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CORRELATION BETWEEN YIELD OF FORAGE LEGUMES IN GRASS MIXTURES AND ACCUMULATION OF SOIL MINERAL NITROGEN IN SWEDEN

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Abstract

Soil mineral N and DM yield of five forage legume species were investigated in field experiments at two sites in Sweden, established 1997. The species studied were: red clover (*Trifolium pratense* L.), lucerne (*Medicago sativa* L.), white clover (*Trifolium repens* L.), galega (*Galega orientalis* Lam.) and lotus (*Lotus corniculatus* L.), all grown in grass-legume mixed swards. No nitrogen was applied to the legumes. Results from two years of ley (1998 and 1999) are presented.

Correlation was found between accumulated mineral N in the soil in the autumn and the total seasonal DM yield of the legume fraction of mixed grass-legume swards under temperate conditions. In the first year of ley, the correlation was stronger than in the second year ley. The levels of mineral N in the soil were highest in spring first year of ley at both sites and thereafter the levels decreased until autumn of the second year of ley. Legumes alone showed a poor correlation between soil mineral N in the autumn and DM yield of the legume both years of ley. Most likely the N leaching is taking place at the spring thaw, not

during winter when the ground is frozen. In conclusion, when high proportions of legumes in the harvest occur, there could be an environmental risk of N leaching.

Keywords: Forage legumes, soil mineral nitrogen, dry matter yield

Introduction

Forage legumes have an important role in low-cost and sustainable agriculture because of their role in nitrogen fixation and their high feeding value, benefits which are well recognized under grazing. The use of red clover, white clover and lucerne has declined, however, in much of Northern Europe because of cheap N fertilizer, poor persistence and difficulties in effective conservation. There is only limited information on other cool temperate legumes, such as Galega and Lotus, for Northern Europe. Galega has been newly developed as a forage in Estonia and may be highly productive and persistent. Lotus (birdsfoot trefoil) may be productive under conditions of low fertility nutrient stress, and has nutritional advantages associated with condensed tannins. Production results of these legumes in Northern Europe have recently been presented (Halling et al, 2000). In using high amounts of forage legumes there is also a risk of accumulation and leaching of nitrogen from the soil. This paper reports results from an EU-funded international research project (LEGSIL – Low-input animal production based on forage legumes for silage, Wilkins et al, 1998). The agronomic part of the project reported here has the specific aim of investigating the productivity of novel and conventional forage legume species at contrasting sites. The nitrate leaching part has the objective to assess losses of nitrate through leaching from forage legumes grown for silage.

Material and Methods

Three small-plot field experiments were established in spring 1997 at three sites in Sweden. One site was on land registered for organic production (OP). Sites were: Uppsala (59º49’N 17º39’E), Rådde (57º36’N 13º16’E) and Lilla Böslid (OP, 56º36’N 12º55’E). Results from Uppsala and Rådde are included in this paper. Similar trials (three in each country) were established in Finland, in Germany and in Great Britain, but not reported here.

The experiment has a one-factor randomised alpha-lattice design with 18 treatments and three replications, in total 54 plots. The most important treatments for comparison have been allocated to sub-replications of six plots. At all sites, ten treatments of standard varieties of each of red clover (cv. Vivi), lucerne (cv. Vertus), white clover (cv. Aberherald), galega (cv. Gale) and lotus (cv. Leo) were established, alone or in mixture with a standard grass (meadow fescue – *Festuca pratensis* Hudson. cv. Kasper). In six additional treatments, the 'best adapted' varieties for the particular country were chosen. In Sweden, red clover (cv. Vivi) pure and mixed with timothy (*Phleum pratense* L.), lucerne (cv. Pondus) pure and mixed with cocksfoot (*Dactylis glomerata* L.) and white clover (cv. Sonja) pure and mixed with meadow fescue (cv. Kasper) were established. For comparison, two treatments with pure standard grass (cv. Kasper) – either not N-fertilized or fertilized with 200 kg N ha^{-1}, applied as 80, 60 and 60 kg N ha^{-1} between the cuts, were established. In this paper, results from standard treatments of lucerne, galega, lotus and adapted treatments of red and white clover mixed with grass and swards with pure grass, are reported. The trial at Uppsala was on a loam with 3.7 % organic content and at Rådde on a sandy loam with 3.5 % organic content.

A common protocol for managing the trials was used. In spring, 28 kg ha^{-1} P and 100 kg ha^{-1} K were applied. Three cuts were taken by using plot mowers. First cut was taken between 11^{th} to 20^{th} June when the adapted red clover was in bud stage (inflorescence of main stem just visible), second cut was taken in late July and third cut in early September.

Additional samples from each plot were hand sorted to determine the proportions of sown legume, grass and unsown species at each harvest. Total seasonal yields of sown legumes in mixture with grass in 1998 and 1999 are presented in this paper. In 1998, the weather was cooler and wetter than normal at both sites and in 1999 it was warmer than normal at both sites but at Uppsala it was drier and Rådde wetter than normal.

Soil mineral N was determined plot-wise in all 18 treatments as the amount of nitrate and ammonium in soil cores (2.5 cm diameter; 6 per plot) extracted to rooting depth (60 or 90 cm) with a cylinder auger in late autumn (late October to early December) and early spring (late March to mid April). After thorough mixing of the 0-60 or 0-90 cm sample, the moist soil was sub-sampled and extracted with 1.0 M KCl (100 g soil to 200 ml KCl). The concentrations of nitrate and ammonium were determined in the extractant using a segmented-flow autoanalyser after 2 hours mixing and filtration. A value for the soil dry bulk density was used to convert the concentration to weight of nitrate and ammonium per ha of land. Soil mineral N (kg ha^{-1}) was taken as the sum of nitrate and ammonium.

In the statistical analyses, the SAS procedure Mixed was used (SAS, 1997). In the model, treatment was set as a fixed factor and the effects of main-replications and sub-replications within main-blocks were set as random factors. Least square means are reported in the paper.

Results and Discussion

In mixed grass/legume swards there was a positive correlation between accumulated mineral N in the soil in the autumn and the total seasonal DM yield of the legume fraction under temperate conditions (Figure 1). The relationship was stronger (r^2=0.74) in the first year (1998) than in the second one (Figure 1). The levels of mineral N in the soil were highest in spring first year of ley at both sites (Table 1). Thereafter the levels decreased until autumn of the second year of ley. During the sampling period, red clover/grass mixture gave the greatest soil mineral N at Uppsala (Table 1). At Rådde, the white clover/grass mixture gave the greatest soil mineral N, except for autumn 1998, when red clover/grass mixture gave the greatest level. The lotus/grass and galega/grass mixtures had the smallest soil mineral N levels at both sites. These correlations were consistent between the two sites. The decreasing trend of DM production over the duration of ley could be explained by winter damages, also reflected by decreasing ground cover of the legumes, assessed in late autumn and early spring (data not shown). Some legumes species like red clover, galega and lotus could also suffer yield penalties due to the three cut system.

The question arises whether the potential for accumulation of soil mineral N in autumn is also dependent on the legume species, not only on the production level of the legume. Results from pure stands of legumes showed a poor correlation between soil mineral N in the autumn and DM yield of the legumes in both years of ley (ley year one and two: r^2=0.04, data not shown). White clover alone gave a much greater soil mineral N in autumn for a given DM yield compared with the other species. Other results (not published) from the UK sites where nitrate concentrations in the ground water were measured directly with ceramic cup samplers at 90 cm, show that there were large differences between the legume species. Lucerne gave the smallest and white clover the greatest concentrations of nitrate in ground water.

The difference between mineral N present in soil profiles during autumn and subsequent spring could provide an indication of the potential levels of leachable N and the net winter loss from the profile following the first harvest year. Thus, net gain of soil mineral N was observed at the Swedish sites and was probably due to release of ammonium and enhanced mineralisation with the spring thaw. At such sites, the value of autumn mineral N is probably a better indicator of treatment effects than net change over winter. The levels of soil mineral N can not give the actual values of N leached. During the winter it is not likely that leaching of N is taking place through the frozen ground. The environmental risk may appear by leaching of N at the spring thaw. In conclusion, when high proportions of legumes in the harvest occur there could be an environmental risk of N leaching.

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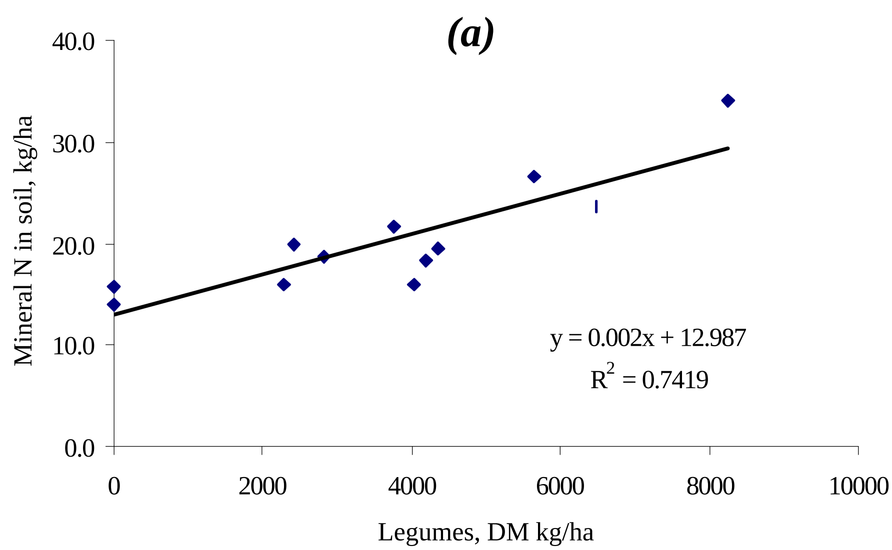
Table 1 - Least square means of soil mineral N (kg ha^{-1}) sampled from autumn 1997 to autumn 1999.

	Uppsala					Rådde				
Treatment	A. 97	S. 98	A. 98	S. 99	A. 99	A. 97	S. 98	A. 98	S. 99	A. 99
Grass 0N	14.6	20.3	15.8	16.5	12.3	11.4	18.1	14.0	14.8	9.7
Grass 200N	15.6	20.4	16.6	18.0	22.4	10.6	17.4	13.0	14.3	13.2
Red clover + grass 0N	18.1	33.3	34.0	27.9	17.9	18.0	26.5	26.7	16.9	12.8
White clover + grass 0N	15.0	28.4	19.5	21.1	13.4	19.2	33.8	21.6	24.1	17.2
Lucerne + grass 0N	19.4	33.5	23.6	18.4	14.4	24.1	27.5	18.3	18.2	10.9
Galega + grass 0N	18.3	21.2	15.9	18.1	11.4	18.3	21.4	19.9	17.9	13.7
Lotus + grass 0N	16.2	30.9	18.8	20.9	10.7	14.5	20.6	16.0	15.9	10.0
Mean	17.1	27.9	21.4	20.7	15.0	17.4	24.5	19.2	17.9	13.0
CV %	16.2	16.3	25.4	23.5	23.7	26.2	6.9	27.4	13.1	20.8
Probability	.0101	.0001	.0001	.0001	.0001	.0004	.0001	.0001	.0001	.0001
LSD	4.9	10.5	12.0	11.7	7.4	9.0	3.6	11.4	4.6	5.7

0N=0 kg N/ha, 200N=200 kg N/ha, A=autumn, S=spring
CV=coefficient of variation, LSD=least significant difference at P<0.05



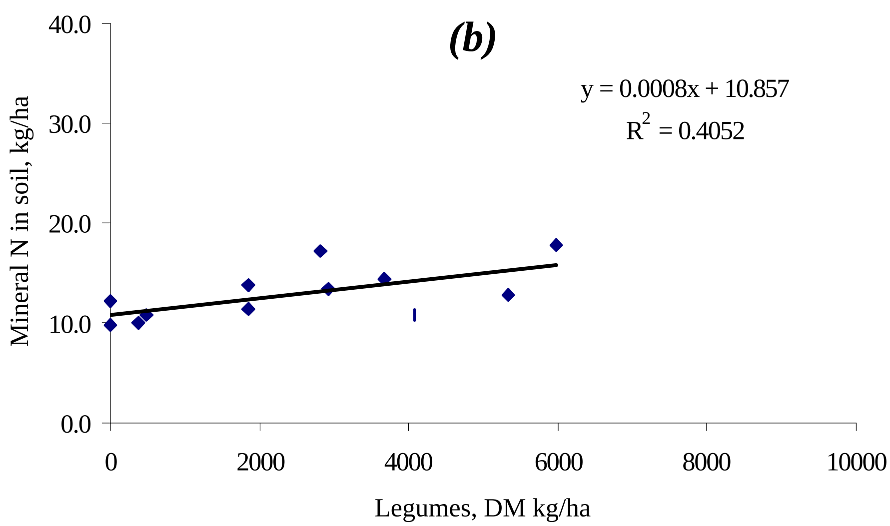


Figure 1 - Relationship between soil mineral N sampled in autumn 1998 (a) and 1999 (b) and total seasonal yield of legumes in grass mixtures in 1998 (a) and 1999 (b).