Effectiveness of a nitrification inhibitor (DCn) on a Coastal Taranaki dairy farm

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Abstract

The issue of high nitrate levels in fresh water is becoming increasingly important in New Zealand. This trial examined the effectiveness of using a nitrification inhibitor applied to a dairy farm pasture to reduce the amount of nitrate leached in coastal Taranaki soils. The product used (DCn) was a granular form of dicyandiamide. It was applied as recommended. Two 5 ha farmlets (Control and DCn) were established and managed for 2 years. Leachate samples were collected using 240 ceramic cups. Milk production, cow liveweight (Lwt), pasture growth and amount conserved were also measured. There was no significant difference between treatments for milk, fat and protein yield, fat and protein concentration, Lwt, body condition or pasture growth. Analysis of the leachate results showed that, except at the first samplings (when the DCn paddocks were highest), there was no difference in nitrate and Kjeldahl N content. The application of DCn did not increase milk or pasture production, nor did it decrease nitrate leaching. It is possible that N leachate measurements were compromised by the use of insufficient porous ceramic cups and that urine deposits over or near these cups could have reduced treatment effects. Current recommendations are that DCn be applied when soil temperature is <10°C (winter/spring). This has practical on-farm limitations and it may be preferable to apply DCn in early autumn to coincide with the period of greatest leaching risk.

Keywords: leachate, nitrate leaching, dairying, milk production

Introduction

The New Zealand dairy industry has set a target of increasing pasture production in Taranaki and other regions. An increase of 30 % in pasture production in Taranaki would increase the gross dairy output in this region by $200 million/year. An opportunity exists to achieve this by using high rates of nitrogen (N) fertiliser (>100kg N/ha/yr). However, if high rates of N are applied as fertiliser in a grazing system, nitrate leaching from soils into groundwater may increase due to interactions between the fertiliser, pastures and animals (Ledgard *et al.* 1997). The consumption of pastures with high protein concentrations in excess of animal requirements, results in excretion of urine with high N concentrations. The urine is usually deposited onto the ground in discrete patches so the N application rate in these patches can be as high as 1 000 kg/ha, exceeding the amount that can be taken up by plants (Steele 1982; Haynes & Williams 1993; Jarvis *et al*. 1995). Any N that is not utilised rapidly by the plants is converted to nitrate (NO_3) and nitrous oxide (N_2O) by soil bacteria. Nitrate is then readily leached from the soil during drainage events (Di & Cameron 2005) and nitrous oxide is lost via gaseous emissions (Ledgard 2001).

The issue of high nitrate levels in ground water is becoming more important in New Zealand. In the Lake Taupo region, for example, new rules have been adopted to cap the amount of N leaching into Lake Taupo from surrounding properties (Environment Waikato 2007). Essentially, it means that farmers cannot increase stock numbers or they will be required to adjust on-farm management to mitigate nitrate leaching. These rules do not apply in the Taranaki region, and some farmers are increasing stocking rates and their use of N fertiliser to meet their production goals.

Nitrification inhibitors have the potential to assist with the balancing of economic and environmental sustainability on highly productive dairy farms. Nitrification inhibitors are chemicals that impair the activity of the *Nitrosomonas* spp of soil bacteria, thereby slowing nitrate formation from ammonium in soil. This provides more opportunity for plants to use N before it is leached from the root zone, particularly during times of slow plant growth such as winter.

Considerable research at the lysimeter and small plot scale has shown nitrification inhibitors to be effective on soils in New Zealand (Smith *et al*. 2005; Cameron *et al*. 2007; Moir *et al*. 2007). In these studies, the inhibitors were applied from May to August, when maximum leaching of N would be expected (Di & Cameron 2005). They were applied together with large loadings of urine and sometimes fertiliser N. However, in normal farming practice, cows add urine to the soil throughout the year and at any one time there is a mosaic of urine and non-urine affected areas. Thus, the overall effectiveness of nitrification inhibitors on nitrate leaching in a realistic whole farm system has not been determined.

Nitrification inhibitors are currently being used as one of several tools to reduce nitrate leaching in the 'Tight-N Prototype' farmlet study at DairyNZ's Scott Farm in the Waikato. In this study it will be difficult to quantify the exact effect of nitrification inhibitors on reduction of NO_3 leaching due to the effects of other treatments also being used. The project reported here (where the only variable is whether or not a nitrification inhibitor is applied) was aimed at addressing this lack of knowledge at the farm system level as well as providing information specific to Taranaki.

Methods

Two 5 ha farmlets were established within the Westpac Taranaki Agricultural Research Station (WTARS - Hawera) farm on 1 June 2008, with herds of 16 Friesian-Jersey crossbred cows/farmlet (3.2 cows/ha). At the start of the second year a new group of predominantly Jersey cows was allocated to the trial and the number per farmlet increased to 17 (3.4 cows/ha). Cows were randomly allocated to each treatment balanced for age, calving date, liveweight (Lwt) and body condition score (BCS). Mean calving date was 12th and 7th August, for Years 1 and 2, respectively. The area was dedicated to the farmlet trial for 2 years. Ten paddocks were used and each paddock was split in half, one half randomly assigned to Control (no nitrification inhibitor applied) and the other to DCn (nitrification inhibitor applied). Thus 10-half-paddocks formed the basis for each of the two farmlets.

The soil was an Egmont ash (Allophanic) on a gently undulating and free-draining area. The pasture composition was mainly perennial ryegrass (*Lolium perenne*) with small proportions of white clover (*Trifolium repens*) and other grass species.

Application of DCn

In Year 1 the first application (early winter) of the inhibitor (DCn; Ballance Agri-Nutrients) was in early June and in Year 2 mid-May; the second application was in late July-August, as is currently recommended. Applications of DCn did not start until soil temperatures were below 10°C and there were no excessive rainfall events. For the early winter application, standard DCn was used (50 kg/ha; 16% N), followed by N-rich DCn (110 kg/ha; 32 % N) in late winter-spring. An additional eight and 16 kg N/ha (as urea; autumn and winter/spring, respectively) was applied to the Control area at the same time as the DCn application, ensuring the same N application rates on each farmlet. The nitrification inhibitor was applied from a calibrated spreader behind a quad-bike.

Nitrogen was applied (four to six applications of 23 or 46 kg N/ha per application) to all paddocks in both farmlets at an annual application rate of 114 and 142 kg N/ha/yr (for Years 1 and 2, respectively). Maintenance fertiliser applications (400 kg/ha of Pasturezeal G2 Equaliser (29 kg P, 34 kg S and 74 kg Ca/ha) was applied in May of both years, giving an additional 30 kg N/ha/yr. Thus, total N applied was 168 and 196 kg/ha for Years 1 and 2, respectively.

Grazing management

Cows grazed the paddocks rotationally as part of normal farm grazing practice, with the same management applied to both farmlets. A set of management decision rules (Macdonald & Penno 1998) was used to ensure that management was consistent across farmlets. Cows had access to a fresh allocation of pasture once daily and only returned to the same area, when pre- grazing levels were approximately 2 700 kg DM/ha in spring, 4 000 kg DM/ha in summer and 3 000 kg DM/ha in autumn and winter (all measurements to ground level). This was generally when a minimum of two leaves had appeared on the majority (>66%) of perennial ryegrass tillers. The target post-grazing stubble height was 40 mm.

Grazing management was determined by weekly monitoring of farm pasture cover. The total farmlet area was available for grazing for the entire year. However, pasture surplus to requirements was conserved as silage when growth rates exceeded cow requirements (primarily in October and November). Surplus pasture was conserved as baled silage and then fed to the cows on the farmlet where it was grown.

Measurements

Leachate samples were collected from soil percolation water using 12 PVC tubes with a porous ceramic cup buried (March 2008) on an angle at 1 m depth in each farmlet paddock (120 per farmlet). Samples were collected after every 40-50 mm of rain resulting in two and four samples in the first and second year, respectively. Leachate samples were analysed for nitrate N and total N (Kjeldahl N) (NZLabs, Hamilton).

Pasture cover (kg DM/ha) of each paddock was assessed weekly using calibrated visual assessment. The pasture growth was calculated weekly from the increase in herbage mass on ungrazed paddocks. Pasture that cows were about to graze was sampled weekly (from each farmlet, to ground level) and bulked monthly to provide a general description of the quality of pastures eaten in the two farmlets. These samples were analysed by near infrared spectroscopy (NIRS, FeedTech, Palmerston North) to determine

Table 1 Average annual milk, milk components, end of season liveweight and body condition for cows for 2 years (Friesian-Jersey cross-bred cows in Year 1 and Jersey in Year 2)[1].

	Year 1			Year 2		
	Control	DCn	SED	Control	DCn	SED
Milk (kg)	3760	3771	354.6	2758	2675	150.4
Milksolids (kg)	258	249	22.4	255	246	13.7
Fat (kg)	139	133	11.9	145	140	8.0
Protein (kg)	119	116	10.9	109	106	6.0
Fat (%)	4.40	4.27	0.173	5.80	5.75	0.210
Protein (%)	3.77	3.69	0.088	4.29	4.30	0.091
Cow liveweight (kg)	538	530	22.1	418	423	11.5
Body condition score	3.8	3.8	0.12	4.3	4.5	0.14

[1]All treatment comparisons were not significant.

standard nutritional components (e.g. organic matter digestibility, crude protein, fibre, soluble sugars). Every 2 months, a sub-sample of pasture was sorted into plant species to determine botanical composition.

Individual cow milk yields were recorded weekly (Westfalia™ milk meter system). Milk fat, protein, and lactose concentrations were determined on daily composite aliquot samples by Fossomatic FT120 (Foss Electric, Denmark). Liveweight and BCS of each cow were determined every other week following the morning milking or at approximately 0900 h during the non-lactating period. Body condition score was assessed pre- and post-calving on a 10-point scale, where 1 is emaciated and 10 is obese (Macdonald & Roche, 2004).

Statistical analysis

Total milk, fat, protein and milksolids (MS) yield, mean fat and protein content were calculated for each cow for the season and these summary measures were then analysed using ANOVA with herd as the fixed effect and cow as the random effect. Liveweight and BCS were each analysed on the last weighing for the season using ANOVA and these analyses included only the cows still on the trial on this date. GenStat 12.1 (2009) was used for all statistical analyses. The water leachate data for each month was analysed as mixed models using REML including treatment as a fixed effect and paddock and paddock half within paddock as random effects. A $\log_{10}$ transformation of the data was used because of a few high values causing heterogeneity of variance.

Figure 1 Pasture growth on the Control and DCn farmlets for 2 years, Control ♦, DCn •-•■•-• farmlets.

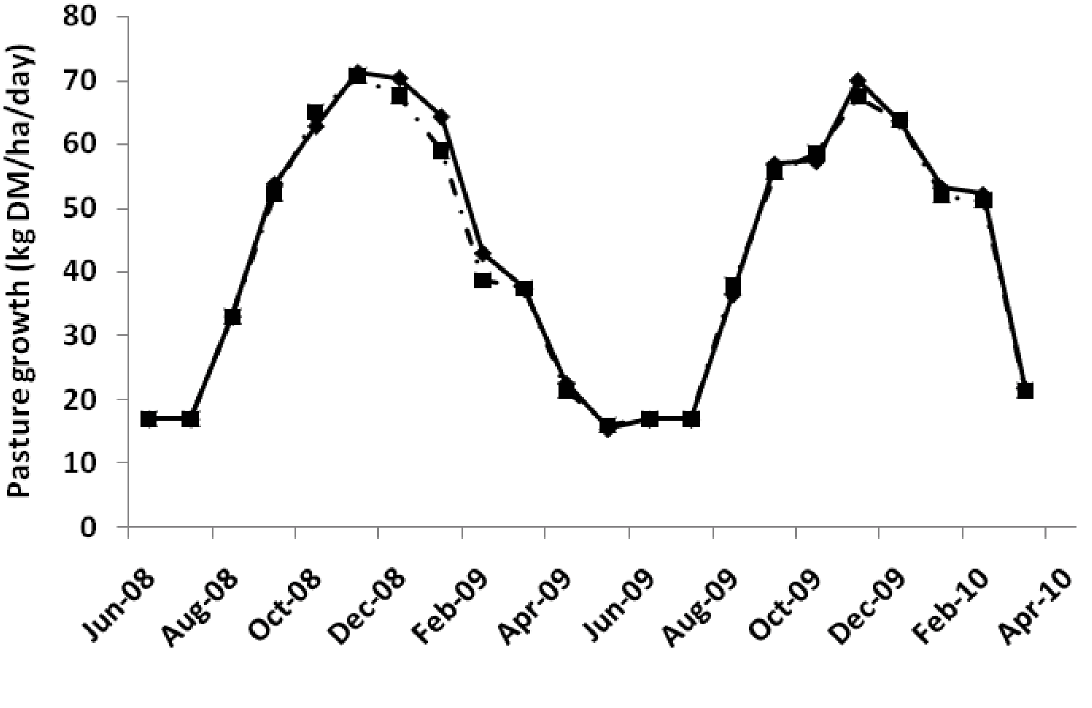


Figure 2 Back transformed means and SED for Nitrate-N (NO_3) in water samplings (from ceramic cups) on Control ♦, and DCn treated ■ farmlets.

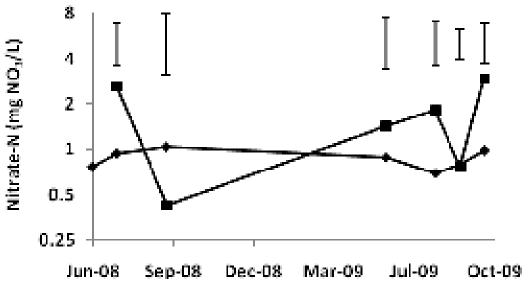
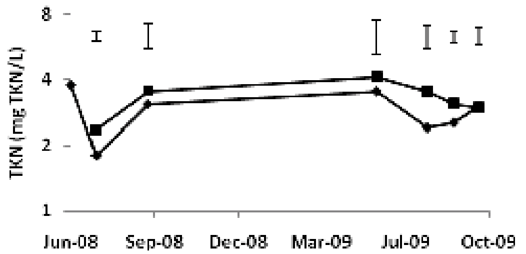


Figure 3 Back transformed means and SED for the Total Kjeldahl N (TKN) in water samplings (from ceramic cups) on Control ♦, and DCn treated ■ farmlets.



Results and Discussion

Pasture growth (kg DM/ha/day) is shown in Fig. 1 indicating there was no difference between the treatments. Total annual pasture growth measured was 15.0 and 15.4 t DM/ha for Year 1 and 14.3 and 14.7 t DM/ha for Year 2 for the Control and DCn farmlets, respectively. Conservation for the farmlets was similar in both years, with 50 and 52 bales of silage being made on the Control and 47 and 45 on the DCn farmlet, equivalent to about 555 and 503 kg DM/cow on the Control and DCn farmlets, respectively. Pasture on the Control and DCn farmlets had average crude protein contents of 26.3 and 25.6% of DM, OM digestibiliity of 84.8 and 84.0%, and ME of 12.3 and 12.2 MJ/kg DM, respectively. The average pasture ryegrass, other grasses, and clover contents were 62 and 63, 27 and 21 and 1 and 4 % of DM for the Control and DCn farmlets, respectively.

Milksolids production off both farmlets was similar reflecting the lack of difference in pasture quality and amount of pasture grown. There was no treatment difference in milk production per cow within year, but production per cow in Year 2 was less than in Year 1 (Table 1) partly due the use of Jersey cows in Year 2, offset to some extent by their higher milk fat and protein concentration.

At the end of each lactation there were no treatment differences in cow Lwt and BCS (Table 1). This reflects the lack of a treatment effect on pasture growth and the rules governing the farmlet management that were designed to ensure that cows attained BCS 5 at calving. All cows were dried off at a BCS that ensured this goal was achieved while taking into account farm feed cover.

In Year 1 there was variability in the number of water samples collected from the ceramic cups. Analysis of the results shows that, except for the first sampling, there was no difference in nitrate and Kjeldahl N concentration in the leachate (Figs. 2 & 3). There were no samples collected between October 2008 and May 2009 due to low rainfall. These results are consistent with those from previous samplings (C.G. Roach pers. comm.). The average nitrate concentration for the trial was 2.31 and 5.02 mg Nitrate/L for the Control and DCn treatments, respectively, compared with the 4-year WTARS average (2003-2006) of 1.53 mg Nitrate/L when no urea was applied. Higher levels (>10.0 mg Nitrate/L) were leached when 200 kg N was applied at nearby Normanby. Similarly for Kjeldahl N the average was 3.00 (Control) and 3.72 (DCn) compared with the 4-year WTARS average of 1.50 mg Kjeldahl N/L.

At the time of the first samplings in Year 1, only about 40% of the ceramic cups had leachate in them and leachate samples were collected from about 70% of the paddocks. A small number had problems with holding the vacuum at the time of collection. These samplers were identified and repaired. Other cups held vacuum but did not extract any leachate suggesting that the interface between the cup and the soil was 'broken'. These cups were installed during a dry period (February-March) and after installation the soil may have compacted to form cracks around the cups, allowing drainage away from the cups. In Year 2 leachate was collected from most samplers indicating water flow occurred around the cups, allowing absorption of leachate. A further difficulty was that some samples had anomalously high nitrate N concentrations suggesting that they were closely associated with urine patches. Thus the sampling errors were high.

Most of the previous reports on the use of DCD's have been from small plots or lysimeters (Smith et al. 2005; Cameron et al. 2007; Moir et al. 2007) to which large N loadings, either as urine or fertiliser N, were applied. The results presented here are from a farmlet study which better represents the normal farm situation where at any one time there is a mosaic of urine patches of varying age and deposition rate. Notwithstanding the problems which arise from using ceramic cups to collect leachate, the present results indicate high variability in the measure of nitrate N concentration. This demonstrates how difficult it is to accurately measure DCD treatment effects on nitrate leaching in a farm situation.

The amount of N leached from a urine patch represents a balance between the amount of N excreted by animals and that taken up by plants, gaseous losses and immobilisation in the soil. Urine excretions in March are at greater risk of leaching N than those deposited in May or June (Sprosen *et al*. 2002). Nitrification inhibitors are recommended to be applied when soil temperature is <10°C and within 5 days of grazing, and so applications commonly start in late May through to mid-June. Year 1 followed a serious drought in Taranaki and soil temperatures were >10°C until early June. At the time of DCn application the cows were on a long grazing interval (≥80 day rotation) and as such the first applications were not until early June 2008 (Year 1). This meant that the final applications did not occur until early September, when soil temperatures were > 10°C.

The results presented here are substantiated by a study at DairyNZ (Shepherd *et al*. 2010) that showed urine deposited in March is possibly at greater risk of leaching than that deposited in May or June. Thus, the inhibitor may be of more benefit in reducing N leaching when targeting autumn urine deposits.

Conclusion

These results show that at a farm-system level, DCn had no effect on pasture production and quality and hence MS production. There was no measured effect of DCn on N leaching, although data were highly variable. These conclusions are different from those of Cameron *et al*. (2007) who reported large effects of DCD on nitrate leaching and pasture production. A possible reason for this discrepancy is that they were measuring the effects of DCD in the presence of large loadings of urine N (1 000 kg/ha) plus fertiliser N (200 kg/ha), compared with the on-farm situation for the work reported here, where a mosaic of urine patches existed that may or may not have been close to the ceramic cups.

The absence of treatment effects could also be because application times did not coincide with an actual leaching event during the trial period. Another consideration is that nitrate leaching events occurred in early autumn before the application of DCn; this possibility requires further investigation. This study also suggests refinements when using ceramic cups to measure nitrate leaching, including more cups per treatment and with the required soil contact. This may mean inserting the cups well in advance of commencing the trial.

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