus luteus</i>	6.4	1030	988	1254
<i>Lupinus mutabilis</i>	8.4	1346	1288	1443
<i>Macrotyloma axillare</i>	3.9	623	598	727
<i>Medicago truncatula</i>	5.7	914	902	956
<i>Mucuna pruriens</i>	11.0	1760	1689	1895
<i>Ornithopus sativus</i>	6.3	1004	924	1105
<i>Pisum abyssinicum</i>	7.9	1268	1178	1567
<i>Pisum fulvum</i>	6.0	954	932	1032
<i>Pisum sativum</i> var. <i>arvense</i>	10.9	1748	1654	2012
<i>Pisum sativum</i> var. <i>sativum</i>	11.5	1843	1744	2314
<i>Pisum sativum</i> subsp. <i>elatius</i>	10.8	1732	1454	1799
<i>Stylosanthes capitata</i>	2.6	410	402	433
<i>Trigonella phoenum-graecum</i>	5.8	929	901	1062
<i>Vicia beghalensis</i>	9.0	1432	1321	1665
<i>Vicia ervilia</i>	8.4	1350	1267	1789
<i>Vicia faba</i>	10.7	1706	1653	1974
<i>Vicia grandiflora</i>	8.2	1311	1221	1564
<i>Vicia hirsuta</i>	4.5	723	654	772
<i>Vicia narbonensis</i>	9.5	1518	1234	1875
<i>Vicia noeana</i>	8.1	1289	1089	1523
<i>Vicia pannonica</i>	8.3	1329	1176	1658
<i>Vicia sativa</i> subsp. <i>nigra</i>	7.3	1162	1034	1362
<i>Vicia sativa</i> subsp. <i>sativa</i>	10.5	1674	1245	2332
<i>Vicia serratifolia</i>	6.7	1076	978	1285
<i>Vicia villosa</i>	12.1	1940	1572	2455
<i>Vigna angularis</i>	6.3	1000	885	1276
<i>Vigna mungo</i>	6.1	969	834	1310
<i>Vigna radiata</i>	6.3	1011	923	1189
<i>Vigna unguiculata</i>	9.1	1450	1211	1675

found in the wild, there are those such as *Lathyrus latifolius* L., *Pisum abyssinicum* A. Braun, *Vicia grandiflora* 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).

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Forage and grain legumes in ruminant production systems in Bangladesh

by Nathu Ram SARKER^{1*} and Md. Omar ALI²

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 Schumacher) 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 T₀ (Napier silage alone as a control), T₁ (75% Napier silage + 25% grass pea hay, dry matter basis), T₂ (Napier silage + concentrate with coconut cake) and T₃ (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 T₁ than T₀, and with T₂ and T₃ 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 (*Triticum 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 ($P < 0.05$)

¹Bangladesh Livestock Research Institute, Dhaka, Bangladesh (sarkernr@yahoo.com)

²Bangladesh 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. 

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

- *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. 

Acknowledgements

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

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





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Knowledge Creation

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.

Conveners

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

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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 value 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**

**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>**

ICLGG VIII

**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, agroecology, sociology, scientometrics and networking.

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