Effect of soil moisture status and animal treading on N_2O emissions and the effectiveness of a nitrification inhibitor mitigation technology

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Keywords: Nitrous oxide, soil moisture, animal treading, nitrification inhibitor.

Introduction

Nitrous oxide (N_2O) is a potent greenhouse gas with a long-term global warming potential about 298 times that of carbon dioxide (CO_2). In grazed grassland, most of the N_2O is emitted from nitrogen (N) excreted by the grazing animal, particularly in the animal urine. When the soil is wet, such as that in winter grazing conditions, animal grazing can cause soil structural damage, leading to soil compaction. The combination of a wet soil plus soil compaction is particularly conducive for N_2O production. A nitrification inhibitor technology using dicyandiamide (DCD) has been developed to reduce N_2O emissions from grazed grassland (Di and Cameron 2002; 2003). However, the efficacy of this technology under wet and compact soil conditions has not been well studied.

The objectives of this study were to determine: (1) The impact of soil moisture content on the abundance of ammonia oxidizers and N_2O emissions; (2) the impact of animal treading on N_2O emissions; and (3) The effectiveness of the nitrification inhibitor DCD in reducing N_2O emissions, as affected by soil moisture status and animal treading.

Materials and methods

A laboratory incubation study was conducted to determine the effect of soil moisture status on the abundance of ammonia oxidizers and N_2O emissions using a grassland soil (Horotiu soil: Typic Udivitrand). Two sets of incubations were set up, one set for soil sampling to determine the ammonia oxidizer abundance and the other set for determining N_2O emissions using a method similar to the static chamber methods by filling up glass bottles to two thirds the height and leave the top third as air space under the lid for N_2O sampling. Three soil moisture conditions were compared: 60%, 100% and 130% field capacity. For each moisture regime, the following treatments were applied: Control; Control + DCD (dicyandiamide nitrification inhibitor) at the equivalent rate of 10 kg/ha; Urine at 700 kg N/ha (simulating N application rate under a dairy cow urine patch in grazed grassland); Urine + DCD. The incubation vessels were incubated at a constant 12 ^oC to simulate late autumn conditions in New Zealand when DCD was applied to reduce nitrate leaching and N_2O emissions. Soil samples were collected to determine mineral N concentration and the abundance of ammonia oxidizing bacteria (AOB) and ammonia oxidizing archaea (AOA) using real-time PCR (Di *et al*. 2009). N_2O emissions were determined over about eight months using gas chromatography (GC).

A field experiment was conducted to determine the impact of animal treading on N_2O emissions on a Wakanui sandy loam (Aquic Dystric Utrochrept) (Ball *et al*. 2012). Field plots of 0.5 m diameter were established to simulate dairy cow urine patches. Dairy cow urine at the rate of 1000 kg N/ha was applied to the plots to simulate animal urine deposition. The nitrification inhibitor DCD was applied to some of the plots at 10 kg/ha. Some plots were un-trampled, and some were trampled with a mechanical hoof delivering the same pressure as that of an adult cow hoof walking over the field. N_2O emissions were determined using field static chamber methods.

Results

The laboratory incubation study showed that soil moisture content was a major driver affecting the growth of ammonia oxidizing bacteria (AOB) and N_2O emissions in the soil that received animal urine. Total N_2O emissions from the soil at 130% field capacity were 400 times higher than those from the soil at 60% field capacity. Total N_2O emissions were significantly related to the abundance of AOB *amoA* gene copy numbers but not to that of the AOA. The field plot study showed that animal treading of a wet soil resulted in a reduction in air permeability and air-filled pore space in the top 5 cm soil layer, and led to significant increases in N_2O emissions (Fig. 1). Trampling increased average cumulative N_2O emissions over a three month period from 15.9 kg N_2O-N/ha to 45.0 kg N_2O-N/ha in the urine treatments (Fig. 1). DCD was highly effective in reducing N_2O emissions, with N_2O emissions being decreased by 58-63%. Trampling did not significantly affect the effectiveness of DCD in reducing N_2O emissions. These reductions are similar to those that have been reported previously (*e.g*. Di *et al*. 2010).

Conclusions

Soil moisture status and animal treading are critical factors

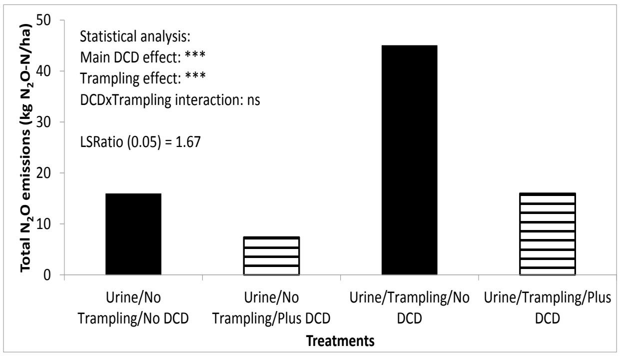

Figure 1. N_2O emissions from a field plot experiment showing the effect of animal trampling and the application of the nitrification inhibitor DCD. LSRatio(5%) is Least Significant Ratio (5%); two treatment means differ significantly at *P*=0.05 if their *ratio* (larger/smaller) is greater than the LSRatio(5%).

affecting N_2O emissions which were related to the abundance (copy number of the *amoA* gene) of ammonia oxidizing bacteria. The combination of wet soil conditions and animal trampling makes the winter forage system highly conducive for N_2O emissions. The DCD nitrification inhibitor is an effective mitigation technology for N_2O emissions under both trampled and un-trampled soil conditions, thus showing the potential of this mitigation technology for wet and heavily trampled winter grazing conditions.

Acknowledgments

We would like to thank the New Zealand Agricultural Greenhouse Gas Research Centre for funding, and Steve Moore, Carole Barlow, Jie Lei, Neil Smith, Trevor Hendry and Manjula Premaratne of Lincoln University for technical support.

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