Use of nitrification inhibitors to reduce N_2O emissions from southern pastures

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Abstract
Nitrous oxide (N_2O) is a potent greenhouse gas and is a product of both nitrification and denitrification in soils. Agriculture contributes 75% of national N_2O emissions, with the majority coming from fertilised agricultural soils. Nitrification inhibitors suppress the activity of the ammonia oxidizing bacteria in soil and can consequently reduce N_2O emissions, but their efficacy is variable.

A field experiment was conducted over an eight month period on a ryegrass seed pasture in southern Australia. Urea and urea treated with the nitrification inhibitor 3,4-dimethylpyrazole phosphate (DMPP) (Urea with ENTEC®) was applied on a near monthly basis at 40 kg N/ha, and dicyandiamide (DCD) was also used in spring. Nitrous oxide emissions were measured using manual chambers at least weekly. Soil mineral N and pasture biomass were measured monthly. DCD and DMPP performed equally well. DMPP reduced net-N_2O emissions by 64%, with greatest reductions in spring when N_2O emissions were greatest; caused N to be retained N as ammonium for longer; and increased biomass production but not at all times. Nitrification inhibitors appear to be an effective strategy to mitigate agricultural greenhouse gas emissions.

Key Words
3,4-dimethylpyrazole phosphate, dicyandiamide, ryegrass pasture

Introduction
Nitrogen (N) use efficiency from fertiliser applied to pasture in Australia is considered to be low, with around 40% reported lost either from ammonia (NH_3) volatilisation, denitrification (as N_2O and N_2) or leaching as nitrate (NO_3^-) (Chen *et al.* 2008). Nitrous oxide is a potent greenhouse gas (300 CO_2e), and emissions from agriculture are 75% of the national total, with 73% of this from agricultural soil. The Carbon Farming Initiative (CFI), a carbon off-set scheme where credits can be earned by either sequestering carbon or reducing greenhouse gas emissions, provides an economic incentive to reduce N_2O emissions from applied nitrogen fertilisers. Nitrification inhibitors can reduce N_2O emissions from pastures but their effectiveness is variable, and to date most studies have looked at the impact of inhibitors on N_2O emissions from cattle urine patches (Di and Cameron 2011; Giltrap *et al.* 2012). This paper reports a field experiment that measured N_2O emissions, soil mineral N and pasture production, from surface applied granular urea with and without the addition of the nitrification inhibitors DMPP (Urea with ENTEC®) and DCD.

Methods
A randomized complete block small plot (2 × 1 m) trial was conducted at Murroon in south-western Victoria on a two year old perennial ryegrass (*Lolium perenne* L) seed crop grown on a texture contrast soil with an acidic (pH_{CaCl2} 4.6) clay loam topsoil (0-25 cm) from April 12th 2010 to December 23rd 2010 (seed harvest). Five replicates were used per treatment. Granular urea (40 kg N/ha) ± DMPP and DCD (DCD from September only: DCD was added to compare the effectiveness of the two inhibitors at a time of predicted high N_2O emission) was applied at near monthly intervals. Soil mineral N (0-5 cm, composite of 3 × 18 mm diameter cores) was measured fortnightly and pasture biomass cuts were taken to simulate grazing (~ monthly). Manual gas collection chambers (25 cm height and 23 cm diameter, inserted 5 cm into the ground and left on-site during the course of the experiment) were used to measure a flux of N_2O over a one hour period (with samples collected at 0, 30 and 60 minutes), at regular intervals over the course of the experiment, with samples analysed in the laboratory using an Agilent GC 7890a. Soil and ambient moisture and temperature were measured.

Results

Rainfall during the experiment totalled 648 mm, with 196 mm falling between April 12th and August 2nd, 150 mm between August 2nd and August 30th, and 303 mm between August 30th and December 23rd (Figure 1). Nitrous oxide (N_2O) emissions fluctuated with higher emissions in spring (Sept-Nov) when the soil became drier and warmer (Figure 1) after a wet winter (the site was saturated). Cumulative N_2O emissions were greater in spring than autumn (Table 1). DMPP reduced net-N_2O emissions from April to December by 64%, with greatest reductions over spring. DMPP and DCD performed equally well during September to December.

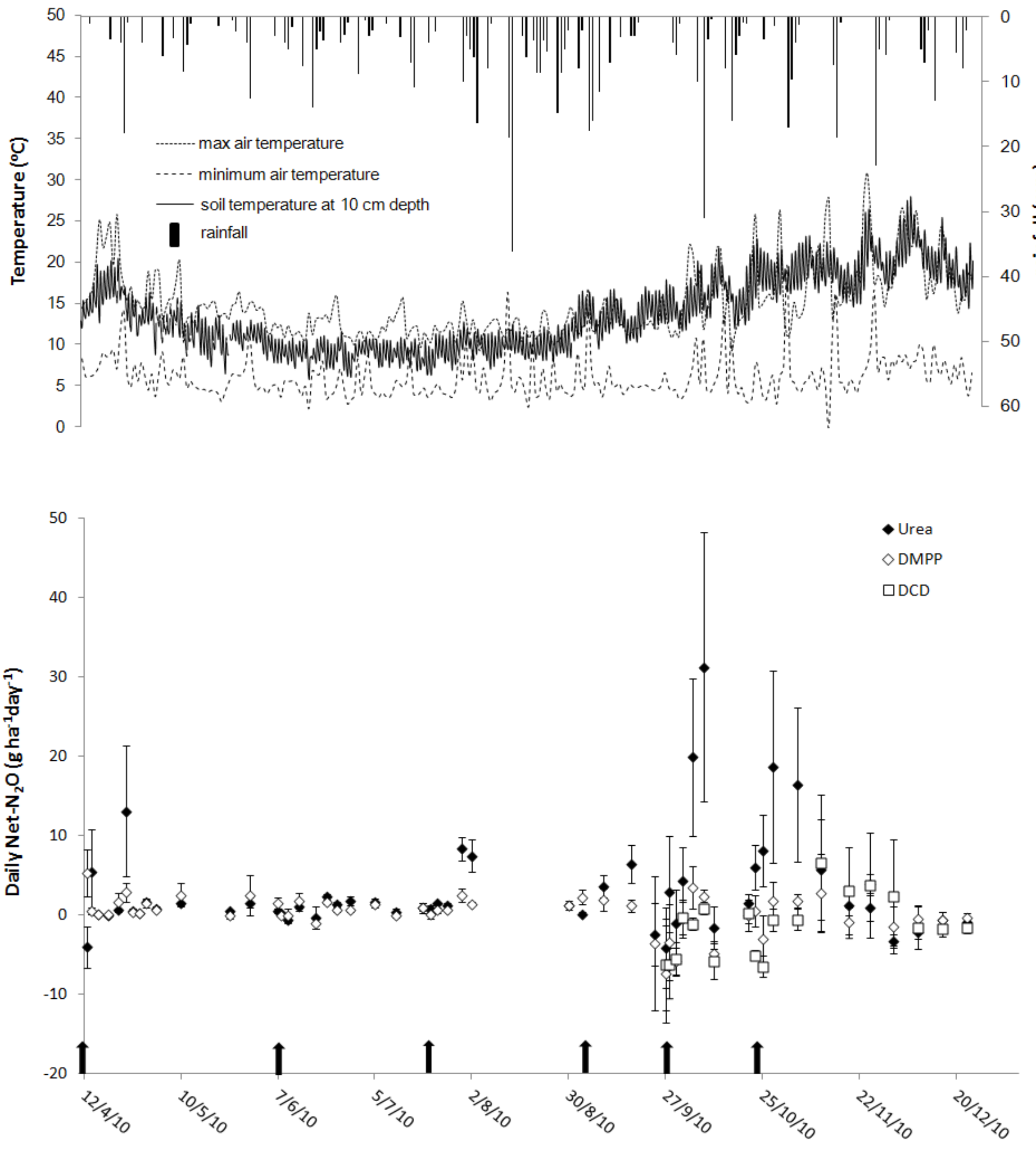

Figure 1. Daily N_2O emissions (g/ha/day) (bottom chart) and daily rainfall, and air and soil temperature (top chart).

Table 1. Cumulative N_2O emissions (kg/ha) measured from April to August and August to December for control, urea and urea + DMPP treatments, showing standard errors of the mean.

	Control	Urea	Urea + DMPP
April 12th -August 2nd	0.2±0.02	0.36±0.04	0.34±0.02
August 30th* –December 23rd	0.8±0.04	1.27±0.20	0.85±0.07

* No samples collected from August 2nd to 30th as site was saturated.

Use of the nitrification inhibitors led to retention of N in ammonium (NH_4^+) form for longer periods after urea application, reducing the risk of leaching losses. During the wetter months (July-Sept), the average NH_4^+ concentration from four sampling times was 7.5 kg N/ha for urea and 27.8 kg N/ha for urea +DMPP.

Over the eight month trial cumulative biomass production was increased by use of nitrogen fertilisers, but was not affected by the use of the nitrification inhibitors (Table 2). However greater biomass was observed at most sampling times when DMPP was used, most noticeably: 1) 2 months after fertiliser application (April-June); and 2) at the end of winter (September 3rd), indicating that the N saved as NH_4^+ was not lost through leaching or denitrification and remained available for plant uptake. The reason for the lack of significant biomass response at most sampling times is unclear but likely due to the small loss of N as N_2O (Table 1) relative to the N applied (240 kg N/ha over 8 months), and the limited loss of N as leached nitrate at this site due to the duplex nature of the soil.

Table 2. Biomass production (kg/ha) for control, urea and urea + DMPP treatments over the entire experiment and at times when greatest increase with use of DMPP was observed, showing standard errors of the mean.

	Control	Urea	Urea + DMPP
April 12th –December 23rd	4576±393	8515±454	8415±577
June 17th cut*	123±10	159±9	207±36
September 3rd cut	231±13	876±82	949±74

* 2 months after fertiliser application

Conclusions

The nitrification inhibitors DMPP and DCD were able to reduce N_2O emissions and retain NH_4^+ for longer periods compared to granular urea from pastures in southern Australia. Biomass production was improved with the use of DMPP most of the time but not always and the reason for this variable response requires further investigation.

References

Chen D, Suter HC, Islam A, Edis R, Freney JR, Walker CN (2008). Prospects of improving efficiency of fertilizer nitrogen in Australian agriculture; a review of enhanced efficiency fertilizers. Australian Journal of Soil Research 46(4), 289-301.

Di HJ, Cameron KC (2011). How does the application of different nitrification inhibitors affect nitrous oxide emissions and nitrate leaching from cow urine in grazed pastures? Soil Use and Management, 28, 54-61.

Giltrap DL, Saggar S, Singh J, Harvey M, McMillan A, Laubach J (2012). Field-scale verification of nitrous oxide emission reduction with DCD in dairy-grazed pasture using measurements and modelling. Soil Research 49(8), 696-702.