Nitrate leaching is similar in N_2-fixing grass–clover pasture and N-fertilised grass-only pasture at similar N inputs

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Abstract

Nitrate leaching losses were measured in farmlets containing ryegrass–clover pasture which received most of its nitrogen (N) input in the form of N_2 fixation by white clover, or a ryegrass-only pasture which received a similar amount of N in the form of urea fertiliser. The farmlets were rotationally grazed by dairy cows between 1993 and 1996 at the Dairying Research Corporation's No. 5 dairy, Hamilton. Total N inputs ranged from 146 to 200 kg/ha/year. Total pasture production was similar in both treatments in year 2, but was 22% lower in the grass–clover pasture in year 3. Milk production was similar for both farmlets in years 1 and 2, but was not measured in year 3. Nitrate concentrations in the leachate were measured using ceramic cup collectors at 1 m depth. The average nitrate-N concentration in leachate over the 3 years was 3.9 and 3.7 mg/litre for the fertiliser and clover treatments, respectively. This is well below the 11 mg nitrate-N/litre limit set for drinking water. Over the 3 years of the trial, 76 and 71 kg N/ha were leached from the fertiliser and clover treatments, respectively. Thus there was no significant difference between N sources in the amount of nitrate-N leached.

Keywords: dairying, nitrate leaching, nitrogen fertiliser, N_2 fixation

Introduction

Increasing use of nitrogen (N) fertiliser on New Zealand's intensively grazed dairy pastures has led to concern about nitrate leaching into groundwater. Historically, most New Zealand dairy pastures received N from biological N_2 fixation by white clover. In contrast, use of N fertiliser on ryegrass-only pastures is widespread in Europe. Using fertiliser enables the N to be applied at times of feed shortage or maximum plant uptake. While this could improve the efficiency of N use, much of the nitrate leaching under grazing occurs from urine patches rather than directly from fertiliser N (Ledgard *et al.* 1996).

In grass–clover pastures, self-regulation of N_2 fixation may result in a greater efficiency of N use, e.g., in urine patches the high level of inorganic N inhibits N_2 fixation thereby reducing N inputs to these patches. However, as N fertiliser is applied uniformly to pastures this may lead to increased losses from urine patches. Ruz-Jerez *et al.* (1995) showed lower leaching losses from grass–clover pastures than from N fertilised grass-only pastures under sheep grazing, although total N inputs from fertiliser of 400 kg N/ha/year were much higher than from N_2 fixation.

The aim of the present study was to compare production and nitrate leaching losses from grass–clover and N-fertilised grass-only pastures at similar N inputs under intensive dairy cow grazing.

Methods

The experiment was conducted on the Dairying Research Corporation's No. 5 dairy unit near Hamilton. The soil type was a Bruntwood silt loam (Aquic Hapludand). In the autumn of 1993, one farmlet was sown with Yatsyn 1 perennial ryegrass while the other was sown with a mixture of Yatsyn 1 perennial ryegrass and Grasslands Kopu white clover. Site details were given by Thom *et al.* (1994). The farmlets were rotationally grazed at 3.8 cows/ha.

Within three replicate paddocks of each farmlet, pasture production was measured using shifting exclosure cages between September 1994 and September 1996 (subsequently called years 2 and 3). Pasture samples were collected 8 times per year, dissected into grass and clover, and analysed for total N concentration. N_2 fixation by clover was estimated using clover N yield data in conjunction with estimates of the proportion of N fixed, using ^{15}N data from neighbouring trials which covered a range of conditions including the soil, clover content and management conditions used in the current experiment (Ledgard *et al.* 1990, 1996). In the fertilised farmlet, urea was applied in split applications (17–50 kg N/ha/application; 146–200 kg N/ha/year) at an annual rate similar to that from N_2 fixation in the grass–clover farmlet. The grass–clover paddocks also received a small quantity of urea in the first two years.

In autumn 1994, 8 leachate samplers were installed in each paddock (24/farmlet, increased to 30 in 1996). The samplers consisted of a ceramic suction cup attached to an 80 cm long PVC tube. The samplers were inserted at a 45° angle into undisturbed soil in order to prevent any preferential flow down the outside of the collector. To avoid any effects on grazing patterns, all parts of the collection system were below ground level. Leachate samples were collected at fortnightly intervals throughout the winter leaching period. This involved applying tension to each sampler and extracting a soil water sample 24 hours later. Ammonium and nitrate concentrations were determined using flow injection analysis.

Drainage volume was measured using four 1 m deep lysimeters containing undisturbed soil cores (40 cm diameter) supporting a ryegrass–clover sward. The lysimeters were buried flush with the surrounding soil surface near the trial paddocks. The edges of the soil cores were sealed with vaseline to eliminate by-pass flow.

Results

Pasture production was not significantly different between treatments in 1994/95 (year 2), but was higher ($P<0.05$) in the N-fertilised grass treatment in 1995/96 (year 3; Figure 1a). Pasture N yield showed a similar trend (Figure 1b), although the difference was less because of the higher N concentration in the clover plants. In 1995/96, the grass in the fertilised paddocks had significantly higher N concentrations than the grass in the clover paddocks (3.21 vs. 2.92%N, respectively).

In the second and third years after pasture establishment, both treatments had similar total N inputs (Table 1).

Table 1 N inputs (kg N/ha/year) in grass–clover and N-fertilised grass-only treatments.

	----- Clover treatment ----- fixed N	fertiliser N	total N	Fertiliser treatment fertiliser N
1993/94 (Year 1)	n.d.	40		200
1994/95 (Year 2)	104	42	146	157
1995/96 (Year 3)	175	0	175	165

n.d. = not determined

Ammonium-N concentrations in the leachates were low, with none over 1 mg N/litre and nearly half the samples below the detectable level (< 0.01 mg/litre). Nitrate concentrations showed a high degree of spatial variation, associated with urine distribution in the paddocks (Cuttle 1992). Concentrations greater than 100 mg nitrate-N/litre were recorded from some individual samplers, but over 75% of recorded values were less than 5 mg/litre. The mean nitrate-N concentration was below 10 mg/litre throughout the trial (Figure 2). In the second winter (1995), the mean nitrate concentrations from the clover treatment were consistently higher than from the fertiliser treatment. However, in the following year the situation was reversed for most of the season. In neither year were the differences significant.

Figure 1 Pasture (a) dry matter and (b) N yields in grass–clover and N-fertilised grass-only treatments. Error bars represent SEDs.

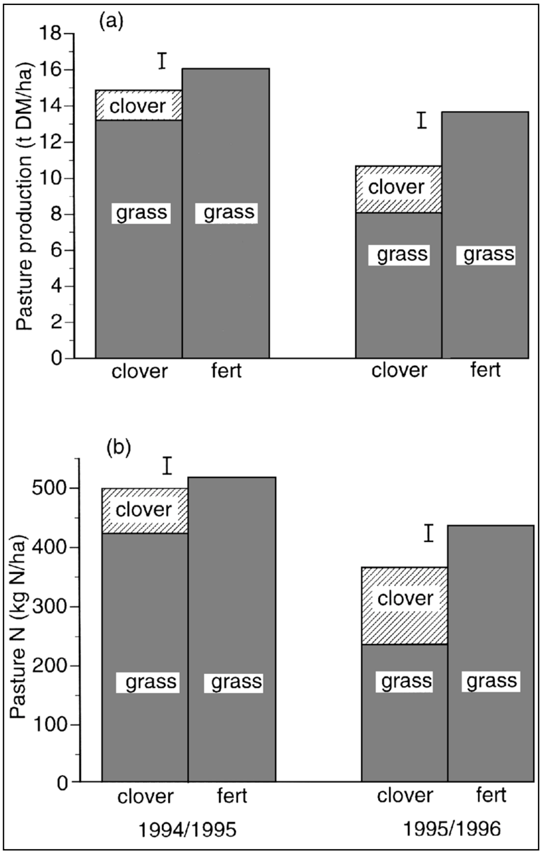
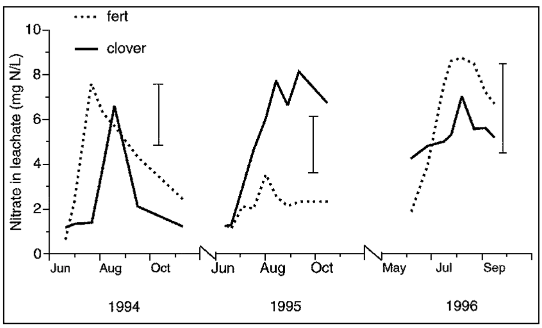
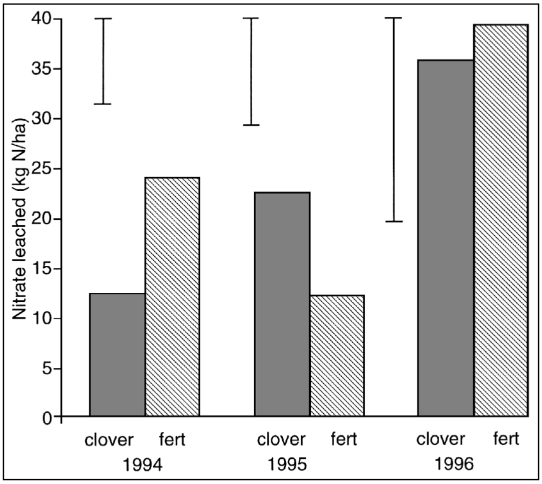


Figure 2 Amounts of nitrate-N leached from grass–clover and N-fertilised grass-only treatments. Error bars represent SEDs.



There were no significant differences between treatments in the amounts of N leached (Figure 3). In years 1 and 2, the amounts lost were relatively low at 12–24 kg N/ha/year but in year 3 the losses rose considerably.

Figure 3 Nitrate-N concentrations in leachate collected at 1 m soil depth from grass–clover and N-fertilised grass-only treatments. Error bars represent SEDs.



Discussion

Annual dry matter production was similar for both farmlets in year 2, but was 22% lower in the grass–clover pasture in year 3. Milk production showed no significant difference between farmlets in years 1 and 2, but was not measured in year 3 (Thom *et al.* 1994; Thom *et al.* unpublished).

Several studies have shown that leaching losses from grazed pasture increase with additional N fertiliser applications (Scholefield *et al.* 1993; Ledgard *et al.* 1996). This is mostly owing to an increase in dry matter production, N uptake and recycling in animal excreta leading to a corresponding increase in leaching losses from urine patches. The present study showed no significant differences in leaching losses when fertiliser N was substituted for biologically-fixed N at a similar rate. Cuttle *et al.* (1992) also measured similar levels of nitrate leaching from grass–clover and N-fertilised (150–200 kg N/ha/year) grass pastures under sheep grazing in Wales. The extreme spatial variation in leaching losses owing to urine patches make small differences difficult to detect. Despite the increase in the number of collectors in the third year the error bars in Figures 2 and 3 indicate that a greater degree of replication was desirable.

The actual amount of N leached in the first year of measurements in the trial (1994) was low compared with the results obtained from another trial on a neighbouring site (72 kg N/ha; Ledgard *et al.* 1996). Leaching losses were probably high in 1993 owing to increased N mineralisation associated with pasture establishment procedures, and that this was followed by increased microbial immobilisation, thereby reducing the amount of N available for leaching in 1994 (Scholefield *et al.* 1993). The increase in leaching in the third year was in part due to higher than normal drainage from heavy winter rainfall (the average drainage in the first two years was 612 mm compared with 714 mm in year 3). In the third year, the pasture N yield tended to be higher in the N-fertilised grass treatment than the grass–clover treatment, and this trend was also evident in the amounts of N leached.

Conclusions

The results of this experiment showed similar nitrate leaching from grazed pastures receiving fixed N or fertiliser N at similar N inputs. This indicates that the environmental impact of N in dairy pastures is determined largely by the amount of N input rather than the source of N.

ACKNOWLEDGEMENTS

We thank Fiona Clarkson, Deanne Waugh, George Brier and Ernest Nemaia for technical assistance; Li Ouyang for nitrate and ammonium analyses; John Waller for statistical analyses, and the farm staff at the Dairying Research Corporation's No. 5 dairy for their co-operation throughout the trial.

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