SIMULATED EARLY AND LATE WINTER GRAZING: EFFECTS ON NITROGEN LEACHING ON PUMICE SOILS

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Abstract

Wintering of dairy cows on forage crops is an increasingly common management strategy. Grazing of brassica winter forage crops returns large amounts of excreted nitrogen (N) to the soil. Previous work on pumice soils has shown that N leaching losses from a June-grazed winter brassica crop could be 100-150 kg N/ha, with 50-100 kg N/ha remaining in the soil in the spring. The hypotheses of this experiment were that later grazing would leach less N than an early grazing and that using a nitrification inhibitor, dicyandiamide (DCD), would be more effective in decreasing mineral N leaching for the earlier grazing than the later grazing. A small plot scale trial was established on a free draining pumice soil near Mangakino in the upper Waikato River catchment in the winter of 2012. Grazing of plots was simulated by manual removal of the forage brassica crop in early June (early grazing) or July (late grazing) and adding artificial cattle urine (600 kg N/ha equivalent). Half of the plots also received DCD (12.5 kg DCD/ha x 2 applications on the early plots, 1 application on the late plots). Nitrogen leaching was measured using porous ceramic cups, and by measuring soil mineral N to a depth of 60 cm. The experiment was duplicated in a pasture paddock for comparison. Total mineral N leached was significantly lower ($P<0.001$) for the late grazing for both the brassica crop and for pasture. Retained N in the soil was also significantly higher ($P<0.005$) for late grazing in both the crop and pasture. Application of DCD did not result in a significant measured reduction in N leached, but there was an indication of more mineral N retained in the soil at the end of drainage (significant in the forage crop at $P=0.05$). Monitoring of the plots will continue into a second winter to look for carry-over effects of the N remaining in the soil at the end of the first winter.

Key words:

Winter forage, nitrogen, leaching, DCD

Introduction

Wintering of dairy cows on forage crops is an increasingly common management strategy. Forage crops can provide large amounts of quality feed suitable for wintering cows or growing young stock. A cropping phase in a pastoral system also provides an opportunity for pasture renewal. Grazing of brassica winter forage crops returns large amounts of excreted nitrogen (N) to the soil. Monaghan *et al*. (2007) reported that the wintering component of dairy systems in Southland made a disproportionately large contribution to total annual N losses (c. 60%), despite representing a relatively small area of the farming system (<15%). Previous work on pumice soils has shown that N leaching losses from a June-grazed winter brassica crop could be 100-150 kg N/ha, with a further 50-100 kg N/ha remaining in the soil in the spring (Shepherd *et al*. 2012). The purpose of this study was to measure the effect of grazing timing and a nitrification inhibitor, dicyandiamide (DCD) application, on the amount of nitrate nitrogen (NO_3-N) lost from simulated cattle urine patches applied to a winter forage brassica crop, and to pasture as a comparison. The hypotheses were that a later grazing and its associated urine N deposits would leach less N than an earlier grazing and that DCD would be more effective at reducing N loss from urinary N when used on an early grazing compared to a later grazing. We also hypothesised that leaching losses would be less on pasture because of the presence of a nitrogen sink throughout the winter and the spring.

Methods

The trial was located on a farm near Mangakino in the upper Waikato River catchment. The property is on rolling land on a freely draining pumice soil (Taupo sandy loam). For this experiment, adjacent paddocks of a kale/swede (*Brassica oleracea/Brassica napus*) mixed winter brassica crop and pasture were identified in April, 2012 and 36 plots (1.5 x 1.5 metres) were marked out in each paddock. The trial areas were fenced off to prevent stock access. Four porous ceramic cups (Webster *et al*. 1993) were installed in each plot to a depth of 60 cm (at a 45 degree angle). Grazing of plots was simulated by manual removal of the forage brassica crop, or by mowing of the pasture plots and removing herbage, and application of synthetic cow urine. Grazing treatments were ‘early’ (in early June) and ‘late’ (in late July). At the time of simulated grazing synthetic cattle urine was applied to each plot at a rate equivalent to a urinary N loading of 600 kg N/ha. Half of the treated plots received DCD. The DCD applied was a granular zeolite coated DCD formulation (DCn ™; 24% DCD) which was applied at a rate of 50 kg/ha, or the equivalent of 12 kg a.i./ha immediately after ‘grazing’. This application was repeated 6 weeks after the first. Thus the early treatment received 2 applications of DCD whereas the late grazing received only one application.

Thus for each site (crop or pasture) the experimental structure was a 2x2 factorial with four treatments: urine applied early or late; with or without DCD.

Soils were sampled for mineral N (NH_4-N plus NO_3-N; ‘Nmin’) to 60 cm before treatments were imposed on 29 May and 27 July. Eight bulked soil cores per sample were taken on a block basis from around the outside of the plots to avoid damage to the plots. At the end of the drainage season soils from the plots themselves were sampled (4 cores per plot) and chemically analysed.

Sampling of porous cups started on 22 June and continued until the end of spring drainage period in October. A leachate collection was made from the porous cups for every 30-50 mm of rainfall by applying a suction of *ca.* 60 kPa for four hours before removing all the collected soil solution. In total, there were nine collections taken before drainage ceased in the spring. The collected leachate samples were frozen for storage before being thawed for analysis of nitrate-N (NO_3-N) and ammonium-N (NH_4-N). A soil water drainage model (Woodward *et al.,* 2001) was used to estimate winter drainage.

Results

The Waikato region experienced above average rainfall during the spring and summer of 2011-12. After a drier than normal April, rainfall levels were generally near the 10 year average for May through to Octoberfrom data based on NIWA’s Virtual Climate Station network (Tait *et al.* 2006) as shown in Table 1. The crop had accumulated 10.9 t/ha DM when assessed in late May, above the farm’s target of 10 t/ha. This represented an N accumulation of 337 kg N/ha in the trial area potentially available to be consumed and redeposited by grazing animals. Drainage began in mid May and the accumulated drainage for the winter and early spring period was 489 mm, with most of this occurring after the first urine application (Table 1). There was approximately 121 mm after the grazing in late July (Table 1).

Table 1. Rainfall totals(mm) (NIWA Virtual Climate Station) for the experiment period and estimated monthly drainage (mm) using the water balance model of Woodward *et al*. (2001).

Month	Monthly Rainfall 2012	Rainfall 10 year average	Monthly drainage	Cumulative drainage
January	135	78	0	0
February	95	92	0	0
March	97	68	0	0
April	67	101	0	0
May	147	119	58	58
June	113	134	78	136
July	206	143	144	280
August	147	143	88	368
September	135	112	56	424
October	136	136	64	488

Soil Nmin, pre graze

Measurements of soil Nmin prior to the “grazing” of the crop and pasture indicate the amount of N potentially available for leaching before there had been any contribution from the addition of synthetic urine. Amounts of Nmin at soil depth to 60 cm were 34 and 18 kg N/ha under pasture and crop areas, respectively at the early grazing, and 20 kg N/ha for both the pasture and crop areas at the late grazing (Table 2). This indicates that the crop had utilised a large amount of the available fertiliser and soil N during its growth. The higher and more variable Nmin in the pasture suggests that there were likely urine spots remaining from previous cattle grazings, despite the area having been excluded from grazing since April.

Table 2. Summary of soil mineral N (kg N/ha) prior to treatment application.

	Sample depth	Early graze Mean	Early graze SED	Late graze Mean	Late graze SED
Pasture	0-30 cm	21	11.4	14	1.1
	30-60 cm	13	1.7	6	2.2
	Total	34	8.0	20	2.3
Crop	0-30 cm	14	0.9	13	1.8
	30-60 cm	4	1.6	7	1.4
	Total	18	2.1	20	2.0

Mineral N leaching

Cumulative mineral N (NH_4-N + NO_3-N, though most was as NO_3-N) leaching in the drainage under the pasture and crop is shown in Figure 1. In the early grazed treatments in both crop and pasture, mineral N leaching increased quickly from July onwards, presumably as the early deposited urine N was leached to the porous cup sampling depth of 60 cm. In the late grazed treatments the increase in N leaching did not begin until August as the deposited urine N took time to be leached to sampling depth. There was approximately 150 mm of drainage from the time urine was applied until mineral N concentrations increased in the collected leachate.

Cumulative N leaching losses are reported for the entire winter drainage period (Table 3). In both crop and pasture areas, N leaching losses from earlier grazing were significantly more than later grazing ($P<0.001$). The differences in leached N were 118 kg N/ha under pasture and 93 kg N/ha in the crop area as a mean of +/- DCD treatments. The DCD applications did not significantly decrease N leaching in either pasture or the crop in either the early or late grazing.

Figure 1. Cumulative N leaching in drainage measured by porous ceramic cups at 60 cm depth (kg N/ha). Standard error bars are shown.

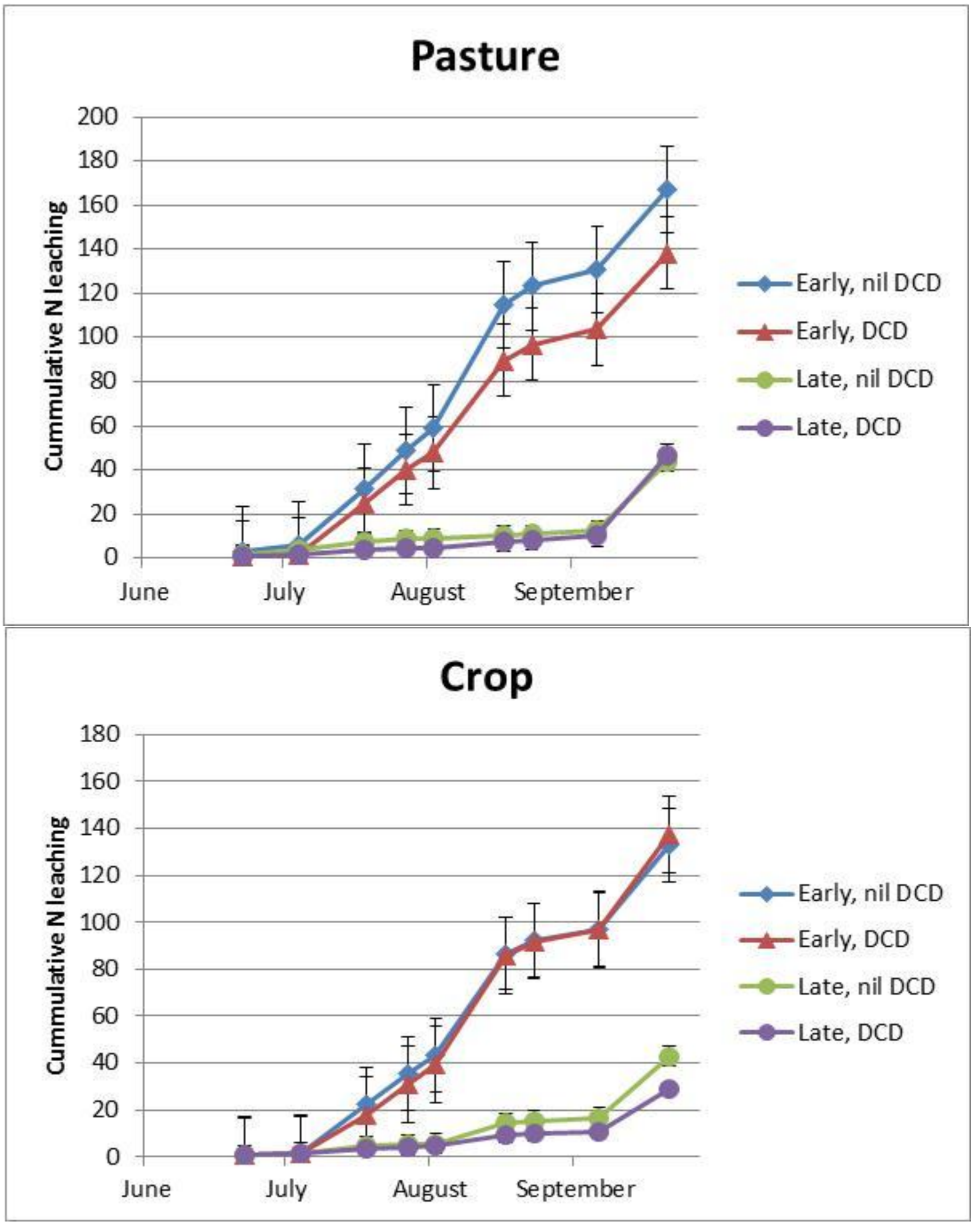

Table 3. Summary of mineral N leaching losses (kg N/ha) post grazing of the forage crops and pasture treatments,as a mean of +/- DCD treatments.

	Grazing timing		
	Early	**Late**	**P value**
Pasture	152	34	<0.001
Crop	119	26	<0.001

Soil Nmin, end of drainage

In all treatments, in both the pasture and the crop, a large amount of Nmin remained in the soil at depths 0-60 cm at the end of drainage season (Table 4). There was a statistically significant benefit from the later grazing on the amount of soil Nmin at the end of drainage. The increase in Nmin was 50 kg N/ha in pasture and 129 kg N/ha in the crop on plots as a mean of +/- DCD treatments.

There was no great difference between pasture and crop Nmin for the early grazed treatments. This shows that there was little pasture uptake of the urine-N in June and July due to slow/low pasture growth. However, there was a sizeable difference in the late graze treatments. In the top 30 cm there was an average 52 kg N/ha of the pasture plots compared with 168 kg N/ha in the crop paddocks, which indicates a more substantial pasture N uptake occurring in the late winter/early spring.

There was a significant (P<0.05) interaction of DCD with grazing time on soil Nmin on the cropping plots (Table 4). The general pattern was that there was more soil Nmin at all depths in the early grazing where DCD had been applied, and there was no effect for the later grazing. Although the same trends were apparent in the pasture plots, these effects were not significant, possibly masked by greater N removal from the soil in spring, as described above.

Table 4. Summary of soil mineral N at the end of drainage (kg N/ha).

Crop & Depth (cm)	**Early grazing**			**Late grazing**			**P value**		
	-DCD	**+DCD**	**mean**	**-DCD**	**+DCD**	**mean**	**T**	**DCD**	**Tx DCD**
Pasture									
0-15	19	21		22	27		*	*	ns
15-30	14	24		22	33		ns	ns	ns
30-60	93	125		138	150		*	ns	ns
Total	126	170	147	182	211	197	*	ns	ns
Crop									
0-15	8	18		49	57		***	*	*
15-30	25	49		120	110		***	*	**
30-60	98	142		138	125		ns	ns	*
Total	131	209	170	306	292	299	***	ns	*

*** <0.001; ** <0.01; * <0.05; after log transformation

Discussion

N leaching

The total amount of mineral N leaching for the drainage season on the early grazed plots was 152 and 119 kg N/ha respectively for pasture and crop. These are consistent with N losses previously measured in grazed paddocks at this site (Shepherd *et al*., 2012). The total amount of N leaching from the late grazed plots was 34 and 26 kg N/ha for pasture and crop, respectively. This is an important finding since most measurements on N leaching after a grazed forage crop have tended to focus on early grazing when N leaching losses are large. This experiment confirms our hypothesis that later grazing will result in less leaching than early grazing and this needs to be factored in to the assessment of N leaching risk from winter forage crops given that the crop block tends to be grazed over the June-July period, not just the June period.

The DCD applications on the early grazed plots made no reduction in measured N loss on the pasture. On the crop the reduction in N loss by DCD was small (16 kg N/ha), and not significant. Previous work at this site has measured an average 20-27% reduction in N with DCD application in early grazed crops. These previous measurements were made on large grazed plots with 200 porous cups per treatment. It may be that there was insufficient replication to measure an effect with porous cups in this experiment. However, there did appear to be effects from DCD when we measured soil Nmin, as described below.

Carry-over effects after spring

Soil Nmin measurements (Table 4) confirmed that large amounts of N remain in the soil at the end of drainage and that there was a significant increase with a later grazing in both pasture and crop.

The distribution of this Nmin down the soil profile also has to be considered; most of the retained N is below 30 cm depth and this N will only be of value to the farm if it can be exploited by a crop with a suitable rooting habit. If it is not taken up during the growing season then it will be leached during the following winter. Thus, the cropping sequence after the grazed forage crop could determine the overall N efficiency of the system. The crop plots were sown with chicory in October as a potential deep rooted crop. Monitoring of the plots will continue into a second winter to look for carry-over effects of the N remaining in the soil at the end of the first winter.

The second hypothesis was that the applied DCD would be more effective on the early grazed crop, rather than the late grazed. This was supported by the soil Nmin measurements on the cropping block, with a significant interaction of grazing time and DCD on the amount of soil Nmin at each soil depth (and the total). This suggests that DCD (or any nitrification inhibitor) needs only to be targeted at the early grazings because there is insufficient drainage at this ste to cause large leaching losses from later grazings. A simple 'rule of thumb' might be that only June grazings are targeted for treatment. This needs further work to confirm this and to also test across a wider range of sites.

The final hypothesis tested was that there would be less leaching from the pasture than from the grazed crop. This was not found to be true for the early grazed crop, possibly because growth is very slow at that time of year. Therefore there would be little benefit, in terms of N leaching, from standing off cattle on pasture instead of leaving them on the crop. However, for the late grazed treatments there was a difference between the crop and the pasture, which shows that when there is actively growing pasture there will be uptake of N, although this difference was only found in the top 30 cm (the extent of most pasture roots).

Conclusions

- Nitrate leaching from grazing in early June was greater than N leaching from a grazing in late July.
- There was also a greater amount of plant available N in the soil the following spring from the later grazing.
- Leaching losses from pasture and early grazed crops were similar.
- Crops sown after a winter grazing should optimise the use of N remaining in the soil to prevent further losses the following winter.
- Timing of grazing is an important consideration when trying to model N losses on a farm.
- There was an indication that DCD (or any nitrification inhibitor) needs only to be targeted at early grazings: more work is required to confirm this.

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