Mitigation of diffuse-source nitrate leaching from grazed pastures using a nitrification inhibitor

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In New Zealand, the predominant land use is grazed grassland where animals graze outdoor pastures all year round. Two of the major environmental issues in intensively grazed pasture systems are nitrate (NO_3^-) leaching and nitrous oxide (N_2O) emissions. Nitrate is a water contaminant that can contribute to surface water eutrophication and nitrous oxide (N_2O) is both a greenhouse gas and an ozone-depletion substance.

In grazed grassland, most of the NO_3^- leaching and N_2O emissions come from the animal urine-N returned to the pasture by the animal during outdoor grazing (Di & Cameron, 2002a). The N loading rate under a dairy cow urine patch in intensively grazed dairy grassland can be as high as 1000 kg N ha^{-1} (Di & Cameron 2002a). Most of the N in the urine is urea which, when deposited onto the soil, produces ammonium, which is subsequently nitrificatified to nitrate. Over the past few years, we have developed a mitigation technology that has been shown to be effective in reducing NO_3^- leaching and N_2O emissions from animal urine patch soil using a nitrification inhibitor, dicyandiamide (DCD) (Di & Cameron, 2002b; Di & Cameron, 2003; 2004a; 2004b; 2004c; 2005; 2006; 2007; 2008; Di *et al*., 2007; 2009a; 2009b; 2010a; 2010b).

Large undisturbed soil monolith lysimeters (0.5 m diameter and 0.7 m deep) were collected and used to determine NO_3^- leaching and N_2O emissions (Di et al. 2009b; 2010b). The lysimeters were installed in field lysimeter facilities where the tops of the lysimeters were exposed to the same climatic conditions as the soil and pasture in the surrounding field. Two rainfall conditions (1260 mm and 2145 mm p.a.) were created using a rainfall simulation system in order to test the influence of rainfall inputs on NO_3^- leaching and N_2O emissions. Leachates from the lysimeters were collected as required and analyzed for NO_3^-, nitrite (NO_2^-), and NH_4^+ concentrations. A standard closed chamber method was used to determine N_2O emissions from the treated lysimeters (Di et al. 2010b).

Under the 1260 mm rainfall treatment, total NO_3^--N leaching losses in the Urine treatment ranged from a low of 122.9 kg NO_3^--N ha^{-1} in the West Coast (WC) Harihari soil to a high of 435.8 kg NO_3^--N ha^{-1} in the Southland (SL) Mataura soil (Table 1) (Di et al., 2009b). These losses were significantly decreased to between 35.8 and 176.5 kg NO_3^--N ha^{-1}, when DCD was applied ($P < 0.05$). The application of DCD therefore reduced the NO_3^- leaching losses by between 56 to 71%. Under the 2145 mm rainfall condition, the total NO_3^--N leaching losses in the Urine treatment varied from 67.7 kg NO_3^--N ha^{-1} in the WC Harihari soil to 457.0 kg NO_3^--N ha^{-1} in the SL Mataura soil. These losses were decreased to 29.7 and 257.4 kg NO_3^--N ha^{-1} with the application of DCD. The application of DCD therefore reduced these NO_3^- leaching losses by between 44 to 56%. The difference in the amount of NO_3^--N leached between the two rainfall conditions was not statistically significant ($P > 0.05$). The average reduction in NO_3^--N leaching loss by the DCD treatment under both rainfall conditions was 59%.

Total N_2O emissions varied significantly between the different soils, with those in the urine treatment ranging from a low of 13.9 kg N_2O-N ha^{-1} in the WC Harihari soil under the higher rainfall condition to a high of 39.8 kg N_2O-N ha^{-1} in the Canterbury (CT) Lismore soil under the higher rainfall condition (Di et al., 2010b). The different water inputs did not result in significantly different total N_2O emissions ($P > 0.05$). However, the DCD treatment decreased the total N_2O emissions from all of the four soils. The emission factor from the urine (EF_3) varied from 1.4% to 3.0% (averaging 2.2%), and this was decreased to between 0.3% and 1.4% (averaging 0.8%) with the DCD treatment. Therefore, the DCD treatment resulted in a reduction of the average EF_3 by 64%.

Table 1. Total NO_3^--N leaching losses (Di et al., 2009b)

Soil region	Rainfall (mm p.a.)	Treatment	NO_3^--N leached (±SE) (kg ha^{-1})	% reduction of NO_3^--N leaching
CT	1260	Urine	399.0 (27.3)	---[A]
CT	1260	Urine+DCD	176.5 (15.5)	56
SL	1260	Urine	435.8 (13.7)	---
SL	1260	Urine+DCD	142.2 (0.9)	67
WC	1260	Urine	122.9 (59.1)	---
WC	1260	Urine+DCD	35.8 (17.4)	71
SL	2145	Urine	457.0 (53.4)	---
SL	2145	Urine+DCD	257.4 (22.3)	44
WC	2145	Urine	67.7 (25.1)	---
WC	2145	Urine+DCD	29.7 (11.5)	56
SED for Treatment			20.0	
Average reduction of NO_3^--N leaching by DCD				59

[A] Not applicable. CT: Canterbury Lismore shallow stony soil; SL: Southland Mataura soil; WC: West Coast Harihari soil;

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