What are the key drivers of nitrification inhibitor efficacy in Australian agricultural soils?

Helen Suter[a]*, Rohan Davies[b] , Charlie Walker[c] and Deli Chen[a]

[a] Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Victoria 3010*E-mail: helencs@unimelb.edu.au
[b] BASF Australia, Freshwater Place. Southbank, Victoria, 3006. [c] Incitec Pivot Limited, Po Box 54, North Geelong, Victoria 3215.

THE UNIVERSITY OF MELBOURNE

Poster 614

Introduction

Nitrogen (N) is a key requirement for agricultural productivity, and in most broadscale production systems is supplied as fertiliser-N. The reactive nature of N can lead to large inefficiencies from the application of fertiliser, causing both economic and environmental impacts.

Nitrification inhibitors (NIs) (eg. 3,4-Dimethylpyrazole phosphate, Dicyandiamide and Nitrapyrin), which inhibit the oxidation of ammonia, have been shown to effectively reduce the rate of nitrification and nitrous oxide (N_2O) emissions from applied fertilisers across a broad range of soils and environmental conditions. They therefore can have positive N efficiency and environmental outcomes. It is clear that edaphic and climatic factors impact on the performance of the inhibitors, however it is not clear whether any particular soil property or properties are the key driver(s) of this performance, and this is one reason for their low adoption rate. This research aimed to identify whether any key soil factor could be used as a predictor of the efficacy of nitrification inhibitors in Australian soils.

Materials and Methods

- Thirty soils were collected from different land uses around Australia, covering a range of properties (Table 1).
- Soils were air dried and sieved (<2 mm). Samples (60 g oven dried equivalent) were placed into 250 ml vials and pre-incubated (25ºC) for 3 weeks prior to the experiment to reactivate the microbial community.
- Treatments: 1) Ammonium chloride (100 µgN/g soil) (F), and
  2) F + NI (DMPP, 3MP+TZ, DCD, N-serve*) (inhibitors at recommended rates)

[*DMPP: 3,4-Dimethylpyrazole phosphate; 3MP+TZ: 3 methylpyrazole 1,2,4-Triazole; DCD: Dicyandiamide; N-serve: Nitrapyrin]

- Incubation conditions: 25 ºC, 60% Water Filled Pore Space (WFPS), 42 days
- Measurements: Soil mineral N (2M KCl, 1:5 soil : solution), gas (N_2O) emissions
- **Average nitrification** was calculated over 14 days of incubation as this length of time best reflected nitrification from fertiliser addition (ie. prior to reduction in nitrate formation due to loss of substrate and denitrification)
- **Cumulative N_2O emissions** were calculated for 28 days (complete flux emitted from all soils tested)
- Model algorithms were developed to predict the rate of nitrification (Vnit_max) and N_2O emissions from the nitrification inhibitor treatments relative to the F treatment (Dr. Yong Li, The University of Melbourne)

Results

Nitrification

- Average nitrification for F (no inhibitor) was 6.26 ± 4.97 µg NO_3^-N produced /g soil/day (range 0.00 to 25.45).
- There was a weak trend for increasing nitrification with increasing C content (R^2=0.17).

Inhibition

- NIs reduced average nitrification by on average 39 ± 27%, with a wide range of responses (<0-100%, Figure 1).
- Increasing organic C reduced (P<0.05) inhibition of nitrification, but the relationship was weak (R^2= 0.25-0.28). No other soil property influenced the inhibition achieved.
- This translated into low effectiveness of NIs in pasture soils (OC : 1.8 to 5.6%) compared to the sugarcane (OC: 0.8 to 1.1%), vegetable (OC: 0.6 to 3%) and cropping (OC: 0.8 to 4.8%) soils.

N_2O emissions

- Average cumulative N_2O emission over 28 days for F was 161 g N_2O/ha (range 19-2039).

Inhibition

- NIs reduced N_2O emissions by on average 60 ± 45%, however the range of was large (<0-115%, Figure 2).
- Increasing soil pH increased (P<0.01) the inhibition of N_2O emissions, but the relationship was weak (eg. 3MPTZ: R^2=0.19, DMPP: R^2=0.24). No other soil property influenced the inhibition achieved.
- This translated into lower overall efficacy in the pasture soils (pHCaCl$_2$: 4.8 to 5.9) and higher efficacy in the vegetable soils (pHCaCl$_2$: 6.2 to 7.8) but does not describe the higher efficacy in the sugarcane (pHCaCl$_2$: 4.1 to 6.5) and cropping (pHCaCl$_2$: 4.6 to 7.9) soils.

Nitrification inhibitors were more effective in inhibiting N_2O than nitrification (nitrate production) across most soils.

Table 1. Summary of selected properties for the 30 soils

Parameter	units	Mean	Standard deviation	Min	Max	Median
Climate zone :	Temperate to tropical (Victoria, NSW, Qld)					
Land use :	Dairy pasture, Sugarcane, Cropping, Vegetables					
clay	%	22	17	1	83	17
silt	%	25	16	1	60	26
sand	%	53	24	7	91	56
pH (water)		6.7	1.1	4.6	8.5	6.5
pH (CaCl$_2$)		6.1	1.1	4.1	7.9	5.9
Organic C	%	2.2	1.5	0.6	5.6	1.6
Active C	mg C/kg	574	240	276	1130	549
Potentially mineralisable N	mg N/kg	59	51	1.7	220	40
Total N	%	0.2	0.2	0.1	0.6	0.1
CEC	meq/100 g	18.7	15.2	2.6	60.4	13.1

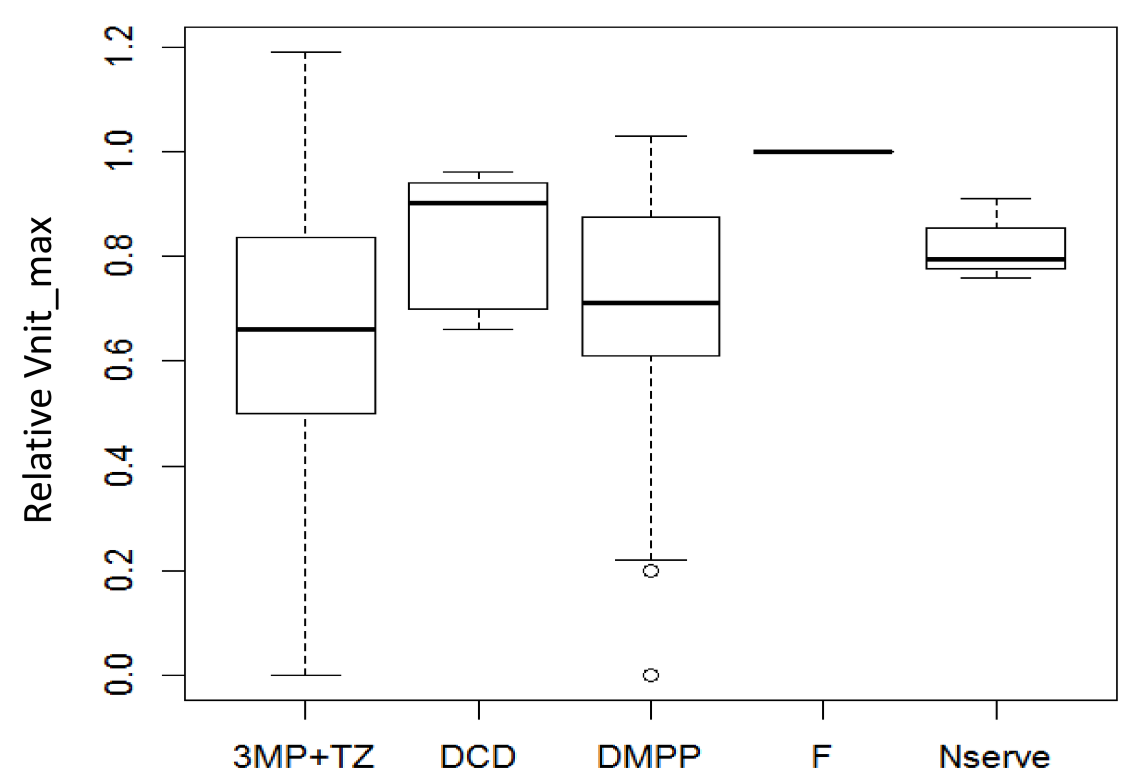

Figure 1. Reduction in nitrification (Vnit_max) with the use of NIs compared to fertiliser (F).

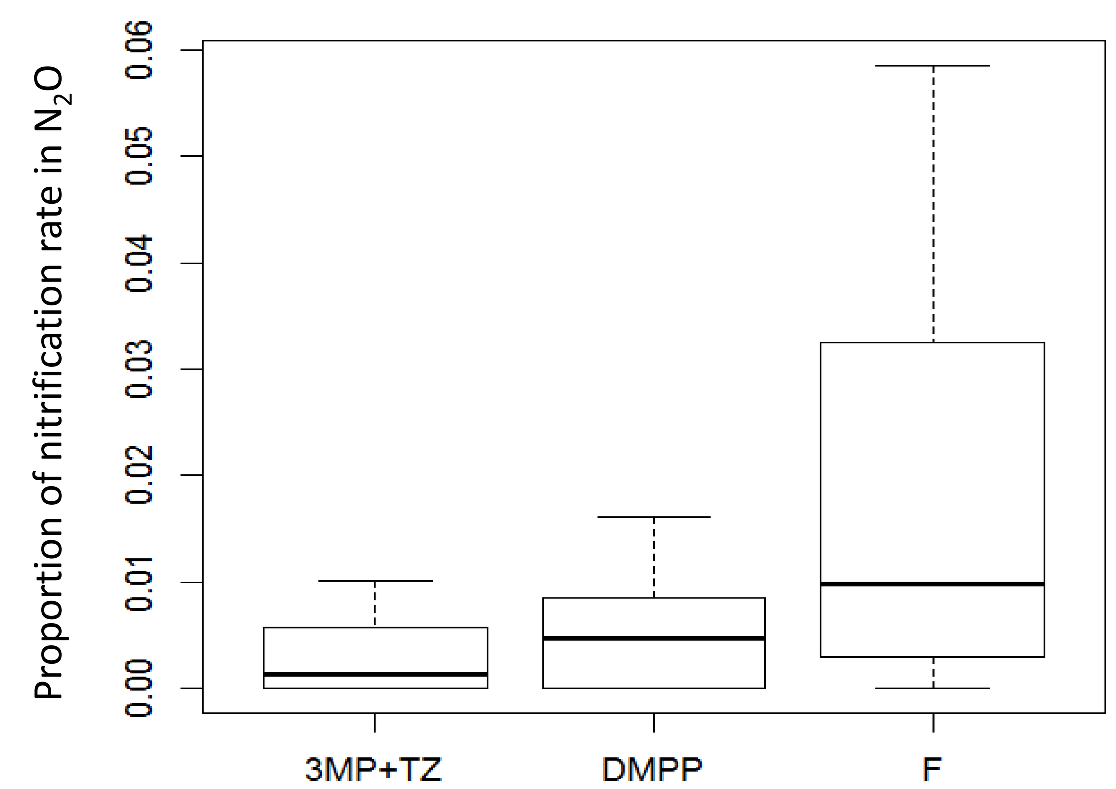

Figure 2. Reduction in proportion of nitrification rate in N_2O with the use of NIs (DMPP and 3MP+TZ) compared to fertiliser (F). Note: range in emissions for F is due to variation across soils.

Summary

- Nitrification inhibitors can reduce both nitrification and N_2O emissions.
- Soil organic carbon content and pH were drivers of inhibitor efficiency at reducing nitrification and N_2O respectively (significant but weak correlation implying other factors drive inhibitor effectiveness).
- At this stage soil properties cannot be used to determine how well an inhibitor will work as other factors will influence this.
- Further research is required on the microbial response to the inhibitors to see if a microbial screening system can be used to identify when the inhibitors will work.

Incitec Pivot Fertilisers | Australian Government Department of Agriculture | piccc Primary Industries Climate Challenges Centre | N2O Network

Acknowledgements: Funding was provided by The Department of Agriculture and Incitec Pivot Fertilisers. The authors acknowledge the contribution of Dr Narges Milani in the processing of the soil laboratory incubation experiments. The authors acknowledge the contribution of Dr Yong Li in developing model algorithms to describe the impact of the inhibitors.