Effect of nitrogen fertiliser rate on production and nitrogen leaching from Italian ryegrass following a maize silage crop

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Abstract

Dry matter (DM) yield responses and field nitrogen (N) leaching losses were assessed following the application of 4 rates of N fertiliser to an Italian ryegrass (*Lolium multiflorum*) crop grown after maize. The trial was conducted on a free-draining Horotiu silt loam (typic orthic allophanic soil) at Dexcel's Scott Farm near Hamilton, New Zealand. The grass was direct drilled into maize stubble on 13 April 2002. Small plots received a total of 0, 40, 100 or 160 kg N/ha as urea, split into 4 equal applications from May to July. Total DM production over 24 weeks for the 0, 40, 100 or 160 kg N/ha treatments was 2730, 3487, 4238 and 4840 kg DM/ha, respectively. Additional kg DM produced/kg N applied was 19, 15 and 13, respectively. The 'apparent' proportion of applied N removed in the herbage from all plots was 55- 60%. Herbage nitrate-N concentrations exceeded the commonly accepted critical level of 0.21% on the 160 kg N/ha treatment at the first harvest on 3 July 2002, when only half of each N rate had been applied.

There were no significant treatment differences in leaching losses (range 17-34 kg N/ha).

Italian ryegrass grown on a silt loam soil after maize showed an almost linear yield response to N fertiliser over the range 40-160 kg N/ha, without increased inorganic N leaching. Further work is necessary to confirm these results and to establish whether or not higher rates of N fertiliser can be used to increase winter dry matter yields from Italian ryegrass, without increasing N leaching losses.

Keywords: annual ryegrass, dairy systems, double cropping, nitrogen leaching

Introduction

Winter forage crops can be grown in rotation with summer crops as part of a double-cropping system to provide high annual dry matter (DM) production in New Zealand dairy systems. Annual ryegrass, oats and triticale are commonly used as the winter crop and may be grazed or cut for silage, before maize is replanted in spring.

New Zealand research has shown mixed responses to applying nitrogen fertiliser to the winter crop. Thom & Gillespie (1987) used Florida oats (marketed as Hat-trick oats) as a winter crop in a double-cropping system with maize. In two out of three years there were no 'ensiling-time' yield responses to N and in the other year, 35 kg N/ha improved yield by 29% with no further response to another 35 kg N/ha. Davies & Neilson (1975) grew Italian ryegrass crops for winter forage at a North Island and a South Island site following a summer maize crop. The ryegrass crop showed no yield response to N at the North Island site but a large increase at the South Island site. Vartha & Rae (1973) followed a summer wheat crop with an Italian ryegrass winter crop and recorded increased yields with 67 kg N/ha compared with 22 kg N/ha. N leaching losses were not measured in any of these trials, but late-autumn/early-winter N applications are particularly vulnerable to leaching (Ledgard *et al*. 1988).

The aim of this study was to determine herbage yield responses and inorganic N leaching losses following the application of 4 rates of N fertiliser to an Italian ryegrass crop grown over winter after a maize silage crop.

Method

Design

In summer 2001/2002, a maize crop was grown on a Horotiu silt loam soil at Dexcel's Scott Farm, Hamilton, New Zealand. This was the third summer crop (sulla, maize, maize) off the area, breaking at least 20 years of grazed pasture. Forty-one kg N/ha, as urea, was applied at drilling, and a further 138 kg N/ha in December 2001. The maize crop was harvested on 28 March 2002 yielding 17 t DM/ha. Soil tests showed low Olsen P levels (14 µg/ml) so 750 kg/ha of superphosphate (68 kg P/ha, 83 kg S/ha) was applied before Italian ryegrass (*Lolium multiflorum* cv. Cordura) was direct drilled (20 kg/ha) into the maize stubble on 13 April 2002.
The trial area was fenced to prevent animal grazing and divided into (5 x 2 m) plots using a 4 replicate, randomised block design. Maize stubble was cut to ground level in the fenced trial area to avoid contamination of herbage samples.

Treatments
Nitrogen as urea (46% N), was applied at 4 different rates representing a total of: (1) 0; (2) 40; (3) 100; and (4) 160 kg N/ha. The urea was applied in 4 equal applications of (1) 0; (2) 10; (3) 25; and (4) 40 kg N/ha at 18, 40, 90 and 109 days after sowing. A single application of urea at 40 kg N/ha was applied to the surrounding paddock on 1 July 2002.

Plant
The plots were harvested (two mower strips from each plot using a rotary mower set to a height of 8 cm) each time the surrounding paddock was grazed. Three harvests were made at 81, 135 and 170 days after sowing. Herbage sub samples were collected from the mower catcher. These were dried at 70°C for 24 hours before determining DM content, total N content using a Kjeldahl digest, and nitrate-N using an acetic acid extraction.

Leaching
After drilling the Italian ryegrass, porous ceramic cup leachate collectors (3 per plot) were inserted approximately 60 cm below the soil surface. A further 30 samplers were installed in the surrounding paddock to assess leaching losses under grazing. At each sampling a small tension was placed on the ceramic cup to collect a sample of the surrounding soil solution. Samplings were carried out 69, 88, 104, 129, 157 and 171 days after sowing. Samples were analysed by high pressure liquid chromatography for nitrate and ammonium-N. Drainage was estimated by collecting water draining through lysimeters (0.4 m diameter by 1 m depth) containing intact soil cores.

Soil and root sampling
Soil cores (0-15, 15-30 and 30-60 cm; 6 /plot) were collected 9 days after drilling and immediately after each harvest for analysis of soil inorganic N. Root material was separated out and washed, then analysed for total N. Total soil carbon (C) and N concentrations, and soil bulk density were measured at the initial sampling.

Statistical analysis
Genstat 5 software was used to analyse data for statistical significance using analysis of variance.

Figure 1 Italian ryegrass dry matter yield response to N fertiliser (kg/ha). Data are the sum of 3 harvests (April–September 2002).

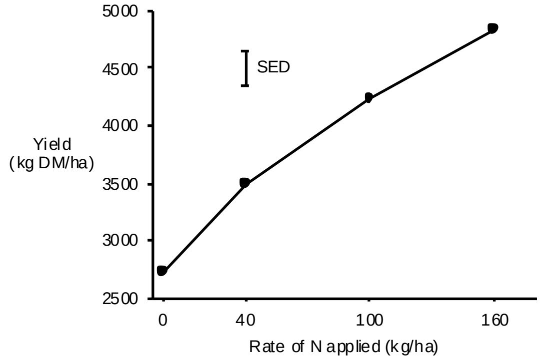


Figure 2 Dry matter yield response to N fertiliser at 3 harvests.

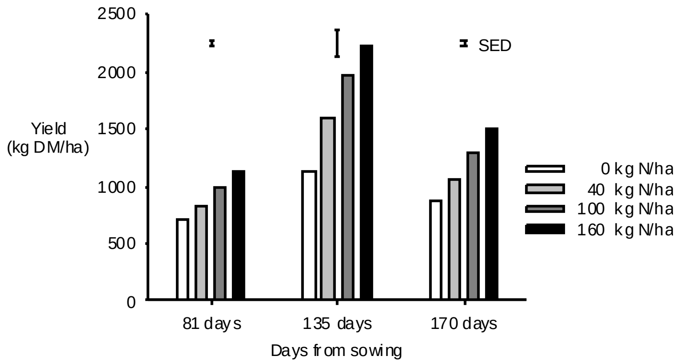
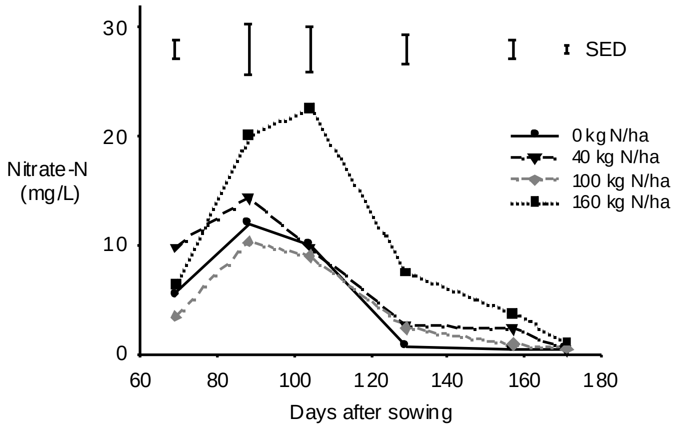


Figure 3 Nitrate-N concentration in leachate (mg/L).



Results
Herbage
DM yield increased by 28% in response to 40 kg N/ha and by 77% at 160 kg N/ha (Figure 1). Additional DM grown per kg of applied N declined from 19 kg DM/ kg N at 40 kg N/ha to 15 and 13 kg DM/kg N at 100 and 160 kg N/ha, respectively.

Table 1 Total herbage N concentration (% of DM).

Treatment (kg N/ha)	1st Harvest (81 days) half N applied	2nd Harvest (135 days) all N applied	3rd Harvest (170 days) all N applied	Average[1]
0	4.36	2.71	2.27	3.05
40	4.58	2.79	2.14	3.03
100	4.73	3.29	2.28	3.34
160	4.81	3.91	2.55	3.70
SED	0.22	0.18	0.10	

[1] weighted for yield differences over time

Table 2 Herbage nitrate-N concentration (% of DM).

Treatment (kg N/ha)	1st Harvest (81 days)	2nd Harvest (135 days)	3rd Harvest (170 days)	Average[1]
0	0.13	0.03	0.01	0.05
40	0.17	0.03	0.01	0.05
100	0.20	0.05	0.01	0.07
160	0.25	0.19	0.02	0.15
SED	0.043	0.041	0.009	

[1] weighted for yield differences over time

Table 3 Soil inorganic N – 0-60 cm (kg N/ha).

Treatment (kg N/ha)	Initial[1]	1st Harvest (81 days)	2nd Harvest (135 days)	3rd Harvest (170 days)
0	85.1	15.1	3.4	4.1
40		45.6	4.2	3.7
100		58.7	8.5	4.6
160		98.5	9.5	5.4
SED		36.4	2.9	0.8

[1] 8 days after drilling annual ryegrass

Table 4 Inorganic N (nitrate-N and ammonium-N) leached (kg/ha) over the winter drainage period.

Treatment (kg N/ha)	NO_3^--N	NH_4^+-N	Total
0	20.6	1.37	22.0
40	30.9	1.44	32.3
100	15.7	1.54	17.2
160	31.7	2.28	34.0
SED	6.2	0.35	6.3

The greatest DM yield response occurred at the second harvest (day 135), but the response was still significant ($P < 0.001$) at the final harvest (Figure 2). Total N concentration in the herbage was highest at the first harvest (day 81), regardless of treatment and lowest at the third (day 170) harvest (Table 1).

The ‘apparent’ proportion of applied N removed in the herbage was 55, 58 and 60% for the 40, 100 and 160 kg N/ha treatments, respectively. There was a significant increase ($P < 0.05$) in herbage nitrate-N concentration (Table 2) with increasing fertiliser N rate at the first and second harvests. By harvest 3, pasture nitrate-N concentrations in all treatments had fallen to control levels (0.01%).

At all harvests, root N concentration was higher in the N treatments (1.00, 1.06, 1.25 and 1.23% for the 0, 40 100 and 160 kg N/ha treatments, respectively, averaged for all harvests) but this was only statistically significant ($P < 0.05$) at the first harvest (data not presented).

Soil

At the initial sampling on 22 April, soil inorganic N levels were high at 85 kg N/ha (0-60 cm), with most as nitrate-N in the top 15 cm of the soil. By the end of the trial inorganic N levels had fallen to 3-5 kg N/ha with no significant differences between treatments (Table 3).

Leaching

Nitrate-N concentrations in the leachate (Figure 3) peaked at the second and third collections (days 88 and 104), when they were higher ($P<0.05$) in the 160N treatment than in the other treatments. The concentrations declined rapidly, and at the final collection only one of the 40 collectors recorded a nitrate-N concentration of more than 1 mg/L. Weighted leachate nitrate-N concentrations for the season (sum of the total nitrate leached over each sampling interval divided by the total drainage volume) were 6.5, 9.8, 5.0 and 10.1 mg/L for 0, 40, 100 and 160 kg N/ha treatments, respectively. No significant treatment differences were detected.

Ammonium-N concentrations in the leachate were much lower than nitrate-N. Treatment averages never exceeded 1 mg/L.

A total of 310 mm of drainage occurred during the trial (60% of the long-term average) with about half the total annual drainage occurring during May/June.

Almost all the inorganic N leached (94%) was in the form of NO_3^- (Table 4).

The average N leaching loss measured by the collectors in the surrounding grazed paddock (34.2 and 1.9 kg N/ha as nitrate-N and ammonium-N, respectively) was slightly higher (3.8 kg N/ha) than from the corresponding treatment under mowing.

Discussion

Italian ryegrass responded strongly to N fertiliser up to 160 kg N/ha, the highest application rate. Response ranged from 13-19 kg DM/kg N, much higher than the 8-12 kg DM/kg N typically recorded on established, Waikato perennial ryegrass-based dairy pasture during winter (Feyter *et al.* 1985) but within the range of results reported by Stephen *et al.* (1978) for Italian ryegrass following summer wheat or oat crops at various South Island sites.

Herbage nitrate-N concentrations were above or close to the critical animal health threshold (0.21%) for the two highest N rates at the first harvest, and for the 160 kg N/ha treatment at the second. Nitrate accumulates in grass when the roots absorb nitrate faster than the plant can assimilate it by conversion to protein (Kemp *et al.* 1978). This could be caused by a combination of slower grass growth due to the onset of winter and high N fertiliser rates. Herbage with nitrate-N concentrations near 0.21% of DM requires careful management to avoid nitrate poisoning in the grazing animals.

Although the 160 kg N/ha treatment recorded higher nitrate-N concentrations at the second and third samplings there were no significant differences between treatments in the amount of N leached. The high proportion of the drainage that occurred in May/June meant the nitrate-N concentrations in the initial (June) sampling had a disproportionate influence on the total nitrate-N leached.

Previous European studies have shown N leaching losses from ungrazed perennial ryegrass plots of less than 20 kg N/ha with annual applications of less than 250 kg N/ha (Barraclough *et al.* 1984; Triboi 1987), and negligible leaching from non-N fertilised cut grass swards (Whitehead 1995). The high N leaching loss in all plots including the untreated controls (averaging 26 kg N/ha), was probably due to the build-up of inorganic N in the soil following the maize harvest or residual fertiliser N in the soil at the end of March. Soil analysis showed 85 kg/ha of inorganic N present in the top 60 cm of soil before the first N fertiliser application was made. By the time of the first harvest, the soil inorganic N level in the control treatment had fallen to 15 kg/ha and 15.7 kg/ha of nitrate-N had been leached. In double cropping systems, soil inorganic N is vulnerable to loss by leaching before the winter forage crop matures sufficiently to utilise it (Ludecke & Tham 1971; Trindade *et al.* 2001). The volume of rainfall at this time may explain some of the reported variation in winter forage crop response to N.

Nitrogen leaching losses can be affected by the volume of drainage in a year and 2002 was a dry year in the Waikato (994 mm vs the long term average of 1201 mm). However, low inorganic N concentrations in the later leachate samplings and soil inorganic N measurements indicated that there was little inorganic N left to leach by the end of the trial.

From a groundwater contamination perspective, the concentrations of nitrate-N in the leachate exceeded the recommended maximum for drinking water of 11.3 mg/L (Ministry of Health 1995) at the second and third collections. However, these collections represented only a small component of total drainage and concentrations declined rapidly to below this level for all treatments by the fourth collection. Weighted average concentrations for total winter drainage (5-10 mg/L) were all below the recommended maximum level.

The losses from the surrounding grazed paddock area were within the 10-70 kg N/ha/year range found in previous studies in the Waikato under intensive dairying in the absence of N fertiliser (Ledgard *et al.* 1996). Leaching losses from grazed pastures are normally higher than from mown pastures due to the effect of urine patches and this was the case in this experiment (36 versus a treatment average of 26 kg N/ha). The high standard deviation (30) reflects the spatial variability of urine patches in the paddock.

Conclusions

Applications of 40, 100 and 160 kg N/ha to Italian ryegrass grown after a maize crop increased DM yields by 28, 55 and 77%, respectively. Between 55 and 60% of the applied N fertiliser was removed in the herbage. Under cutting, increasing the fertiliser N rate from 0 to 160 kg N/ha did not significantly increase the amount of inorganic-N leached from the plots. If the plots had been grazed, however, leaching differences between treatments may have been higher, as a proportion of the additional N recovered in the herbage would have been returned to the soil in urine patches. Replacing animal grazing with a single silage harvest before replanting maize would remove animal health concerns over high herbage nitrate concentrations at the initial grazings and, when used in conjunction with a feedpad, would minimise leaching losses. However, a single silage harvest may have produced less total DM than regrowth from several grazings.

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