Performance of red clover mixtures in high output dairy systems: an agro-economical comparison

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Abstract

Inclusion of red clover (*Trifolium pratense*) in grasslands offers important economic and environmental advantages as nitrogen (N) fertilizer is replaced with N from N_2 fixation. These advantages seemed to be reduced under high fertilization rates. In a field experiment we compared perennial ryegrass swards (*Lolium perenne*) with grass-clover mixtures in which the artificial N fertilizer was omitted. The experiment was conducted at two locations (sandy and clay soil) at high fertilization levels (254 and 306 kg total-N ha^{-1} on grass-clover and 389 and 489 kg total-N ha^{-1} on the pure grass swards). Grass-clover mixtures produced more dry matter (+18%), digestible energy (+12%), crude protein (+45%) and digestible protein (+27%). Economic evaluation at farm level shows that grass-clover mixtures had a surplus of €510 ha^{-1} year^{-1} over pure grass swards. This surplus would be reduced (to €282 ha^{-1}) if the higher crude protein content of grass-clover cannot be balanced in the feed ration, resulting in extra N excretion of the animals and subsequent higher costs for manure disposal if maximum allowable manure application rates per ha are exceeded. These results show that inclusion of red clover in grasslands has agro-economic benefits, also under high fertilization rates.

Keywords: *Trifolium pratense*, ecological intensification, protein production, economic advantages

Introduction

Inclusion of red clover in grassland offers important economic and environmental advantages as nitrogen (N) fertilizer is replaced with N from N_2-fixation. The economic benefits of grass-red clover mixtures for organic dairy farms have been described by Doyle and Topp (2002). However, the yield advantages seem to be reduced under high levels of N fertilization (Nyfeler, 2009). Nevertheless, for conventional dairy farmers, the relevant question is: What are the differences between grass-red clover (fertilized with animal manure) and grass (fertilized with animal manure and artificial fertilizer) in terms of yield, fodder quality and economic cost and benefits? A field experiment was conducted to make such an agro-economic comparison.

Materials and methods

Experimental fields were established on two intensive dairy farms early September 2011 on sandy soil (52°19' N, 6°28' E) and clay soil (51°62' N, 4°62' E). Red clover (*Trifolium pratense,* 7 kg ha^{-1}) and white clover (*Trifolium repens,* 3 kg ha^{-1}) were sown with five different grass mixtures specifically selected for cutting regimes at commercially advised seeding rates, and compared with perennial rye grass (*Lolium perenne*). Mixtures were sown in two replicates and pure grass was sown in four replicates per location.

Measurements were conducted in the second and third production year (2013 and 2014). In each year, grass-clover mixtures received on average 254 (sand) and 306 (clay) kg N ha^{-1} from slurry, whereas pure grass received on average 135 (sand) and 183 (clay) kg N ha^{-1} from artificial fertilizer in addition. Plots were harvested four (2013) or five (2014) times per year. Dry matter yield was determined by cutting a strip of 0.81×5 m with a two-wheel-drive tractor. After weighing the fresh biomass, sub-samples were analysed for nutritive value by NIR at a commercial lab. (By mid-2012 red clover had almost disappeared from one of the mixtures on clay; therefore this treatment was not included in the analyses.) Results were tested by analysis of variance (unbalanced design) using GenStat 13.3. Experimental results were combined with actual historical prices and literature data for economic comparison.

Results and discussion

Dry matter yield was 18% higher in grass-clover plots than in plots with only grass (Table 1), and had a 22% higher crude protein content and a 8% higher intestinally digestible protein content (Table 2). Subsequently, crude protein yield was 43% higher and intestinally digestible protein was 27% higher in grass-clover (Table 1). Net energy lactation content of grass-clover was slightly lower than that of grass (Table 2), but due to the higher dry matter yield the net energy lactation yield of grass-clover surpassed that of grass (Table 1). Yields differed between years (+3 Mg dry matter for grass and grass-clover in 2014) and somewhat between locations, but differences between grass and grass-clover were constant.

The average economic value of these differences is given in Table 3. Average annual costs for grass-clover were comparable to those for grass only. Higher costs for seed and sowing and the higher renewal rate of grass-clover compared with grass resulted in higher annual establishment costs, but costs for artificial fertilizer and weed control were absent. Higher crude protein production may result in extra N-excretion of the cattle, and the total amount of N in animal manure may exceed the maximum application level for the farm. If all additional N produced needs to be disposed elsewhere, the costs for manure disposal increase to €228 ha^{-1} (or higher, if the manure needs to be transported long distances), resulting in an economic benefit of grass-clover, compared to grass, of €282 ha^{-1}. However, if either the N-surplus can be applied on own land or the additional protein production is used to replace the use of off-farm protein-rich fodder, the economic benefit of grass-clover compared with grass can rise to €510 ha^{-1}. On most farms the costs for manure disposal are likely to be around €114 ha^{-1}, as part of the extra crude protein from the grass-clover can be balanced by using more maize silage or concentrate with a lower protein level. In that case the net annual result is €396 ha^{-1}.

Conclusions

Successful inclusion of red clover in grasslands has major agro-economic advantages, and these also apply under high fertilization rates. Dry matter production, total energy production and protein production

Table 1. Mean yields of pure grass (n=8) and grass-clover mixtures (n=18) of two years.

	Dry matter Mg ha^{-1}	Net energy lactation MJ ha^{-1}	Crude protein kg ha^{-1}	Intestinally digestible protein kg DVE ha^{-1}
Grass only	11.0	6.97×10^4	1.88×10^3	8.20×10^2
Grass-clover	13.0	7.76×10^4	2.69×10^3	10.4×10^2
Difference	18%	11%	43%	27%
Significance	<0.001	<0.001	<0.001	<0.001

Table 2. Mean energy and protein content of pure grass (n=8) and grass-clover mixtures (n=18) of two years.

	Net energy lactation MJ kg^{-1}	Crude protein g kg^{-1}	Intestinally digestible protein g DVE kg^{-1}
Grass only	6.32	169	74.0
Grass-clover	5.98	207	80.1
Difference	-5%	22%	8%
Significance	<0.001	<0.001	<0.001

Table 3. Differences in annual costs and benefits in € ha^{-1} for grass and grass-clover mixtures, based on measured yield differences in experimental plots.

	Grass only	Grass-red clover	Difference
Costs			
Seed & sowing[1]	48	114	66
Manure & fertilizers	396	189	-207
Weed control	15	0	-15
Harvesting[2]	750	790	40
Manure disposal[3]			114
Total costs			-2
Benefits			
Energy yield difference[4,5]			152
Protein yield difference[5,6]			241
Total benefits			393
Net annual result			396

[1] Assuming €455 and €385 seed and seeding costs and 4 and 8 productive years for grass-clover and grass, respectively.

[2] Slower sowing and harvesting may result in slightly higher costs for grass-clover.

[3] Assuming 50% of the additional N-yield needs to be disposed at a cost of €7 Mg $manure^{-1}$ (mean value 2010-2013 (LEI, 2014)), and assuming an N-content of 4 kg N × Mg $manure^{-1}$, thus €1.75 kg N^{-1} disposed.

[4] Assuming €0.0192 MJ^{-1}.

[5] Mean value 2013-2014, based on Wageningen UR Livestock Research, 2014.

[6] Assuming €1.09 kg DVE^{-1} (intestinally digestible protein).

are increased in grass-clover compared with grass. Grass-clover fodder has a higher protein content and slightly lower energy content than grass. The economic benefits mainly result from the higher production in combination with avoiding the costs of artificial fertilizer. The financial benefits of grass-clover depend on the farming system into which it is integrated, as well as on the extent to which a farmer is able to adapt his fodder regime.

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Element concentrations in forage plants grown on power station ash deposit

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Abstract

Intensive livestock production is concentrated in the northern part of Serbia, particularly in the vicinity of Belgrade. This area is very important for forage production, but the main power stations of the Serbian power supply system are located in this region and these produce high emissions of fly ash. Forage plants are exposed to the pollution effects of fly ash, and some agricultural systems are located very close to the Nikola Tesla A (TENT-A) power station. A study of three forage plants (*Medicago sativa, Phalaris arundinacea*, *Melilotus officinalis*) was done on 'TENT-A' ash deposit in order to analyse bioaccumulation of maximally exposed plants. Plant samples were collected at tillering stage and concentrations of 10 elements were analysed. The results show lower concentrations of trace metals in the herbage shoots than in the ash, which had excessive contents of As, Ni and Cr. None of the examined species accumulated a high amount of the above-mentioned elements, even though they were from different families, with different morphology and dry matter yield. Alfalfa had the highest concentrations of As and Ni among the species that were analysed.

Keywords: *Medicago sativa, Phalaris arundinacea*, *Melilotus officinalis*, trace elements

Introduction

The use of coal to produce electricity in the 'TENT-A' thermal power station in Obrenovac, Serbia requires large quantities of coal annually. The production of by-products of coal combustion is very large and the vegetation of the region is exposed to emissions of different types of pollutants (Pavlović *et al.*, 2004). To prevent ash dispersion by wind, spare lagoons are covered by vegetation, consisting of adaptive grass-leguminous species. There is interest in studying bioaccumulation in plants because they form the base of the food chain and also because of their potential use in phytoextraction. Absorption depends upon the availability of the metal rather than the total amount of metal in the soil (Kelepertsis and Andrulakis, 1983). Uptake of heavy metals by plants is largely a function of the physiology of the species and the availability of the element concerned. Since coal residues contain potentially hazardous substances, improper handling and disposal could cause undesirable environmental effects (Adriano *et al.*, 1980). The latter may be influenced by the strength of organometalic complexes in the soil. The study reported here covered three species: alfalfa (*Medicago sativa* L.), reed canarygrass (*Phalaris arundinacea* L.) and sweetclover (*Melilotus officinalis* (L.) Pall.). The primary objective of this research was to evaluate trace element concentrations in plant shoots, on a site at the Obrenovac ash deposit site, which is very close to the Serbian capital and main livestock production area of Serbia. The high concentrations of pollutants in the air and those contained in the ash in these areas are considered severe stress factors for the metabolism of plants. Since the thermal power station of TENT-A and the ash disposal sites are in the vicinity of a densely populated area, the same pollutants could be potentially detrimental to the health and well-being of animals and humans.