CAN FORAGES REDUCE NITRATE LEACHING LOSSES FROM MIXED CROPPING ROTATIONS IN NEW ZEALAND?

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ABSTRACT

The objective of this two-year experiment was to determine the ability of forages grown as winter cover crops to reduce nitrate leaching losses after temporary leguminous pastures were ploughed. In both years, cover crops reduced cumulative leaching losses compared with bare fallow and were most effective when sown early in the autumn. When large amounts of residues with relatively low N concentrations were incorporated in the soil in the spring, there was extensive net N immobilisation that suppressed the yield of the following wheat test crop. When cover crops were grazed, the N consumed by sheep as herbage was returned in highly concentrated urine patch areas. However, due to small amounts of subsequent drainage, grazing did not markedly increase cumulative leaching losses in either year. Compared with incorporation, grazing of cover crops overcame any possible yield reductions of the following spring wheat test crop.

KEYWORDS

Nitrate, leaching, grazing, N immobilisation, yield, urine patches

INTRODUCTION

Mixed cropping (pasture/arable) farming is commonly practised on over 750,000 ha of land on the Canterbury Plains of New Zealand. During the pastoral phase of the rotation (usually 2-5 years), large amounts of N are supplied to the system through symbiotic N_2 fixation by the clover component of the sward. Large amounts of nitrate (NO_3^--N) can be leached over the first and second winters after pasture is ploughed (Francis *et al.,* 1995). Such losses are thought to be a major contributor to the nitrate contamination of surface water and shallow groundwater in Canterbury (Haynes and Francis, 1990).

In New Zealand, rapidly-growing forages planted early in the autumn as cover crops can reduce leaching losses over the winter, but this depends on rainfall amount and distribution (Francis, 1995). In spring, these cover crops can either be incorporated or grazed before the following arable crop is established. These contrasting management options may have markedly different effects on nitrate accumulation in the profile, nitrate leaching losses and yield of the following arable crop.

MATERIALS AND METHODS

This study was conducted from 1993 to 1995 on a freely-draining Templeton silt loam soil that had been under a grazed ryegrass (*Lolium perenne*)/white clover (*Trifolium repens*) pasture for 4-5 years. Mean annual rainfall is 680 mm, with soil drainage likely to occur from about July to September.

Pasture was ploughed in March of each year, with plots either left fallow over winter, or sown with cover crops. Cover crops grown in both years were ryegrass (*Lolium multiflorum*), oats (*Avena sativa*) and winter wheat (*Triticum aestivum*). In 1993, lupins (*Lupinus angustifolius*) and mustard (*Sinapis alba*) were also grown. With the exception of the winter wheat, cover crops were either grazed during the winter or incorporated in the spring. In spring, all plots (except for the winter wheat) were ploughed and established in a spring wheat test crop, that was harvested the following summer.

Soil core samples for ammonium- and nitrate-N analysis were taken at the start and the end of winter leaching. Nitrogen leaching losses were calculated from soil solution N concentrations extracted with porous ceramic cups and calculated drainage amounts (Francis *et al.,* 1992).

RESULTS AND DISCUSSION

Total cumulative drainage from the fallow treatment was similar in both years, although major drainage events were later in 1993 than in 1994. In 1993, cover crops only significantly reduced drainage compared with fallow at the end of winter. In 1994 cover crops had no effect on drainage volumes. In 1993, cover crops were sown in March and had removed considerable amounts of mineral N from the soil in above-ground herbage by the start of winter (June) (Table 1). The exception was winter wheat that was sown in May in accordance with local farming practice. Crop N uptake continued through the winter, with substantial N contents in all crops by October. In 1994, cover crops were sown in April and at all sampling events their herbage N contents were much less and soil mineral N contents much greater than in the previous year.

Cumulative leaching losses from the fallow treatment were smaller in 1993 than in 1994 (Fig 1), largely due to the different patterns of drainage in each year. In both years leaching losses were reduced under all cover crops due to the uptake of soil mineral N before significant drainage occurred. Although differences between cover crops were not significant, there was a trend towards lesser leaching losses from the cover crops that removed the greatest amount of mineral N from the soil profile.

In both years, the management of cover crops had little effect on leaching losses. This was due to insufficient amounts of drainage after grazing to transport substantial amounts of mineral N through the soil profile. However, grazing cover crops markedly increased soil mineral N contents in the spring (October) by 60-270 kg N ha^{-1} compared with the corresponding non-grazed areas. Measured increases were greatest when the time between grazing and soil sampling were the shortest. These results suggest that grazing may increase nitrate leaching losses over winter if substantial amounts of drainage occurs after grazing.

In 1993, the incorporation of large amounts (5.3-9.9 t ha^{-1}) of plant material in ungrazed cover crop treatments in the spring probably caused extensive net N immobilisation. This depressed the yield of the following spring wheat crop compared with the grazed plots (Table 1). Lupins was the exception, with similar wheat yields where residues were grazed or ungrazed. This was probably due to the greater N concentration in the lupin residues, that would have resulted in a shorter period of net N immobilisation than for the other residues. In 1994, cover crops produced less dry matter (3.6-7.0 t ha^{-1}) and their management had no significant effect on the yield of the following wheat test crop.

REFERENCES

Francis, G.S. 1995. Minimising nitrate leaching losses following cultivation of temporary leguminous pastures in mixed cropping rotations in Canterbury, New Zealand. J. Contam. Hydrol. **20:** 313-327.

Francis, G.S., Haynes, R.J., Sparling, G.P., Ross, D.J. and Williams, P.H. 1992. Nitrogen mineralization, nitrate leaching and crop growth following cultivation of a temporary leguminous pasture in autumn and winter. Fert. Res. **33:** 59-70.

Francis, G.S., Haynes, R.J. and Williams, P.H. 1995. Effects of the timing of ploughing-in temporary leguminous pastures and two winter cover crops on nitrogen mineralization, nitrate leaching andspring wheat growth. J. Agric. Sci. (Camb.) **124:** 1-9.

Haynes, R.J. and Francis, G.S. 1990. Effects of mixed cropping farming systems on changes in soil properties on the Canterbury Plains. N. Z. J. Ecol. **14:** 73-82.

Table 1
Soil mineral N contents (0-1 m), herbage N contents at the start of winter (June) and in spring (October) 1993, and grain yield of the spring wheat test crop.

z	Soil mineral N (kg N ha^{-1})		Herbage N (kg N ha^{-1})		Spring wheat yield (t ha^{-1})	
Treatment	June	October	June	October	Ungrazed	Grazed
Fallow	98.2	132.9	0.0	0.0		5.64
W. Wheat	137.3	33.4	3.0	164.1		6.13
Ryegrass	60.1	18.9	53.0	109.2	3.92	5.77
Oats	51.7	27.1	53.0	297.2	3.97	5.40
Lupins	76.0	35.7	50.0	269.3	5.93	5.45
Mustard	46.2	45.3	71.3	159.7	4.53	4.99
LSD	35.80	27.19	11.18	48.53	1.11	1.11

Figure 1
Cumulative leaching losses in (a) 1993 and (b) 1994. Vertical lines represent LSD.

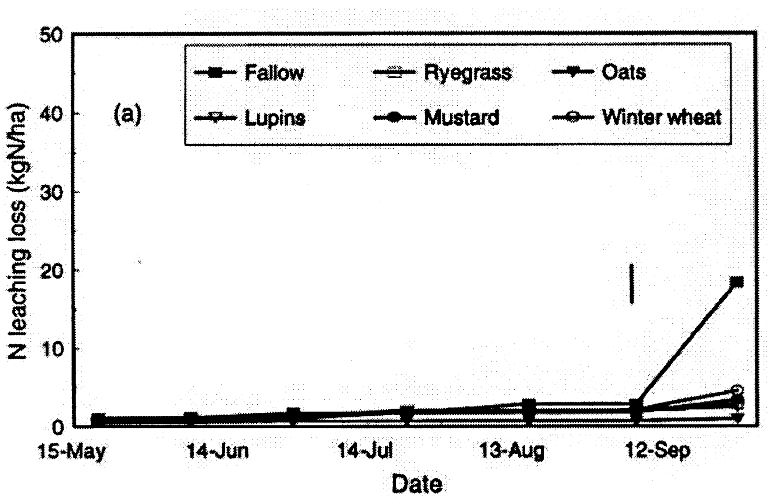

Figure 2