Leguminous Forage Crops in Sustainable Cattle Husbandry

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Abstract. Within Europe, half the annual requirement for feed is provided by grass. However, although the EU is a net exporter of feed grain it is a substantial importer of protein and non grain feed ingredients. For several economical and ecological reasons there is a renewed interest to grow forage legumes and the European Union strengthen the role of protein-rich crops, by providing a supplementary payment for farmers producing these crops. In order to develop sustainable, legume-based live stock production systems, we need to understand the complex relationships that exist between herbivores and the plants they consume. To increase farmers confidence in the use of forage legumes, it is necessary to have more reliable establishment techniques and to reduce the variability in legume contribution within and between years, particularly for legumes in mixed swards.

Key words: European agricultural policy, environment, grass-clover mixtures, alfalfa

INTRODUCTION

The changing society, as stakeholder of the environment, wants to increase its impact on the political decision making of allowable agricultural processes. It is no longer sufficient to adopt new technologies simply because they guarantee greater profit margins or higher production levels. In the future it will be essential to take into account the opinion of the consumer in order to avoid further crises of confidence (Puia et al. 2001). The nowadays EU agricultural policy includes also ecology, animal welfare, sociology and food quality (Council Regulation (EC) No 73/2009 repealing Council Regulation (EC) No 1782/2003).

Within Europe, half the annual requirement for feed is provided by grass. However, although the EU is a net exporter of feed grain it is a substantial importer of protein and non grain feed ingredients. The amount of raw material imported for feed in EU corresponds to the production from 10 million ha of land. The current production of meat, eggs and milk relies on the importation of non-forage protein and this represents around 25% of the total amount of protein consumed by the animal.

Although non-forage proteins of vegetable origin are available, much of the 'by-pass proteins' traditionally come from animal by-products and fishmeal. Imported feed components have high transportation costs, high environmental impact and their quality and safety can be highly variable. A greater reliance on 'home grown' legume-based protein sources would improve the traceability of the feed, enhance consumer confidence in the final market product and promote ecologically sound farming systems.

The main environmental advantage of legume-based forage crop husbandry is the reduction of the fossil energy use that is necessary to synthesize inorganic N fertilizers and to reform other protein sources into useful feed for cattle.

Already in the 13th Century Flanders was recognized as a good region for growing clover (Slicher Van Bath). On his journey over Flanders, Sir Richard Weston describes in
1644 a five years rotation of flax, turnips and clover grass and recognized this crop husbandry system as a model for practice in the commonwealth.

As farming within the north-western European countries moves towards less intensive forms of agriculture, it has been predicted that there will be a growth in intensive agricultural systems in the Baltic States and other Central and Eastern European countries in order to supply consumer demands in these countries. However, the growth of industrial forms of live stock production has been associated with serious environmental and safety problems. Consequently, forage legumes, adapted to a wide range of soil types, climatic conditions and management systems, will become increasingly important components of sustainable agriculture production systems in Europe.

There is a wide range of climates in Europe, and climatic zone will strongly influence the type of legume used in forage systems. In the Mediterranean environment, the most successful legume species might be winter annual-types, which will germinate with autumn rains, grow actively during the winter and produce seed prior to the onset of summer drought. Further north, winter survival becomes then the dominant requirement and various mechanisms are adopted to achieve this. In all environments we need an understanding of the factors affecting the survival and productivity of legumes. Such factors include the presence of various abiotic stresses, competition from other species in mixed swards, the type of sward management imposed, and relationships between the legume and its microbial symbionts (Rhizobium bacteria and vesicular-arbuscular mycorrhizae).

Four main properties of leguminous crops should be better exploited in the future agriculture:
(i) the capacity for N-fixation (e.g. alfalfa may fix up to 320 kg of N.ha\(^{-1}\).y\(^{-1}\))
(ii) the high nutritive value (e.g. high concentrations of unsaturated omega fatty acids)
(iii) intake potential by cattle (e.g. 10% higher intake in comparison to grass species)
(iv) improving and maintaining the soil structure (e.g. better rooting system)

**LEGUMES IN FLANDERS**

Nowadays the interest of Flemish farmers for legumes is very limited: only some 500 ha of alfalfa, and 600 ha of red clover and 6500 ha of grass/red clover are grown. In grassland, only 210.000 ha, the average clover % is not more than 20% as a result of the use of mineral N and manure (L. Carlier, 2010). Although white clover is a common partner of perennial ryegrass in seed mixtures for renovating grassland. For sure temporal and spatial variation in legume performance occurs and this restricts the confidence of farmers in legume-based systems. Grass clover mixtures have the disadvantage that the development of the grasses (especially the Lolium spp) and the white clover are completely different.

Grass growth start early in the season and reaches already its optimum growth in may, while white clover develops the best in mid summer June-July (Carlier et. al 1998). This different growth pattern results in different grass clover relations in the field and hence different chemical composition and feeding value for the grazing cattle. To increase farmer confidence in the use of forage legumes it is necessary to have more reliable establishment techniques and to reduce the variability in legume contribution between parcels and within and between years. White clover is widespread in all grass fields and is the perfect companion for grass species. It grows as a wild species almost everywhere, can tolerate close mowing, and can grow on many different types and pH of soil. But its production capacity is limited and depending of the species (2-3 tons dry matter /ha/y for wild species up to 5-8 tons for
bred varieties). It may therefore not take the most important position in the sward and has to be managed around 30% of the botanical composition.

Nevertheless Flemish farmers are encouraged by the Government to cultivate clover (*Trifolium* species) and lucerne (*Medicago sativa* L.) and grass/clover under cutting conditions to produce more farm grown proteins, especially to fit with the strict environmental EU policy for nitrate leaching.

In this framework monocultures of red clover (*Trifolium pratense* L.), white clover (*Trifolium repens* L.), lucerne (*Medicago sativa* L.), perennial ryegrass (*Lolium perenne* L.), Italian ryegrass (*Lolium multiflorum* Lam.) and grass/legume mixtures were compared at 3 levels of N-fertilisation: 0, 105 and 265 kg N ha\(^{-1}\) in order to investigate the effect on weed control, botanical composition, dry matter yield, forage quality and nitrate residue in the soil. The plots were cut and not grazed by cattle which influences the nitrogen input and efficiency, because there was never a return of N of cattle excrements. The trials was executed at ILVO research institute in Merelbeke (Belgium) during 2004-2006 (De Vliegher and Carlier L, 2008). In table 1 the results of this 3 years old field trial are presented.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Content of sown legumes % in Dry Matter (DM)</th>
<th>DM yield Ton ha(^{-1}) year(^{-1})</th>
<th>DM yield kg kg(^{-1}) fertiliser N</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N0</td>
<td>N105</td>
<td>N265</td>
</tr>
<tr>
<td>Tp+Lm</td>
<td>67</td>
<td>51</td>
<td>30</td>
</tr>
<tr>
<td>Tp+Lp</td>
<td>73</td>
<td>68</td>
<td>56</td>
</tr>
<tr>
<td>Tp+Tr+Lp</td>
<td>61+15</td>
<td>65+6</td>
<td>43+14</td>
</tr>
<tr>
<td>Tr+Lp</td>
<td>57</td>
<td>50</td>
<td>30</td>
</tr>
<tr>
<td>Ms+Lm</td>
<td>81</td>
<td>65</td>
<td>56</td>
</tr>
<tr>
<td>Ms+Lp</td>
<td>87</td>
<td>82</td>
<td>80</td>
</tr>
<tr>
<td>Ms+Tr+Lp</td>
<td>85+6</td>
<td>79+5</td>
<td>68+11</td>
</tr>
<tr>
<td>mean grasses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean legumes</td>
<td>96</td>
<td>94</td>
<td>94</td>
</tr>
<tr>
<td>mean grass/legumes</td>
<td>76</td>
<td>68</td>
<td>55</td>
</tr>
</tbody>
</table>

The proportion of legumes in the grass/legume mixtures significantly (p< 0.02) decreased when more N was applied but the level of legumes was acceptable, especially for Lp in N105. For grass/legume mixtures, N105 and N265 resulted in an increase of the DM yield by 1.02 and 1.31 Mg ha\(^{-1}\) respectively. It is obvious that the small difference in DM yield between these two N levels (0.29 ton ha\(^{-1}\)) did not economically justify the use of 265 kg N on grass/legume mixtures. The use of 105 kg N ha\(^{-1}\) resulted in an additional yield of 9.7 kg DM kg\(^{-1}\)N which corresponded with an cost price of 0.12 € kg\(^{-1}\) DM (765€ Mg\(^{-1}\) N for fertiliser and 20€ fertiliser application\(^{-1}\) ha\(^{-1}\)). The growth of Lp and Lm is still limited by a N fertilisation of 265 kg N ha\(^{-1}\) (Behaeghe and Carlier, 1974) but the strict EU Nitrate Directive regulation does not allow to apply more N. To avoid leaching, the nitrate nitrogen content in the soil profile 0-90 cm should not exceed 90 kg ha\(^{-1}\) at the end of the growing season. The nitrate residue in the soil was relatively higher for the monocultures of legumes (17-22 kg N ha\(^{-1}\)) in comparison with grass/legume mixtures (10-15 kg N ha\(^{-1}\)) and grasses (6-8 kg N ha\(^{-1}\)) but they were always far below the legal limit of 90 kg ha\(^{-1}\). There was no effect of N fertilisation on the nitrate residue in the soil.
If reliability is to be improved and the range of forage legumes extended in Europe we will require understanding of the constraints of environment, the reasons for divergence between species' potential and actual performance, the causes of yield variability and lack of persistence, the mechanisms controlling diet selection in animals and the role of management. Understanding the mechanisms underlying nutrient flows in ruminants fed on legume-based diets is an essential prerequisite for the achievement of high animal performance coupled with high efficiency and reduced environmental impact. Such information is essential for an improvement in nitrogen use efficiency.

The arena in which establishment occurs is a mix of management, environmental and biotic factors. This short phase in its development sets the scene for the future of the legume in the system. An understanding of the processes influencing the survival and growth of legume seedlings, whether in a reseeded pasture, in a perennial sward or as a sown crop in competition with weeds, is a key to increased establishment reliability (Rotar and Carlier, 2005).

Managing for less variable legume performance requires a clear understanding of the factors behind fluctuations of mixed legume swards through the growing and rest seasons (cold winters/dry summers) and their long term dynamics over years. Recent new approaches to understanding competitive and complementary behaviour that utilise the strong relationships between successive phases of the life history of swards and mixed stands will help to develop this knowledge. The effect of animal grazing behaviour, the role of clonal and sexual reproduction and rules governing allocation to reproduction and seed and seedling survival in determining the long-term persistence of legumes in natural and sown grassland need further examination (Carlier et al., 2008). Improving the efficiency of utilisation of legume fixed N and reducing N losses to the environment increases the attractiveness of legume-based systems. Precise information on nitrogen flows and losses in both grazed and only cut grass swards systems will help to achieve these two aims.

In order to develop sustainable, legume-based live stock production systems we need to understand the complex relationships that exist between herbivores and the plants they consume. In addition, more information is required on the processes of energy transfer and nutrient loss from the system. This information is necessary to quantify and predict the performance of beef and dairy production systems, thus promoting their greater economic viability and compliance with environmental legislation. It is essential that such information is transmitted to the farmer if legumes are to be used in an appropriate way, thereby improving the efficiency of these systems.

It is well known that the presence of legumes in the sward encourages high level of forage intake by the grazing animal. However, an understanding of the link between grazing behaviour, dietary preference and animal intake would enhance the prediction of nutrient intake by the ruminant in pasture systems.

Nutrients and energy are lost during field-based harvesting and conservation processes. The extent of these losses is influenced by management practices, by the type of legume used and by its contribution to the sward. It is clear that models predicting nutrient turnover, particularly during forage conservation, need to be formulated and validated.

These models must take into account the species composition and legume content of the sward in order to provide reliable estimates of nutrient intake by the animal. Understanding the mechanisms underlying nutrient flows in ruminants fed on legume-based diets is an essential pre-requisite for the achievement of high animal performance together with high efficiency and reduced environmental impact. New approaches based on the nitrogen/energy ratio in the ruminant diet will improve our understanding of the process of digestion. Information on the role of specific plant constituents (e.g. tannins), known to affect
rumen by-pass protein, can be related directly to the legume content of the diet and will improve nitrogen use efficiency coupled with reduced nitrogen losses to the environment.

CONCLUSION

After a long period of decline, there is a renewed interest in forage legumes for several economical and ecological reasons and the European Union strengthen the role of protein-rich crops, by providing a supplementary payment for farmers producing these crops. There is a wide range of climates in Europe, and climatic zone will strongly influence the type of legume used in forage systems.

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How crops, and especially leguminous crops will adapt to climate change in Europe and how they will behave?

As a result from the field trials in Flanders described above, it can be concluded that the growth of pure ryegrass swards are constrained by the maximum 265 kg N ha\(^{-1}\) because the EU Nitrate Directive regulation does not allow to apply more. Growing legumes or grass/legume mixtures under a cutting regime and with an N fertilization regime restricted by this Directive gave no difficulties in terms of nitrate residue.

REFERENCES

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