# USING A LYSIMETER STUDY TO ESTIMATE NITROGEN LEACHING UNDER GRAZING, AS AFFECTED BY MULTIPLE DCD APPLICATIONS

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**Abstract**

The loss of nitrogen (N) from grazed pasture systems by nitrate leaching and the dominance of animal urine as the main source of leaching have been well documented. Nitrification inhibitors, such as dicyandiamide (DCD), have been shown to be an effective tool in mitigating N loss, particularly from urine patches. As part of the Nitrous Oxide Mitigation Research (NOMR) programme, a series of coordinated mowing and grazing trials were carried out throughout New Zealand to determine how DCD can be most effectively used. This paper reports the results from a lysimeter study that was aligned to the Waikato grazing trial NOMR site. The purpose of this study was two-fold: 1) to measure the effect of multiple DCD applications on N leaching from urine patches, and 2) to estimate total N leached under a grazing system through an entire drainage season.

Forty-five lysimeters of intact pastoral soil (Otorohanga silt loam) were collected from a dairy pasture beside the Waikato grazing trial. Fresh dairy urine was applied to each lysimeter at a rate of 700 kg N/ha in either February, March or April, followed by nil, 2 or 3 DCD applications (10 kg/ha per application). N leaching results from the lysimeters showed that 3 DCD applications were more effective than only 2 applications. Three applications resulted in an average of 39% ($P < 0.05$) reduction in N leached, whereas 2 applications showed no significant reduction. Combining this lysimeter data with urine-N return data from grazed pasture to estimate N leached under grazing, showed an apparent reduction in total N leached over the leaching season of 4 or 32% with 2 or 3 DCD applications, respectively.

## Introduction

Intensively grazed agricultural land is recognised as the main source of nitrogen (N) leaching and the consequent contamination of ground and surface water systems (e.g. Archer, 1994; Monaghan *et al.*, 2007). This is particularly prominent in New Zealand as it is common practice in dairy grazing systems for pastures to be grazed all year round and most of the N consumed by cows is then returned to the pasture as urine and dung (Di and Cameron, 2002). About 80% of this N excreted by dairy cows is in urine and 20% in dung but the urine-N is rapidly converted to plant-available N and is the main source of N leaching (Ledgard *et al.*, 2009).

Most studies of N leaching only take into account urine deposited to pasture during the wet season (winter to early-spring). However, work by Shepherd *et al.* (2010) showed that urine deposited in late-summer and early-autumn significantly contributes to N leaching in winter. It is therefore important to include these earlier grazings when estimating total N leaching from a grazed pasture system through an entire leaching period.

Much recent research on mitigating N leaching has focused on the use of nitrification inhibitors such as dicyandiamide (DCD), and the application of DCD to cow urine patches has been shown to significantly reduce N leaching (e.g. Di and Cameron, 2002; Menneer *et al.*, 2008). DCD applied to soil acts by inhibiting nitrification (conversion of ammonium to nitrate) and the period of effectiveness depends on soil temperature and rainfall/drainage (Di and Cameron, 2004; Di *et al.*, 2009). However, there has been limited research on the most effective frequency and timing of DCD application and that was an aspect of research in the NOMR trials (Gillingham *et al.*, 2012).

The objectives of this paper are 1) to assess the effects of urine and DCD timing on N leaching using lysimeters, and 2) to apply that data with calculated N excretion data over time from an allied grazing trial to estimate the effectiveness of DCD at reducing N lost over an entire leaching period.

## Methods

In February 2010, forty-five lysimeters (50 cm diameter by 70 cm deep) were collected from the Tokanui Research Farm (Soil type: Otorohanga silt loam) in the Waikato region of New Zealand. The intact soil monolith lysimeters were encased in metal cylinders and collected according to the procedure outlined in Cameron *et al.* (1992). This consisted of placing a metal cylinder fitted with an internal cutting ring onto the soil surface and carving around the cylinder while gradually pushing it down the soil profile to a depth of 70 cm. To prevent edge-flow effects, liquefied petroleum jelly was poured into the gap between the soil monolith and cylinder casing. The intact soil monolith was then cut at the base and a metal base plate, with a central drainage outlet was sealed to the bottom of each lysimeter. The lysimeters were transported to the Ruakura Research Centre, Hamilton, where they were installed in a trench at the same level as the surrounding soil surface.

The experimental design consisted of nine treatments (outlined in Table 1) with five replicates of each in a randomised block design. Urine was applied at rate of 700 kg N/ha, and DCD was applied at 10 kg/ha per application.

**Table 1:** Lysimeter trial treatments and month of application of urine or DCD.

| Treatment | Urine | DCD 1 | DCD 2 | DCD 3 |
|---|---|---|---|---|
| Control | Nil | Nil | | |
| Control+DCD | Nil | April | July | |
| Urine February | February | | | |
| Urine March | March | | | |
| Urine March+DCD2 | March | March | May | |
| Urine March+DCD3 | March | March | May | July |
| Urine April | April | | | |
| Urine April+DCD2 | April | April | July | |
| Urine April+DCD3 | April | April | June | August |

Lysimeters were trimmed prior to treatment applications and then harvested as closely as practical to the grazing events in the grazing trial.

Leachate volume was measured at approximately 50 mm drainage intervals. Drainage commenced in June and finished in September 2010. There were 13 samplings of leachate collected over that period. Leachate was sub-sampled and frozen at -20 ˚C prior to chemical analysis. Samples were analysed for ammonium-N ($NH_4^+$-N) and nitrate-N ($NO_3^-$ -N) (including nitrite-N), urea-N and DCD.

The concurrent grazing trial (Gillingham *et al.*, 2012) was carried out at the Tokanui Research Farm and consisted of 70 paired plots and 2 treatments (control and DCD). All plots were grazed when standing pasture cover was approximately 2800 kg/ha dry matter (DM). DCD was applied twice (April and June) at a rate of 10 kg/ha per application. Milk production (and milk-N concentrations) and pasture N intake (using DM and N concentrations data from the grazing trial for February, March, April and June were used to calculate N excreted in urine (as a difference between N intake and milk-N adjusted for the proportion of N excreted in urine (Ledgard *et al.*, 2003)). This was then combined with lysimeter data on the proportion of N leaching from urine at the different application times to calculate total N leached under dairy grazing.

## Results and Discussion

Ruakura climate data (rainfall and air temperature) for the duration of the trial is presented in Figure 1 (data from the Ruakura meteorological site). March, April and July rainfall was considerably lower than the 30 year (1981-2010) average monthly rainfall (15, 20 and 56 versus 78, 84 and 118 mm respectively), whereas June rainfall was considerably higher (242 versus 117 mm). Air temperature was similar to the long term average.

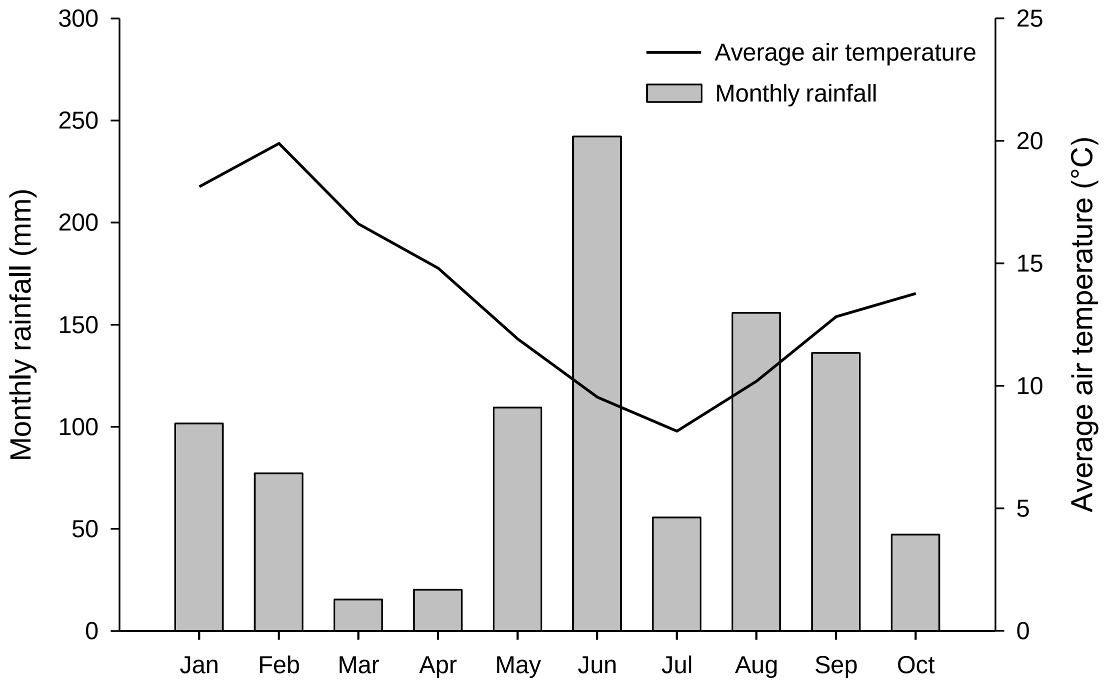


**Figure 1.** Monthly rainfall and average air temperature at Ruakura during the trial period. Data is from Ruakura meteorological station.

Cumulative rainfall and cumulative drainage from the lysimeters are presented in Figure 2 (cumulative drainage represents the average measured across all treatments). Total drainage was 470 mm for the 2010 drainage season.

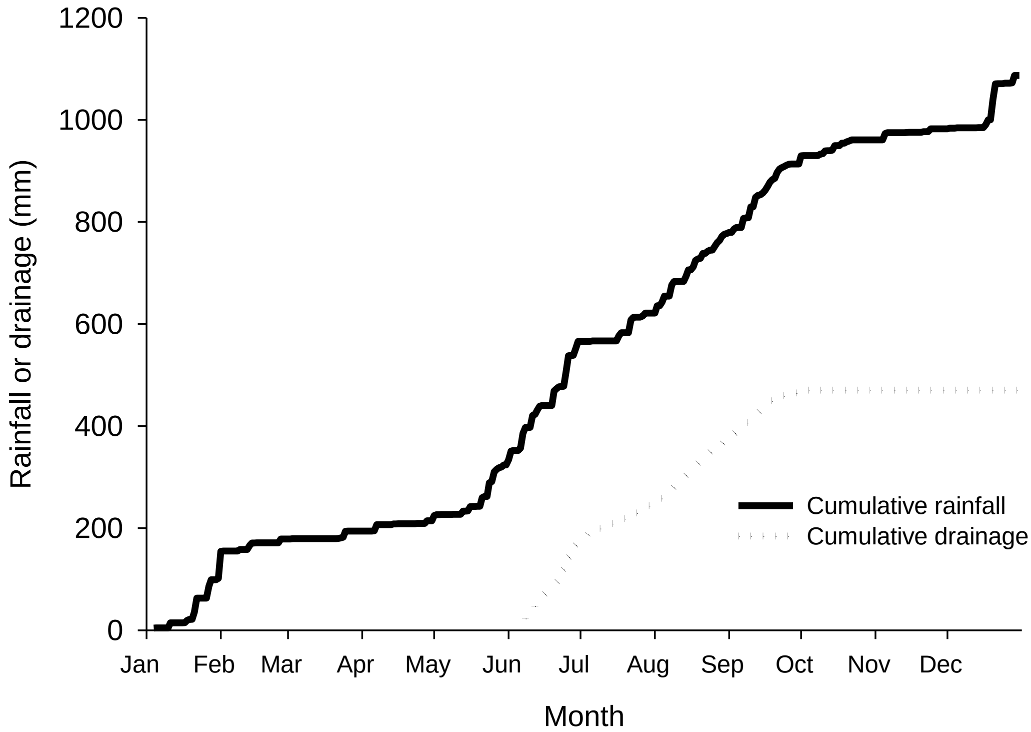


**Figure 2.** Cumulative rainfall in 2011 recorded at the Ruakura meteorological station and the cumulative drainage measured from the lysimeters.

N leaching results from the lysimeter study showed that urine applied in late-summer and early-autumn could contribute approximately 40% of the total nitrate leached over the leaching period (from Figure 3), highlighting the importance of its inclusion in models used to estimate total nitrate leached. Urine applied in April led to significantly higher nitrate leaching than urine applied in February or March (Figure 3). Nitrate leaching from the treatments without urine (control and control+DCD) was negligible, with each treatment leaching approximately 1 kg nitrate-N/ha. Ammonium concentrations in the leachate never exceeded 0.5 ppm and were usually close to the limit of detection. Thus, ammonium contributed less than 1 kg/ha to total N leaching.

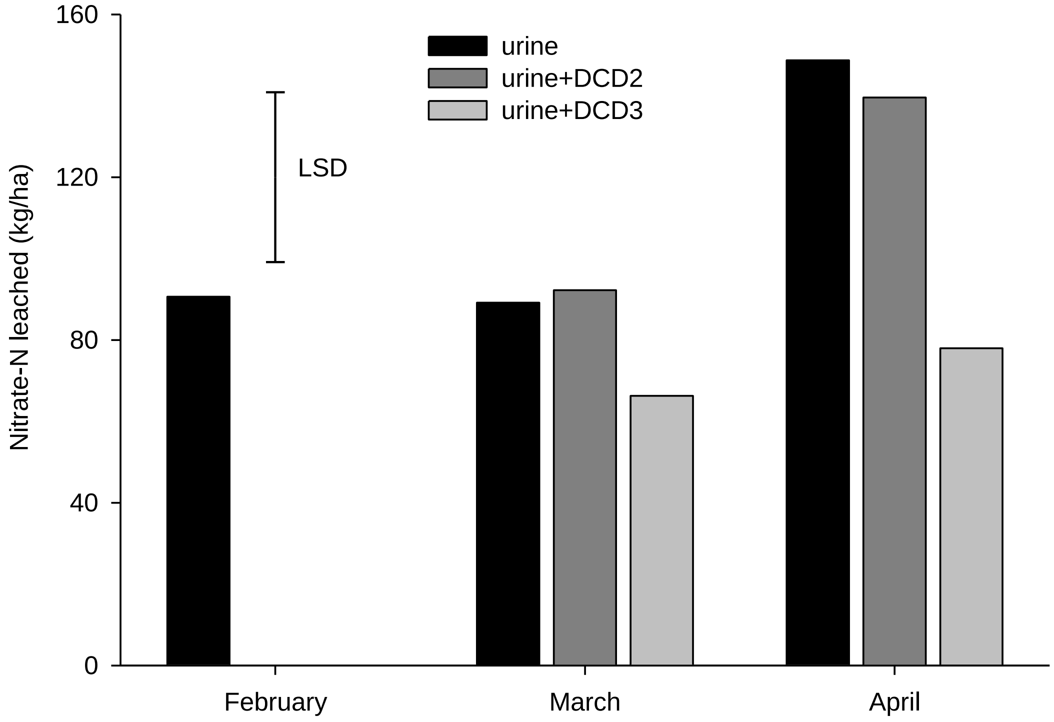


**Figure 3.** Total nitrate-N leached from each of the urine treatments. The error bar represents the least significant difference (LSD $p < 0.05$) between the individual treatments.

DCD proved be more effective at reducing N leached when applied 3 times following grazing rather than only twice (Figure 3). Three applications resulted in an average of 39% ($P < 0.05$) reduction in N leached (for March and April), whereas 2 applications showed no significant reduction. The March and April urine+DCD3 treatments had generally lower nitrate-N concentrations in the leachate than the corresponding urine-only and urine+DCD2 treatments (Figures 4 and 5). The results were statistically analysed by comparing the maximum nitrate-N concentration measured from each lysimeter. The urine+DCD3 treatments had significantly lower ($p < 0.05$) maximums than the urine+DCD2 and urine-only treatments. Figure 5 also illustrates that timing of DCD application is likely to be an important factor in mitigating nitrate leaching. The concentration of nitrate in leachate from urine+DCD3 starts diverging from the urine-only and the urine+DCD2 in late-June, which is much earlier than the third DCD application which didn't occur until August. The second DCD application for urine+DCD3 was in June, whereas the second application for urine+DCD2 wasn't until July which was probably too late to give continued inhibition of nitrification and prevent the rise in nitrate concentration in leachate which occurred in June.

Current commercial use of DCD involves two applications in late-autumn and mid- to late-winter in order to strategically target the critical drainage period. These results indicate that more frequent or better timed DCD applications may be required to achieve substantial reductions in nitrate leaching under these conditions.

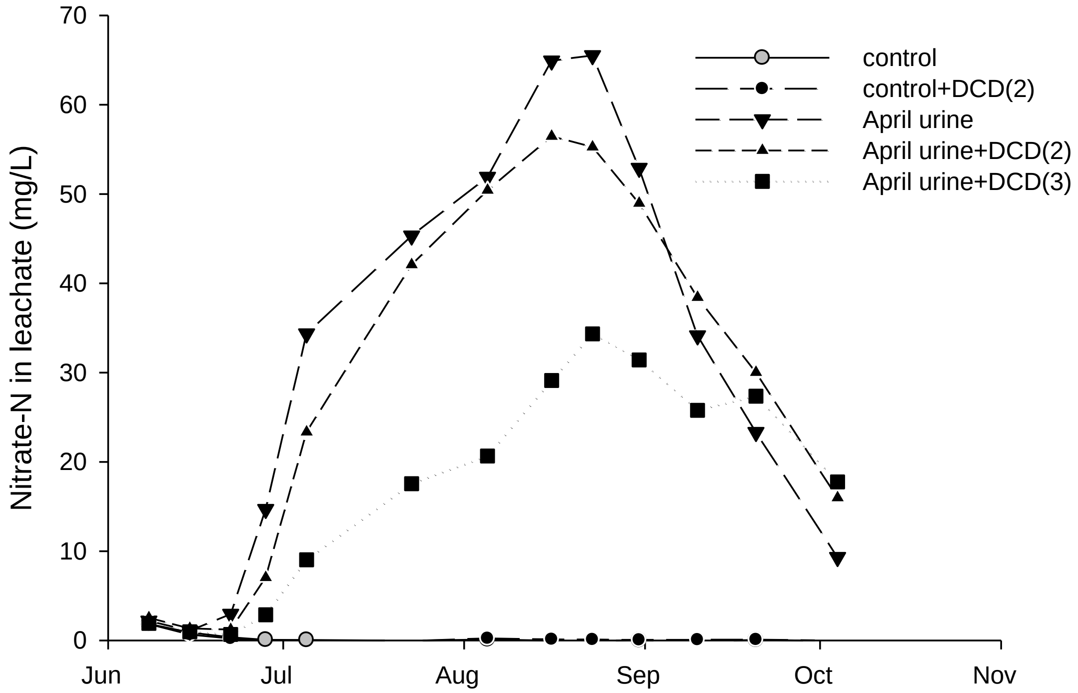


**Figure 4.** Nitrate-N concentrations in leachate from control and March urine application treatments, without or with 2 or 3 applications of DCD. No statistically significant difference between treatments at any sampling.

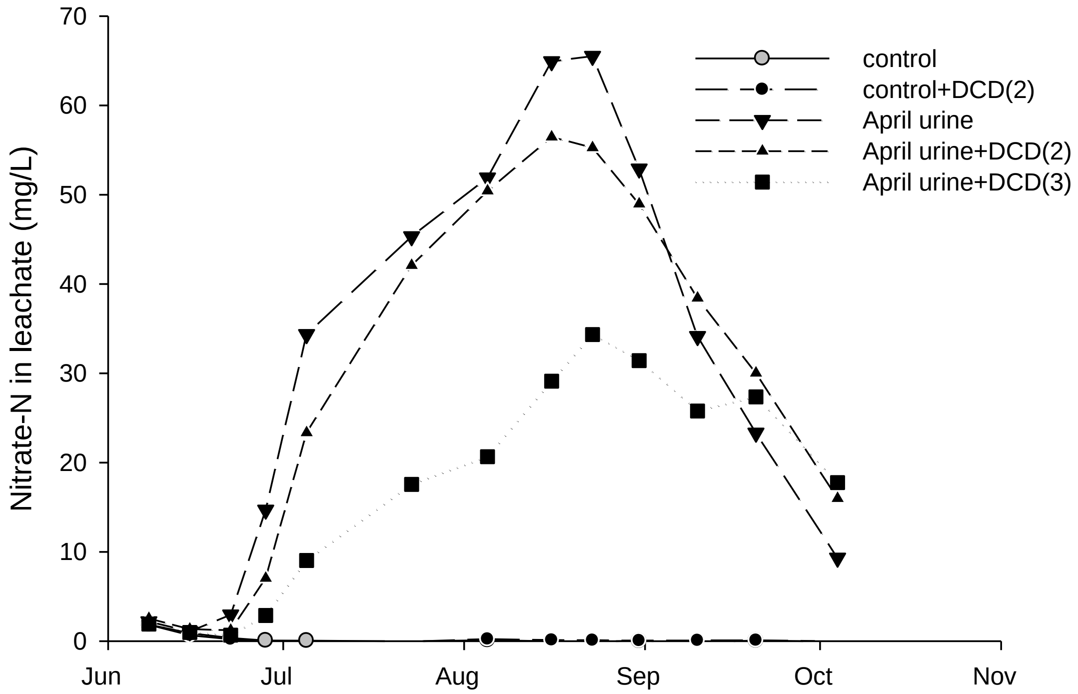


**Figure 5.** Nitrate-N concentrations in leachate from control and April urine application treatments, without or with 2 or 3 applications of DCD. The DCD(3) application treatment had a significantly lower ($P < 0.01$) maximum concentration than the urine only treatment.

Data from the allied grazing trial (Gillingham *et al.*, 2012) for February, March, April and June grazings were used to calculate N excreted in urine and thus returned to pasture. This was linked with lysimeter data on N leaching from urine for these deposition dates to calculate N leaching. These calculations assumed N leaching under grazing only occurred from these urine depositions and resulted in total N leaching without DCD of 19.8 kg N/ha (Tables 2 and 3). Using this data and extrapolating DCD effects on N leaching from lysimeters (Figure 3) resulted in a reduction in N leaching of 4% (not significant) with two DCD applications and 32% ($P < 0.05$) from three DCD applications (Table 3).

**Table 2.** Estimate of cow N intake, N excretion, and N leached from the grazing study, calculated using farm data on DM intake and pasture N concentration and lysimeter data for nil DCD versus 2 or 3 DCD applications.

| Treatment | %N Pasture | N removed in milk (kg/ha) | Urine-N excreted (kg/ha) | % of urine-N leached | N leached from trial (kg/ha) |
|---|---|---|---|---|---|
| Urine (February) | 3.8 | 0.2 | 29.8 | 13.0 | 3.9 |
| Urine (March) | 3.3 | 0.2 | 21.5 | 12.8 | 2.7 |
| Urine (April) | 4.0 | 0.1 | 30.9 | 21.3 | 6.6 |
| Urine (April) + DCD (April/July) | 4.0 | 0.1 | 30.9 | 20.0 | 6.2 |
| Urine (April) + DCD (April/June/August) | 4.0 | 0.1 | 30.9 | 11.2 | 3.5 |
| *Urine June* | *4.0* | *0.0* | *31.0* | *21.3* | *6.6* |
| *Urine June + DCD (April/July)* | *4.0* | *0.0* | *31.0* | *20.0* | *6.2* |
| *Urine June + DCD (April/June/August)* | *4.0* | *0.0* | *31.0* | *11.2* | *3.5* |

N.B. June data was not measured and therefore data was based on the assumption that values for N intake, urine deposited and N leached were the same for June as for April.

**Table 3.** Estimated reduction in N leached from the grazing study (using data from Table 2) for nil DCD versus 2 and 3 DCD applications.

| Treatment | Urine Applied/Grazing | DCD Applied | Total N Leached (kg/ha) | % Reduction |
|---|---|---|---|---|
| Control | Feb, March, April, June | None | 19.8 | |
| 2 x DCD applications | Feb, March, April, June | April, July | 19.0 | 4 NS |
| 3 x DCD applications | Feb, March, April, June | April, June, August | 13.6 | 32* |

*P < 0.05

## Conclusions and implications

Higher rainfall and temperature in northern parts of New Zealand mean that decomposition of DCD in soil is more rapid than in southern parts. Associated measurements in a nearby mowing study showed DCD in soil fell to background levels after about 80 days at this site compared to up to 160 days in the South Island (Gillingham *et al.*, 2012). Thus, more frequent DCD applications than the current commercial recommendation of 2 may be required to achieve useful reductions in N leaching from a grazed pasture system. Alternatively, applying the second DCD application earlier may have resulted in a greater N loss reduction than in the current study. Thus, the timing of applications is also likely to be an important factor and should be studied in more detail.

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