A synergistic mitigation technology for nitrate leaching and nitrous oxide emissions for pastoral agriculture

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1. Background & Objectives

In grazed grassland, most of the nitrate (NO_3^-) leaching and nitrous oxide (N_2O) emissions come from the animal urine-N returned to the pasture by the animal during outdoor grazing (Di and 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 and Cameron 2002a). Most of the N in the urine is urea which, when deposited onto the soil, is oxidized to ammonium (NH_4^+), and then to NO_3^-. The excess NO_3^- remaining after plant uptake or immobilisation is prone to leaching during the wet season or lost as N_2O. Here we present a mitigation technology that is synergistic in decreasing both NO_3^- leaching and N_2O emissions, while at the same time, increasing pasture production. The mitigation technology involves the use of a nitrification inhibitor, dicyandiamide (DCD), to treat grazed pasture soil (Di and Cameron, 2002b; 2003; 2004; 2005; 2006; 2007; Di et al., 2007; 2009a; 2009b; 2010a; 2010b).

2. Materials & Methods

Soil samples (0-0.1 m depth) were taken from different sites across New Zealand and were used to study the inhibition effect of DCD on ammonia oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA). Soil DNA was extracted and the *amoA* gene, which encodes the ammonia monooxygenase enzyme, was quantified using primers and probes coupled with real-time PCR analysis. Large undisturbed soil monolith lysimeters (0.5 m diameter and 0.7 m deep) were also collected and used to determine NO_3^- leaching and N_2O emissions (Cameron et al., 1992; Di et al., 2009b; 2009c). A standard closed chamber method was used to determine N_2O emissions from the treated lysimeters (Di et al., 2009c). The lysimeters were exposed to the same climatic conditions as the soil and pasture in the surrounding field. Pasture was harvested at typical grazing heights and intervals to determine pasture yield. Pasture responses have also been measured on commercial dairy farms under realistic grazing conditions (Moir et al., 2007).

3. Results & Discussion

The AOB population abundance and activity grew rapidly following the application of animal urine at 1000 kg N ha^{-1}, with the *amoA* copy numbers increasing by 3.2-10.4 fold the different soils (Di et al., 2009a). However, when the nitrification inhibitor, DCD, was applied, the AOB population growth was significantly inhibited. In contrast, the AOA population abundance and activity did not change with the supply of the large dose of urine-N substrate. The addition of the urine-N substrate significantly increased the nitrification rate, as indicated by the rising NO_3^--concentrations, but the nitrification rates were reduced by the DCD treatments. DCD did not adversely affect other soil microbial populations, such as methanotrophs (Di et al., 2011).

Fourteen datasets on NO_3^- leaching from a range of soil and environmental conditions published in internationally peer reviewed journals show that the DCD nitrification inhibitor technology reduced NO_3^- leaching from urine patch areas by an average of 64%, with a standard error of ± 3.6% (Cameron et al., 2009). The small standard error of 3.6% indicates that there is a high level of consistency in the effectiveness of this technology in reducing NO_3^- leaching losses. Similarly, de Klein et al. (2011) reported that twenty three datasets of N_2O emissions from a range of soil and environmental conditions across New Zealand published in international peer reviewed journals showed that the nitrification inhibitor technology reduced N_2O emissions from urine patch areas by an average of 57%, again showing the high efficacy in reducing N_2O. Pasture yield increases up to 20% have also been recorded when DCD is applied (Moir et al., 2007).

Acknowledgments
We thank the New Zealand Ministry of Science and Innovation (MSI), Ravensdown Ltd, Ministry of Agriculture and Forestry (MAF), the Pastoral 21 Consortium, and the Pastoral Greenhouse Gas Research Consortium for funding.

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