# NITROGEN LEACHING FOLLOWING A HIGH RATE OF DAIRY SLURRY APPLICATION ON A RYEGRASS SWARD OF A VOLCANIC SOIL IN SOUTHERN CHILE

**Salazar F.[1], Alfaro M.[1], Misselbrook T.[2], Lagos J.[1]**
[1] Instituto de Investigaciones Agropecuarias, Centro de Investigación INIA-Remehue, Casilla 24-0, Osorno, Chile. Tel: +56 64 450420. fsalazar@inia.cl
[2] North Wyke Research, Okehampton, Devon EX20 2SB, England

## 1 INTRODUCTION

Dairy slurry is an important nutrient source on farms, supplying partial or total requirement for grass fertilisation. However, mismanagement such as high application rate and inappropriate application time during the year can lead to nutrient losses to the wider environment. In dairy production systems one of the most important pathways of nitrogen (N) losses is leaching, for which greater losses have been reported on a grazed pasture than on a cut sward (Di and Cameron, 2002), and which is likely to equal or exceed the range observed in arable production systems. Furthemore, increasing manure application rate has been associated with high N losses, especially when N is applied in winter. In general, when comparing cattle slurry and inorganic fertiliser based on similar total N application rates, studies have shown low N leaching losses with slurry (e.g Di et al., 1998). This could be explained by the low input from manures of the available N forms, which can be taken up for plants or lost to the wider environment, mainly as nitrate.

In recent years, dairy production has intensified in Southern Chile, which is based on pasture, increasing stocking rates and nutrient application by purchased fertilisers and cattle slurry. Surveys on manure management have shown that farmers use a high rate of manure application and they use manure all the year around (Salazar et al., 2003), with a potential risk for ground water pollution due to leaching during winter (Olson et al., 2009). There is no local information published on slurry use on grass and its effect on nitrogen (N) losses. The objective of the current study was to evaluate the effect of heavy dairy slurry application on N leaching losses and compare it with an inorganic fertiliser on a volcanic soil.

## 2 METHODOLOGY

A field experiment was carried out from March 2008 to March 2010 at the National Research Institute, Remehue Research Centre (40°35' S, 73°12' W) in Osorno-Chile, on an Andisol of the Osorno soil series (Typic Hapludands), which at the experimental site has more than 1 m depth and, high organic matter (19%). According to the meteorological station, the 33 years average rainfall for the area is 1,280 mm $yr^{-1}$ and a mean ambient temperature of 11.3 °C (7.2 to 15.6 °C). There were two experimental treatments, with a target application rate of 400 kg N $ha^{-1}$ $yr^{-1}$ as either dairy slurry (S) or urea (U) split in four even applications during the year: March, July, September and November. Additionally, a control (C) treatment with no N addition was included. A baseline fertilisation with P, K and Mg but no N, was considered for all treatments.

Fertiliser was applied by hand and dairy slurry was applied using watering cans fitted with a small splash plate, which allowed an even distribution of slurry. The experiment was set up in a randomised block design consisting of 3 blocks with 1 replicate plot per block, each measuring $9m^2$. Measurements of $NO_3^-$ leaching were carried out for all the treatments using 3 ceramic suction cups per plot (Lord and Shepherd, 1993). In both years, samples were taken every 100 mm of drainage during the drainage season and frozen until analysis for available N ($N\text{-}NO_3^-$ and $N\text{-}NH_4^+$). Dry matter yield, N uptake and Apparent Nitrogen Efficiency was also evaluated.

Nitrate concentration was measured using flow injection, reduction and colorimetry methods, and ammonium was determined through the indophenol methodology using and automated sample analyser (SKALAR, SA 4000, Breda, The Netherlands). Drainage for the period and the amount of N leached over the period was calculated according to Lord and Shepherd (1993).

Analysis of variance (ANOVA) was used (Genstat 7.1) to compare nitrate and ammonium concentrations, leaching losses and overall N losses between the treatments tested.

## 3 RESULTS AND DISCUSSION

Rainfall was 1,330 and 1,241 mm and evaporation was 1,011 and 836 mm, for 2008 and 2009, respectively. According to this information estimated drainage, considering when soil was saturated to 60 cm depth, was 574 and 686 mm for 2008 and 2009, respectively.

Nitrogen uptakes were equivalent to 191, 315 and 392 Kg N $ha^{-1}$ $yr^{-1}$ for 2008-09 and 169, 342 and 472 Kg N $ha^{-1}$ $yr^{-1}$ for 2009-10 for control, slurry and urea, respectively. There values are equivalent to an Apparent Nitrogen Recovery Efficiency of 30% and 50% for 2009-10 and 34% and 54% for 2009-10 for slurry and urea, respectively.

Results showed that despite the high N rate and time of application, losses due to $NO_3^-$ leaching were small (Table 1) with no significant differences between treatments in either year ($p>0.05$). Cumulative N losses due to N leaching were less than 2.8 and 4.2 kg $ha^{-1}$ $yr^{-1}$ for 2008 and 2009, respectively. These values are lower than those reported by Di et al. (1998) in a lysimeter experiment comparing a slurry with low dry matter content (<2% DM) and inorganic fertiliser applications (400 kg total N $ha^{-1}$ $yr^{-1}$) over a ryegrass and clover mixture, who found lower leaching losses with slurry (8-25 kg $NO_3^-$-N $ha^{-1}$ $yr^{-1}$) compared with $NH_4Cl$ (28-48 kg $NO_3^-$-N $ha^{-1}$ $yr^{-1}$). However, it is important to take into account that in the later experiment, N was applied as one application whereas in the present study it was split in four even doses. On the other hand, in an experiment carried out in the UK comparing different manure application techniques on a ryegrass and clover sward, Misselbrook et al. (1996) reported leaching losses from 3-6 kg $NO_3^-$-N $ha^{-1}yr^{-1}$, which is similar to those observed in the present study, but using lower N rates.

Concentrations of $NO_3^-$-N in leachates for each sampling period never exceeded *c.* 6.3 mg $l^{-1}$ during the two years of evaluation. Annual mean values of $NO_3^-$-N concentrations were below 0.5 mg $l^{-1}$ for all the treatments, and far below the EC limit for drinking water of 11.3 mg $l^{-1}$ (EC, 1991). Most of the leached N was in the $NO_3^-$ form (*c.* 70 to 90%, which is similar to previous studies elsewhere (e.g Ledgard et al., 1999).

Recent studies has shown that forest volcanic soil of Southern Chile, similar to soil use in the present study, has very specialised microbial and abiotic (e.g. soil texture) retention processes which can reduce the risk for N leaching, despite the high N turnover rates determined in this soil (Huygens et al., 2008). These soil processes equaly explain the low losses observed in the volcanic soil of Southern Chile, which agree with previous studies for cutting grass using high rates of inorganic N applications during autumn (e.g. Salazar et al., 2008).

According to the results of this study leaching was not the main pathway of N loss, where studies will be necessary to asses $NH_3$ volatilisation and denitrification losses from slurry applications, which could be important for dairy system in Southern Chile. This information will help farmers to improve manure management reducing the risk of pollution to the wider environment.

TABLE 1 **Average N concentration in leachates (mg $L^{-1}$) and N losses (kg N $ha^{-1}$) for different treatments, 2008 and 2009 (± sem)**

| | | Soil fertilisation treatments | | |
|---|---|---|---|---|
| **Average leaching concentrations and range (mg $L^{-1}$)** | | **Control** | **Dairy slurry** | **Urea** |
| **$N\text{-}NH_4^+$** | 2008 | 0.1 ± 0.03 | 0.1 ± 0.04 | 0.1 ± 0.01 |
| | 2009 | 0.1 ± 0.02 | 0.2 ± 0.21 | 0.1 ± 0.03 |
| **$N\text{-}NO_3^-$** | 2008 | 0.1 ± 0.06 | 0.4 ± 0.17 | 0.4 ± 0.06 |
| | 2009 | 0.1 ± 0.06 | 0.5 ± 0.17 | 0.4 ± 0.24 |
| **Total N losses (kg $ha^{-1}$)** | | | | |
| **$N\text{-}NH_4^+$** | 2008 | 0.4 ± 0.15 | 0.7 ± 0.19 | 0.3 ± 0.07 |
| | 2009 | 0.7 ± 0.09 | 1.3 ± 0.62 | 1.0 ± 0.20 |
| **$N\text{-}NO_3^-$** | 2008 | 1.0 ± 0.30 | 2.1 ± 0.61 | 2.1 ± 0.07 |
| | 2009 | 0.5 ± 0.24 | 2.9 ± 1.13 | 2.3 ± 1.38 |
| **$N\text{-}NH_4^+ + N\text{-}NO_3^-$** | 2008 | 1.4 ± 0.45 | 2.8 ± 0.80 | 2.4 ± 0.14 |
| | 2009 | 1.2 ± 0.33 | 4.2 ± 1.75 | 3.3 ± 1.58 |

*Different letters in rows within a year shown significant differences among treatments ($p \leq 0.05$)

## 4 CONCLUSIONS

Results from this study showed that the use of high rates of N as dairy slurry or urea did not affect total N leached losses, which range from 2.8 to 4.2 kg N $Ha^{-1}$ $yr^{-1}$ for slurry and 2.4 to 3.3 kg N $Ha^{-1}$ $yr^{-1}$ for urea, for 2008 and 2009, respectively, with no differences among the treatments ($p > 0.05$), being loss mainly as nitrate (*c.* 70 to 90%).

Leaching losses were low for all treatments over the two years, this agrees with previous studies in Southern Chile, using inorganic fertilisers. We suggest that this could be explained by gaseous N losses and/or the unique N retention properties of volcanic soils.

## ACKNOWLDEGMENTS

This research was funded by the Scientific and Technological Research Council (FONDECYT), project 1080368.

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