Effect of short term pastures on soil nitrogen status under contrasting management practices

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Abstract

The amount of nitrogen (N) returned to the soil under two-year old pastures managed either for seed production or grazed by sheep was compared. Under sheep production, clovers fixed 55 kg N/ha per annum, and the net input to the soil was 84 kg N/ha over the two years. In the first year under seed production when ryegrass seed was harvested, clovers fixed only 21 kg N/ha, but 100 kg N/ha was applied in fertiliser. In the second year, when the ryegrass was sprayed out and clover seed harvested, 134 kg N/ha was fixed and 25 kg N/ha fertiliser was applied. However, N was removed in harvested seed (15 kg N/ha in ryegrass seed and 30 kg N/ha in clover seed) and ryegrass straw (65 kg N/ha). Overall, the net input of N to the soil under seed production (157 kg N/ha) was greater than under grazing (84 kg N/ha). Despite the higher net N input to the soil under seed production, there was no evidence that this had a beneficial effect on wheat in a subsequent pot trial, and there was a higher DM yield and N uptake from the wheat following grazed pasture than seed production. The carryover effect of the two management practices on the wheat appeared to be linked to the form of N added to the soil, rather than the total amount of N added.

Additional key words: *nitrogen fixation, nitrogen balance, seed production*

Introduction

Short term ryegrass and white clover pastures are part of many mixed cropping rotations on the Canterbury Plains. These pastures help to maintain soil organic matter content and soil physical condition (Haynes and Francis, 1990). Soil nitrogen fertility increases under pasture because of N_2 fixation by clovers and cycling of N by grazing sheep.

These short term pastures are not always managed as grazed swards. Often they are managed as ryegrass seed crops in the first year, and then as clover seed crops in the second year. In this system, ryegrass and clover plants are established together in the autumn and the ryegrass managed for flowering and seed production in the following summer. Nitrogen fertiliser is usually applied during spring to ensure high seed yields. After the grass seed is harvested, the residues are removed as baled straw. The sward is grazed by sheep until mid-winter when flat weeds and grasses are sprayed with herbicide, leaving a pure stand of white clover. Grazing continues until September when the crop is left for seed production. The impact of seed crop management on the N fertility of soil is unknown. While inputs are still likely to occur through N fixation, there are also N inputs in fertiliser and losses of N in removal of the harvested seed and ryegrass straw. A field experiment compared the amounts of N fixed and soil N fertility in short term pastures under two different management systems (grazing or seed production). The carryover effect of these management systems on the growth and N uptake by a subsequent wheat crop was evaluated in a glasshouse experiment.

Materials and Methods

Field experiment

The field experiment was established on the AgResearch farm at Lincoln. The soil type was a Templeton silt loam (Brown soil, New Zealand classification) with an Olsen P of 30 µg P/g, pH of 5.5, organic C of 3.4% and total N content of 0.27%. The site had previously been under a mixed cropping regime and was ex wheat. Plots (10 m x 10 m) were drilled in April 1993 with 30 kg/ha perennial ryegrass (*Lolium perenne* L. cv. Grasslands Supernui) and 7.5 kg/ha coated (4.5 kg/ha bare seed) white clover (*Trifolium repens* L. cv. Grasslands Tahora). Half of the plots were grazed with dry sheep at approximately monthly intervals when the pasture reached a grazable mass of 1000-1500 kg DM/ha (the 'grazed' treatment). The remaining plots were managed for seed production (the 'seed' treatment). In the seed treatment, the plots were not grazed up to harvest, allowing the ryegrass to flower and set seed.

Nitrogen fertiliser (100 kg N/ha as ammonium sulphate) was applied in the spring and ryegrass seed was harvested in late December 1993. The ryegrass straw was baled and removed. The sward was then grazed until winter 1994. In July 1994 the plots were sprayed with propyzamide and haloxyfop leaving a pure stand of clover. Nitrogen fertiliser (25 kg N/ha as ammonium sulphate) was applied in November 1994 and the seed harvested on 5 March 1995.

There were three replicates of each treatment arranged in a randomised block design. Lime was applied to the grazed treatment plots to raise soil pH to 6.2. No lime was applied to the seed treatment as clover seed production is enhanced at low soil pH (Clifford, pers. comm.). Rainfall during the trial was below the long term average, especially in the summer months. Irrigation was applied regularly from November to April each year with 30-50 mm applied per application.

Nitrogen fixation was measured using the ^{15}N isotope dilution technique (Chalk, 1985; Peoples and Herridge, 1990). In each plot a dilute solution of ^{15}N-labelled urea was applied at 0.3 g N/m^2 (20 atom% ^{15}N enrichment) to a 1 m^2 subplot. Prior to each grazing or seed harvest, the subplot was cut to 10 mm above the soil surface with hand shears. After every 2-3 grazings or after every seed harvest, new ^{15}N plots were initiated. The harvested herbage was separated into clover and grass, dried and analysed for total N and ^{15}N on a Tracer-mass stable isotope analyser in conjunction with a Roboprep-CN biological sample converter. Total herbage production was also assessed from the subplots. Data are presented for year 1 (April 1993 to March 1994) and year 2 (April 1994 to March 1995).

The amount of N fixed by clovers was calculated from the proportion of N derived from the atmosphere (%Ndfa) and the total above ground N yield of clovers. The %Ndfa was calculated as :

$$\%Ndfa = (1-c/a) \times 100 \quad (1)$$

where c and a are the % atom ^{15}N excesses of clover and grasses respectively.

In May 1995, samples of soil and residual herbage (shoots and roots) were collected from each plot to a depth of 150 mm. The material was bulked together on a treatment basis and retained for the glasshouse experiment.

Glasshouse experiment

Soil and pasture residues (shoots and roots) were mixed together in pots on a treatment basis. There were 12 replicates. Each pot contained 1.3 kg dry soil adjusted to a soil moisture content of 30 g/g. In order to simulate ploughing, the plant residues were incorporated into the middle of each pot. The weight of residues was equivalent to that left on the plots at the end of the field experiment (i.e., 13.1 g dry weight in the grazed treatment and 8.3 g dry weight for the seed treatment). The N content of the residues and soil are given in Table 1.

Pots were sown with wheat cv. Sapphire, thinned to four plants per pot, and kept in the glasshouse. Half of the pots were harvested after two months just prior to stem elongation and the remainder at maturity, four months after sowing. At each harvest, plant material was cut at ground level, soil was sieved (2 mm) and the roots removed. Soil, herbage and washed roots were analysed for total N (Bremner and Mulvaney, 1982). Exchangeable ammonium and nitrate were extracted with 2M KCl (soil: extractant ratio 1:5).

Results

Field experiment

On the grazed plots, total pasture dry matter (DM) production averaged 6210 kg/ha in the first and 7310 kg/ha in the second year (Table 2). Dry matter yields were higher from the seed treatment in the first year, but similar to the grazed treatment in the second year. The yield of ryegrass seed was 850 kg/ha, and white clover seed was 610 kg/ha.

There were large differences in the amount of N fixed between the two treatments. In the first year, at least twice as much N was fixed under grazing than under seed production, but in the second year, the differences were reversed (Table 2).

Nitrogen inputs and outgoings were calculated for each treatment (Table 3). Inputs were from fixation and fertiliser, while outgoings included removal of seed, grass seed straw, and meat and wool produced by the grazing sheep. The amount of N removed in animal products was estimated from the amount of N ingested, assuming

Table 1. Concentration and content of N in plant residues and soil collected from the grazed and seed treatments of the field experiment and used in the glasshouse experiment.

Treatment	N (%)	N per pot (mg)
Grazed soil	0.27	3510
Seed soil	0.27	3510
Grazed residues	3.2	418
Seed residues	2.4	199

Table 2. Amount of N fixed and DM yield of grass/clover pastures managed either as a grazed sward or for seed production.

Parameter	Grazed	Seed	$LSD_{p<0.05}$
N fixed (kg N/ha)			
Year 1	56	21	16.3
Year 2	54	134	39.0
Total	110	155	39.0
Clover yield (kg DM/ha)			
Year 1	1720	600	443
Year 2	1460	6050	1370
Grass yield (kg DM/ha)			
Year 1	4490	10031	1938
Year 2	5850	1210	318

Table 3. Inputs and outgoings of N (kg N/ha) in grass/clover pastures managed either as a grazed sward or for seed production.

	Grazed	Seed
Year 1		
Inputs		
Fixation	56	21
Fertiliser	nil	100
Outgoings		
Animal products	8	9
Seed	-	15
Straw	-	65
Net change	+48	+32
Recycled in dung and urine	74	82
Year 2		
Inputs		
Fixation	54	134
Fertiliser	nil	25
Outgoings		
Animal products	18	4
Seed	-	30
Straw	-	
Net change	+36	+125
Recycled in dung and urine	167	38

that 10% was retained for animal production and the remaining 90% was excreted in dung and urine (Haynes and Williams, 1993). In the grazed treatment, N outgoings were low, and overall inputs of N exceeded outgoings in both years resulting in an accumulation of 84 kg N/ha over the two years. Nitrogen inputs in the seed treatment were very high due to a combination of fertiliser and fixation. Outgoings were also much higher in the seed treatment, due to removal of N in the harvested seed and ryegrass straw. However, overall inputs exceeded outgoings, resulting in an accumulation of 157 kg N/ha over the two years.

Large amounts of N were recycled annually in dung and urine (Table 3), particularly in the grazed treatment (241 kg N/ha compared with 120 kg N/ha in the seed treatment) due to the greater number of grazings.

Analysis of the soil at the end of the experiment showed that total N was similar to that at the start of the experiment (Table 1). There were no differences between the treatments in total N or exchangeable nitrate and ammonium (data not presented).

Glasshouse experiment

The DM production and N uptake of the wheat plants at the final harvest are shown in Table 4. Results from the first harvest showed similar trends to those at the final harvest and are not presented. Shoot and root growth in plants grown in soil from the grazed treatment was significantly greater ($P < 0.05$) than in soil from the seed production treatment. Grain yields were similar between the two treatments. The same trends were apparent in the N uptake data (Table 4), although

Table 4. Dry matter production and N content of wheat plants growing in soil that had been previously managed as a grazed sward or for seed production.

Parameter	Graze	Seed	$LSD_{(0.05)}$
Dry matter (g DM/pot)			
Grain	6.4	6.1	0.89
Straw	7.1	6.2	0.58
Roots	3.7	2.7	0.62
Total	17.2	15.0	1.19
N uptake (g N/pot)			
Grain	111	99	18.6
Straw	26	20	4.1
Roots	71	52	18.2
Total	208	171	20.1

herbage N concentration did not differ (data not presented).

Discussion

The rate of N fixation in the short term pasture was low compared to the 100-300 kg N/ha/yr typically fixed in pastures (Crush, 1979; Ledgard *et al.*, 1990). Nitrogen fixation is influenced by the growth of clover and soil mineral N content (Hoglund and Brock, 1987). The presence of grass plants in the sward also affects N fixation. Grass takes up mineral N from the soil, reducing the amount available for clover which increases fixation. However, competition from the grass reduces clover growth (Hoglund and Brock, 1987,) and the more aggressive the grass plant, the greater the reduction in N fixation (Harris and Hoglund, 1980). In this study the ryegrass appeared to have had a negative effect on N fixation. Where grasses were dominant and clover DM production was reduced, so too was N fixation. For example, in the first year of the seed treatment, clovers accounted for 9% of the total DM produced compared with 28% in the grazed treatment. Consequently, N fixation was considerably lower in the seed treatment. When white clover was grown for seed, clover DM production accounted for 83% of the total pasture yield, and N fixation by the clover plants increased 2.5 times compared with the grazed treatment.

Although the amount of N fixed by the clover seed crop was greater than in the other treatment, a previous study estimated N fixation in a white clover seed crop of a similar yield to be 220 kg N/ha (Whelan and White, 1985). This suggested that fixation at our site was limited by some factor such as soil moisture. Even though the plots were irrigated it is possible that the soil moisture was limiting between the irrigations. However, Whelan and White's measurement was made by a different technique (the N balance method) to that used in our study, making further comparison difficult.

Net inputs of N under seed production were about twice that of the grazed sward. However, some of the benefit came from the added N fertiliser. The low yield (850 kg/ha) of ryegrass seed in this study compared with the average Canterbury yield of 1100 kg/ha suggests that a higher rate of fertiliser could have been used to advantage, as commercial crops may receive up to 200 kg N/ha. While these high rates of N fertiliser can be considered excessive in relation to the amount of N removed in seed, recent research shows that the extra N applied is not lost, but remains in the soil or in the plant residues at harvest, and contributes to the overall N fertility of the soil (Williams *et al.*, 1997). If more N fertiliser had been applied to the ryegrass crop in this trial, the effect on soil N fertility may have been higher. While the amounts of N added to the soil in this experiment were significant in terms of the total amount of N taken up in a year by a crop, they are small compared to the total soil N content (4000 kg N/ha in the topsoil), and so did not have a measurable effect on soil N content.

The white clover seed crop also made a significant contribution to the N fertility of the soil. No measurements of N fixation were made after seed harvest. However, provided adequate soil moisture is available, clover growth and N fixation are likely to continue until the clover is cultivated, thereby increasing the contribution of the clover crop to the soil N status. This contrasts with grain legumes like peas and *Phaseolus* beans, whose contribution to soil N fertility is sometimes negative, i.e., the quantity of N fixed is less than the quantity of N harvested in the grain (Haynes *et al.*, 1993; Kelstrup *et al.*, 1996). A white clover seed crop is, therefore, more beneficial in a crop rotation for maintaining soil N fertility than some grain legume crops. Other grain legume crops like faba beans are capable of fixing high rates of N, even when soil N is relatively high, and so may add significant quantities of N to the soil (White, 1991).

Since the net N input was about twice as much under seed production than grazing, it is surprising that in the glasshouse study the wheat plants grew better in the grazed treatment soil. This indicates that the form of N returned to the soil may be more important to subsequent crops than the amount of N added. Although both treatments were grazed prior to the simulated ploughing there were differences in above ground dry matter. Therefore more residues were incorporated into the soil of the grazed treatment, which provided a larger source of residue N which could be mineralised and taken up by the wheat plants. A previous glasshouse experiment showed that adding fresh grass/clover residues to the soil significantly increased the yield of wheat plants (Williams and Haynes, 1997). Furthermore, the residues in the grazed treatment had a high N content, while those from the seed treatment were low (0.24%). During decomposition of residues with a low N content, immobilisation can occur (Haynes, 1986) which may have resulted in low N availability in the seed treatment soil. In the grazed treatment, more of the pasture N was recycled in dung and urine by the grazing animals. While this did not affect the amount of mineral N in the soil at the start of the glasshouse experiment, it is possible that a proportion of the N from excreta patches was more readily available. Whatever the reason for the increased wheat DM yield and N uptake in the grazed treatment, there was no influence on grain yield. However, this experiment was carried out in the glasshouse, with the plant roots confined to very small volumes of soil, and this limits our conclusions. Responses in the field may well be different.

Conclusions

Managing short term pastures for seed production resulted in greater inputs of N through fixation and fertiliser application than with grazing, but also resulted in greater N outgoings through removal in harvested seed and straw. Overall, the net input of N to the soil was higher under seed production than grazing. However, grazing appears to have a bigger beneficial carry over effect on the yield of a following indicator crop. Further research is needed to characterise the readily mineralisable pool of N that accumulates in the soil under short term pastures.

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