NITROGEN LEACHING LOSSES AFTER DAIRY SLURRY AND UREA APPLICATION ON A PERMANENT PASTURE OF A RED-CLAY SOIL OF SOUTHERN CHILE

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ABSTRACT
Dairy slurry has become an important source of nutrients for pastures in southern Chile pastures, increasing its dry matter production. However, mismanage (e.g. high application rate or wrong application time) could lead to N losses such as nitrate leaching. The objective of the study was to evaluate the effect of high application rate of dairy slurry and urea on N leaching losses of a red-clay soil of Southern Chile. A field experiment was carried out from March 2009 to March 2011 on a permanent pasture located in San Juan de La Costa Province(40º 39'S, 73º21'W; 224 m.a.s.l.).Dairy slurry and urea were applied at a rate of 400 kg N ha^{-1} yr^{-1}(split in four parts), also a control treatment with no N was included. Leaching N losses were measured using ceramic suction cups. Samples were taken every 100 mm of drainage andanalysed for $N\text{-}NH_4^+$ and $N\text{-}NO_3^-$. Results showed that cumulative N losses were low and ranged from 2.4 ± 0.3 to 6.8 ± 4.1 kg N ha^{-1} yr^{-1} for slurry and 5.0 ± 1.3 to 10.7 ± 6.2 kg N Ha^{-1} yr^{-1} for urea and 1.8 ± 0.1 to 3.4 ± 0.8 for control treatments for 2009 and 2010, respectively, with no differences among them ($p>0.05$). Losses were mainly in the NO_3^- form (up to 85% and 91% of total losses for urea and dairy slurry, respectively). Results showed that N leaching losses were low for all treatments and years, despite the high N rate and application time. Low N losses by leaching can be explained by natural soil properties and/ or gaseous losses. Better management practices are important to keep low the N leaching levels and to reduce the pollution risk of regional water resources.

Keywords: Dairy slurry, Leaching, Manure, Nitrogen losses, Urea.

INTRODUCTION

Under intensive dairy farming conditions approximately 77% of the Nitrogen (N) consumed by cattle is excreted in the urine, solid faces or slurry (Pain, 1990). The N in livestock excreta is mainly in urea form, which is hydrolyzed and transformed by the urease (Sommer et al., 2004).In manures, the labile-N compounds are referred to Total Ammoniacal Nitrogen (TAN), which is responsible of almost all N losses by pathways such as: nitrate ($N\text{-}NO_3^-$) leaching and ammonium ($N\text{-}NH_4^+$) immobilization in the soil, gaseous losses (nitrous oxide -N_2O-and ammonia volatilization -NH_3-) and surface runoff (Webb, 2001).Dairy slurry is an important N source in the southern Chilean farms, supplying partial or totally the local fertilizer requirements for pastures (Salazar et al., 2003). However, mismanagement such as high application rate or inappropriate application time could produce low and variable N recoveries by the plants and amounts of N lost by leaching. Consequently, concerns have been raised about the economic and environmental aspects of these N losses (Alfaro and Salazar, 2005).

Nitrogen leaching after slurry application could be the result of the transportation of the N mobile forms through the soil by the water drained in excess down the soil profile (Alfaro et al., 2006). Besides, N leaching has been link with important pollution problems (Alfaro and Salazar, 2005) which arethe result of the influence of soil texture and structure, water saturation degree, quantity of soil organic matter, and climatic conditions such as temperature and rain patterns as well (Alfaro et al., 2006). The objective of the study was to evaluate the effect of high application dose of dairy slurry and inorganic fertilizer on N leaching losses of a red-clay soil of Southern Chile.

MATERIALS AND METHOD

A field experiment was carried out from March 2009 to March 2011 on a permanent pasture located in San Juan de La Costa Province (40º 39'S, 73º21'W; 224 m.a.s.l.) on a Red-clay soil (Ultisol of the Cudico soil Series, Typic Hapludults; CIREN, 2005). The pasture was composed predominantly by perennial ryegrass (*Lolium perenne L.*) with no recent history (3 years) of N fertilization or livestock grazing. The climate corresponds to the agroclimatic zone of Osorno,with a 19year mean annual temperature of 11.2ºC (3.4 - 22.8 °C)and average precipitation of 1.322 mm yr^{-1}, according the Curaco Meteorological Station data. Two treatments were tested with a target application rate of 400 kg N ha^{-1} yr^{-1} as either dairy slurry or urea split in four even applications during one year: March, July, September and November. Additionally, a control treatment was included. Fertilizers were applied by hand to small plots (9 m^2) plots, using a randomized block design with three replicates for each treatment. Measurements of N leaching at 60 cm depth were estimated using 3 ceramic suction cups per plot (n=9 per treatment) according to Lord and Shepherd (1993).

A suction pump was used to provide vacuum (0.7 bar) every 100 mm of drainage and the resulted sampleswere obtained 24 h later with plastic syringes. Samples were stored in plastic flasks and frozen until analysis for available N ($N\text{-}NO_3^-$ and $N\text{-}NH_4^+$) by automated sample analyzer (SKALAR, SA 4000, Breda, The Netherlands). Drainage was calculated as the result of the difference between the rainfall and the amount of water evaporated, both parameters measured in an automatic meteorological station placed in the experimental site. The N losses were calculated as the product of drainage and N concentration in samples, and the total N leaching losses were calculated as the addition of the estimated losses for the different sampling periods. Statistics comparisons were done using ANOVA.

RESULTS AND DISCUSSION

Results show that despite the high N rate and time of application, the concentrations of NO_3^- leached were generally low, and did not exceeded 10.2 mg L^{-1} during the evaluation years. Annual average values of $N\text{-}NO_3^-$ concentrations were below 1.1 mg L^{-1} for all the treatments (Table 1)($p>0.05$), and far below the 11.3 mg L^{-1} established as the EC maximum recommendable for drinking water (i.e. European Union, 91/676/ EEC). Total leaching losses where low for all treatments in both years (Table 1) with no differences among them ($p>0.05$).

Drainage occurred mainly at the finish of fall and during the winter for booth study years, specifically from April to August more than 80% of the total average rainfall and more than 30% of the evaporation of the year took place. In this period more N content was expected to be carried on the drained water. According to the meteorological data, the estimated drainage for the study period was 684 and 571 mm. for 2009 and 2010 respectively. During the drainage period most of the N leached was in the NO_3^- form: between 83-85% for urea, 68-91% for slurry and 57-76% for the control treatment in 2009 and 2010, respectively, which is similar to previous studies elsewhere (e.g.Ledgard et al., 1996; 1999). The percentage of NH_4^+ losses were lower than NO_3^- ranging between 15-17% for urea, 9-32% for slurry, and 24-43% for the control in 2009 and 2010 respectively, in agreement with Webster et al. (1993) and Alfaro and Salazar (2008).

Natural soil characteristics played an important role in the results, because soil biomass activity and natural soil N mineralization processes could become more relevant than the addition of N fertilizer in some soils of the region(Alfaro et al., 2006). The biomass activity in southern Chile soils has very specialized microbial and abiotic retention processes which can reduce the risk for N leaching by the immobilization of the N (Huygens et al., 2008). Besides, other amounts of N were probably fixed into the structure of the soil organic matter, been keep into the soil profile (Hasson and Wiley, 2010). In the other hand, studies also suggest that gaseous losses, such as NH_3 emission, are high when urea or slurry is use as fertilizer in local pastures (e.g. Salazar et al., 2012).

In Chile, there is no regulation or recommendations for the quantity or timing of N fertilizer application to pastures, but many voluntary strategies and alternative practices for reducing N losses by leaching are available for local farmers. These actions could include improving the time of N application at appropriate rates, balancing the amount of N needed for optimum plant growth by synchronizing the fertilizer application with the crop demand and optimizing N application techniques (i.e. use of better slurry land spreading techniques) (Cuttleand Scholefield, 1995; Misselbrook et al., 1996; Chambers et al., 2000; Di and Cameron, 2002). These actions will diminish the economic impact of the N losses to farmers, improve the nutrient efficiency in the productive system and reduce the risk of pollution to the wider environment at the same time.

CONCLUSIONS

Results from this study showed that the use of high rates of N as dairy slurry or urea did not affect total N leaching losses, which range from 2.4 ± 0.3 to 6.8 ± 4.1 kg N ha^{-1} yr^{-1} for slurry and 5.0 ± 1.3 to 10.7 ± 6.2 kg N Ha^{-1} yr^{-1} for urea ($p > 0.05$).Losses were mainly as nitrate form (83 to 85% and 68% to 91% of total losses for urea and dairy slurry, respectively). Leaching losses were low for all treatments and yearsin comparison with losses reported elsewhere. We suggest that this could be explained by the N retention properties of volcanic soils of Southern Chile and gaseous losses such as NH_3 emission. However, further studies are required to understand the role of N soil adsorption and gaseous losses on leaching losses in volcanic soils of southern Chile. In order to keep lower nitrate levels in leachates, the adoption and implementation of voluntary strategies and alternative management practices will be important (e.g. timing and rate of application, nutrient balance in pastures, better slurry application techniques)to reduce the risk of N leaching into the regional water resources.

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Table 1. Average N concentration in leachates (mg L^{-1}) and N losses (kg N ha^{-1}) for different treatments, 2009 and 2010 (± sem).

Average leaching concentrations and range (mg L^{-1})		Treatments		
		Control	**Dairy slurry**	**Urea**
$N\text{-}NH_4^+$	2009	0.1 ± 0.01	0.07 ± 0.02	0.2 ± 0.03
	2010	0.2 ± 0.03	0.2 ± 0.02	0.2 ± 0.05
$N\text{-}NO_3^-$	2009	0.4 ± 0.1	0.9 ± 0.3	1.1 ± 0.7
	2010	0.2 ± 0.02	0.3 ± 0.03	0.8 ± 0.2
Total N losses by leaching (kg ha^{-1})				
$N\text{-}NH_4^+$	2009	0.8 ± 0.03	0.6 ± 0.1	1.6 ± 0.7
	2010	0.8 ± 0.02	0.8 ± 0.1	0.8 ± 0.2
$N\text{-}NO_3^-$	2009	2.6 ± 0.8	6.2 ± 4.0	9.1 ± 5.5
	2010	1.0 ± 0.1	1.6 ± 0.2	4.2 ± 1.1
$N\text{-}NH_4^+ + N\text{-}NO_3^-$	2009	3,4 ± 0.8	6,8 ± 4.1	10,7 ± 6.2
	2010	1,8 ±0.1	2,4 ±0.3	5,0 ±1.3