Dairying and the Environment

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Introduction

Over the past decade, there has been a rapid increase in dairy farming in the South Island. A number of the newly established dairy farms are on free-draining course-textured or stony soils. Nitrate leaching from intensive agricultural systems, such as dairy farms, is considered a major contributor to increased nitrate concentrations in ground and surface waters (Cameron et al., 1997). The objective of this research programme was to determine nitrate leaching losses on dairy pasture systems as affected by the application of dairy shed effluent (DSE), nitrogen (N) fertilisers and cow urine on free-draining soils using large, undisturbed soil lysimeters. The data obtained were used to develop a simple, semi-empirical computer model to estimate nitrate leaching losses and critical N application rates in order not to exceed the drinking water standard of nitrate (11.3 mg N/L) in the drainage water.

Material and methods

Undisturbed soil monolith lysimeters (50-80 cm diameter and 70-120 cm depth) were collected from a free-draining Templeton fine sandy loam soil and installed to the field lysimeter laboratory at Lincoln University (Di *et al.*, 1998a, 1998b; 1999; Silva *et al.*, 1999). The gap between the soil core and the metal casing was sealed by injecting petrolatum jelly into the gap (Cameron *et al.*, 1992). N leaching losses were measured after the application of urea, ammonium chloride, DSE, and/or cow urine. Annual application rates of N ranged from 0, 200, to 400 kg N/ha for N fertilisers and DSE, and from 0 to 1000 kg N/ha for cow urine. The rates were applied in one application (urine) or split into two (NH_4Cl) or four (urea) annual applications. The lysimeters received spray (50 mm/month) or flood (100 mm/month) irrigation during the summer months. During the winter, natural rainfall was supplemented with simulated rainfall (if necessary) to reach to the 75th percentile of rainfall records in Lincoln, Canterbury. Pasture N uptake, biological N fixation, volatilisation, and denitrification were also measured.

The data obtained were then used to develop a simple, semi-empirical management model to estimate N leaching losses and critical N application rates for dairy pasture systems (Di and Cameron, 2000). The nitrogen leaching estimation (NLE) model is based on the concept that the annual N leaching loss is related to the annual average amount of potentially leachable N (mineral N and mineralisabe N) in the soil, and the annual drainage. The potentially leachable N (N_{PL}) is determined by the sum of annual fluxes of N cycling processes including atmospheric N deposition (N_{AD}); fertiliser or effluent N application rate (N_F); biological N fixation (N_B); net

N mineralisation (N_M); animal N returns (mainly urine) to the pastures (N_A); pasture N uptake (N_P); volatilisation losses after the application of N fertilisers or effluents (N_V); and denitrification loss (N_D) (Eqn 1) (kg N ha^{-1}).

$$N_{PL} = N_{AD} + N_F + N_B + N_M + N_A - N_P - N_V - N_D \quad (1)$$

The relationship between nitrate leaching and N_{PL} is empirically defined as shown in Figure 1.

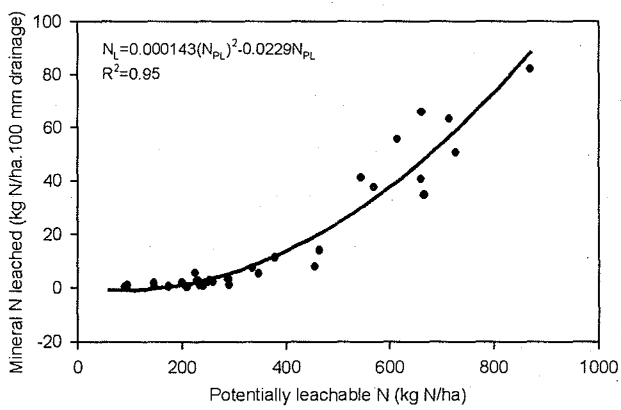

Figure 1: Relationship between annual mineral N leaching loss and the amount of potentially leachable N in the soil determined on the lysimeters (Di and Cameron, 2000).

Results and discussion

In cut-and-carry systems, when urea or DSE were applied at 200 or 400 kg N/ha/year, split into four applications, NO_3-N leaching losses ranged from 6 to 17 kg NO_3-N/ ha/ year. This resulted in NO_3-N concentrations in the drainage water in the range of 2-5 mg/L (Silva *et al.*, 1999). However, when NH_4Cl-N was split into two equal applications rather than four applications as above, the N application rate was not synchronized with the pasture N demand, and the NO_3-N leaching losses increased to 13-49 kg N/ha/year (Di *et al.*, 1998a, 1988b). N applied in the autumn had a higher potential for leaching than N applied in late spring. Between 15.1-18.8% of the autumn-applied NH_4Cl-N was leached, compared with an equivalent of 8.5-11.4% of the NH_4Cl-N applied in late spring (Di *et al.*, 1999).

In grazed pastures, the potential for NO_3^- leaching increases significantly compared to cut pastures because only a small amount of the N ingested by the grazing animal is actually removed from the pasture in animal products, and a large proportion, between 60-90%, of the N ingested is returned to the soil-pasture system, in the forms of urine and dung. Over 70% of the N returned to the pasture is in the urine. The N loading rate under a cow urine patch is equivalent to approximately 1000 kg N/ha. While some of the N is lost through volatilisation, much is nitrified, resulting in the accumulation of NO_3^- in the soil, and leaching when there is drainage through the soil. NO_3-N concentrations in the drainage water under the urine patch reached a peak of about 120 mg NO_3-N/L (Silva *et al.*, 1999). This compared with a peak NO_3-N concentration of 10 mg/L when urea was applied at 400 kg N/ha/year, and 4 mg/L when DSE was applied at 400 kg N/ha/year. Because the whole paddock is not covered by urine patches, the contribution of urine-N to the overall NO_3^- leaching loss from a grazed paddock needs to be weighted by the fraction of area that is covered by urine. Assuming that 25% of the paddock area was covered by urine per year, then the NO_3-N leaching loss from a whole paddock was about 33 kg N/ha/year when no other N fertilisers were applied. When urea or DSE was applied at rates up to 400 kg N/ha/year on top of the urine patches, the NO_3-N leaching loss from the whole paddock ranged from 36-60 kg N/ha/year.

Based on data from the lysimeter studies, the NLE model estimated that the critical N application rates (above which the NO_3-N concentration will exceed 11.3 mg NO_3-N/L) for grazed pasture systems (i.e. with urine input) were 160-200 kg N/ha/year if urea was applied, or 250-300 kg N/ha/year if dairy shed effluent was applied.

Acknowledgements

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References

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Workshop summary

- Start to measure and monitor what is going on, on farm (soils, water quality)
- What is the effect of dairying on these factors?
- Is dairying worse than other primary based industries?
- Development of nitrogen leaching model (based on the N-cycle)
- Model can be used to see the effects of N application on leaching
- Very sensitive to stocking rate (urine patches)