International Nitrogen Initiative

7th International Nitrogen Initiative Conference (INI 2016)

4–8 DECEMBER 2016

MELBOURNE CRICKET GROUND | VICTORIA | AUSTRALIA

THE UNIVERSITY OF MELBOURNE

# Dual effects of nitrification inhibitors on $N_2O$ emission from agriculture


Shu Kee Lam[1], Helen Suter[1], Rohan Davies[2], Mei Bai[1], Jianlei Sun[1], Arvin R Mosier[1], Deli Chen[1]

[1] Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, Australia

[2] BASF Australia Ltd., Australia


THE UNIVERSITY OF MELBOURNE

# Background

- $N_2O$: a greenhouse gas approximately 300 times more potent than $CO_2$
- Global agriculture contributes around 60% of total anthropogenic $N_2O$ emission (Ciais *et al.* 2013).
- Nitrification inhibitors are recommended by the IPCC as a potential mitigation option for agricultural $N_2O$ emission.
- Nitrification inhibitors: $NH_4^+ \nrightarrow NO_3^-$

# Dual effects of nitrification inhibitors

- Nitrification inhibitors decrease $N_2O$ emission by 31–48% across diverse agricultural ecosystems.
- However the inhibitors prolong the retention of $NH_4^+$ in soil, and increase $NH_3$ emission by 20–40% (meta analyses by Akiyama *et al.*, 2010; Qiao *et al.*, 2015)
- $NH_3$ deposition:
  - a major threat to environmental quality and ecosystem biodiversity (Erisman *et al.* 2008)
  - indirectly contributes to $N_2O$ emission (van der Gon & Bleeker 2005)

THE UNIVERSITY OF MELBOURNE

# Knowledge gap

- Previous meta-analyses
  - included studies focussed on either $N_2O$ or $NH_3$
  - expressed the effect as % change, not absolute difference in nitrogen

- No review on studies that **simultaneously measure $N_2O$ and $NH_3$ emissions** in the field under the treatment of nitrification inhibitors

THE UNIVERSITY OF MELBOURNE

# Methodology

- Literature search: Web of Science, Scopus, CAB Abstracts, Academic Search complete and Google Scholar

- IPCC emission factor $EF_4$ (indirect $N_2O$ emission from $NH_3$ volatilization and deposition):
  - Default: 1%
  - Upper range: 5%

| Agricultural system | Inhibitor | Effect of nitrification inhibitor (NI) | | | | Overall NI effect on $N_2O$ emission | |
|---|---|---|---|---|---|---|---|
| | | Direct $N_2O$ emission | | $NH_3$ volatilization | | (kg N $ha^{-1}$) (I + II × $EF_4$) | |
| | | % | Amount (kg N $ha^{-1}$) (I) | % | Amount (kg N $ha^{-1}$) (II) | $EF_4$ = 1% | $EF_4$ = 5% |
| **Cropping** | N-serve | –49.9 | –0.57 | +64.9 | +12.75 | –0.44 | +0.07 |
| **Cropping** | N-serve | –19.2 | –0.27 | +37.5 | +15.80 | –0.11 | +0.52 |
| **Cropping** | DCD | –20.4 | –0.79 | –3.7 | –0.40 | –0.79 | –0.81 |
| **Cropping** | DCD | –52.3 | –1.36 | +3.1 | +0.35 | –1.35 | –1.34 |
| **Cropping; pasture** | DCD | –46.5 | –0.52 | +6.1 | +2.20 | –0.50 | –0.41 |
| **Cropping; pasture** | DCD | –28.7 | –0.48 | +5.4 | +0.15 | –0.48 | –0.47 |
| **Pasture** | DCD | –56.8 | –1.24 | –0.8 | –0.97 | –1.25 | –1.29 |
| **Pasture** | PD | –10.6 | –0.23 | +4.0 | +4.87 | –0.18 | +0.01 |
| **Pasture** | DCD | –30.1 | –0.38 | +7.7 | +2.55 | –0.36 | –0.26 |
| **Pasture** | DCD | –42.1 | –2.93 | +35.5 | +18.65 | –2.74 | –2.00 |
| **Pasture** | DCD | –40.5 | –2.15 | +13.3 | +13.87 | –2.01 | –1.46 |
| **Pasture** | DCD | –37.1 | –4.47 | +43.4 | +12.60 | –4.34 | –3.84 |
| **Pasture** | DCD | –46.8 | –4.33 | +18.2 | +8.00 | –4.25 | –3.93 |
| **Pasture** | DCD | –38.6 | –4.40 | +9.1 | +2.00 | –4.38 | –4.30 |
| **Pasture** | DCD | –20.0 | –0.30 | +17.2 | +8.60 | –0.21 | +0.13 |
| **Pasture** | DMPP | –7.9 | –0.18 | +13.9 | +1.80 | –0.16 | –0.09 |
| **Pasture** | DMPP | –8.8 | –0.39 | –51.7 | –0.15 | –0.39 | –0.40 |
| **Pasture** | DMPP | –29.1 | –4.51 | +42.0 | +3.16 | –4.48 | –4.35 |

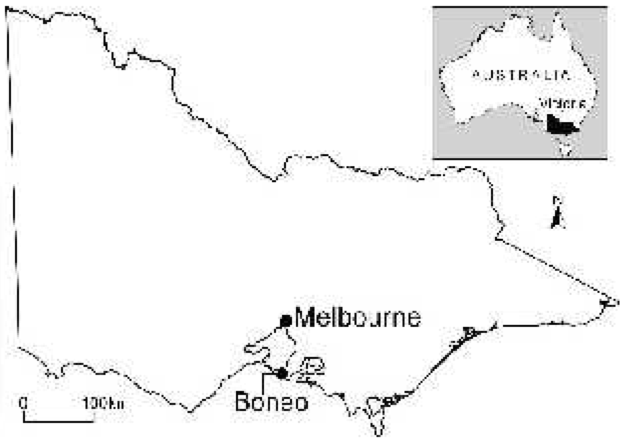
Lam et al. 2016, *Global Change Biology*

# Knowledge gap

- No study on vegetable production systems (intensive N input)
- Chamber techniques for $N_2O$ (closed) and $NH_3$ (open) emissions were widely used

# Case study—vegetable farm

- The National Agricultural Nitrous Oxide Research Program (NANORP) in Australia
- Vegetable production system
  - Boneo, Victoria
  - Chicken manure with and without 3,4-dimethylpyrazole phosphate (DMPP)
  - 255 kg N ha$^{-1}$ as manure; 39 kg N ha$^{-1}$ Nitrophoska® x 5

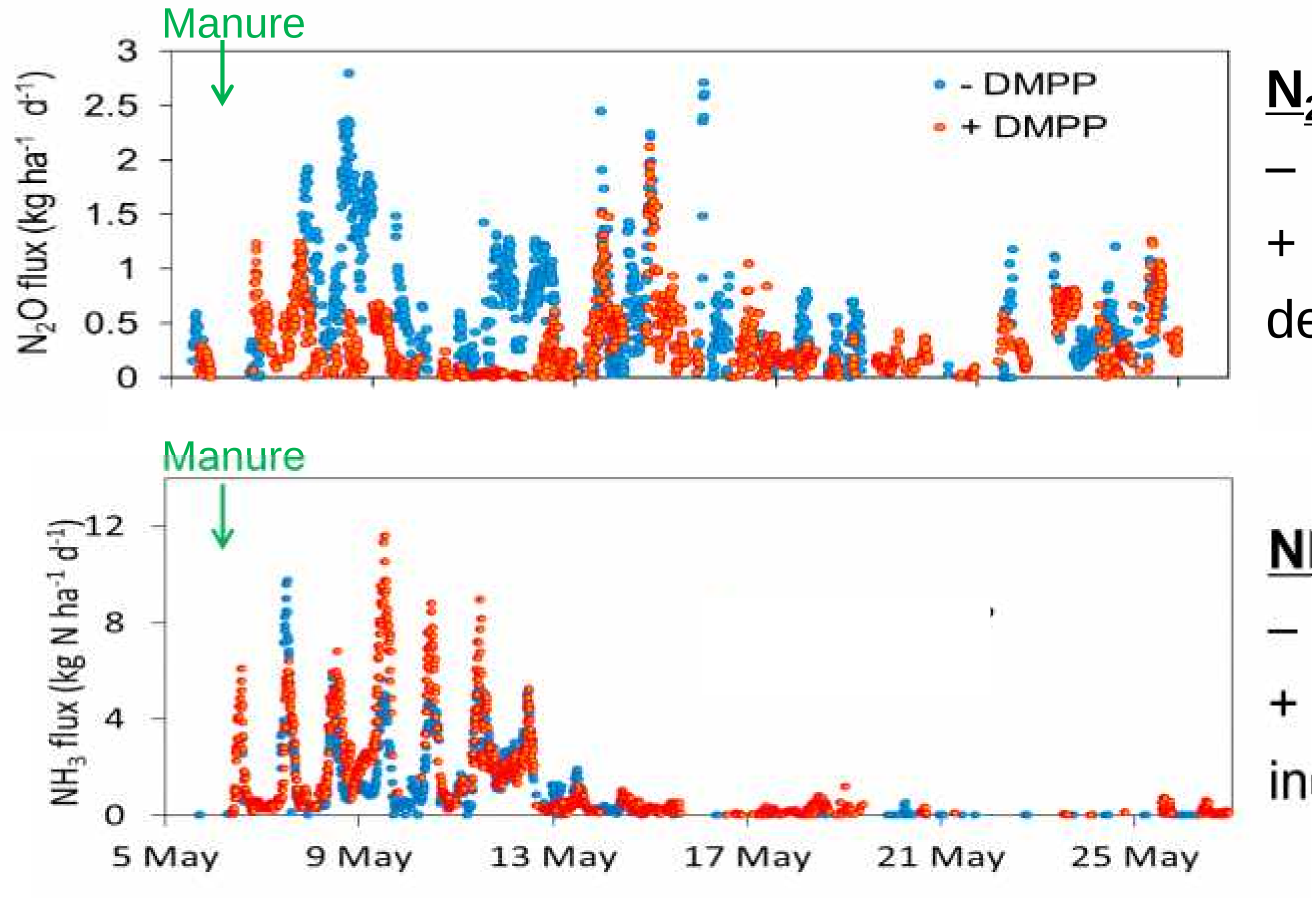


# Micrometeorological methods

NH$_3$ and N$_2$O measurements

- open-path Fourier transform infrared (FTIR) spectroscopy
- paddock-scale (4 ha); continuous; non-intrusive

# DMPP effect on $NH_3$ and $N_2O$ emission




**$N_2O$**

– DMPP: 5.7 kg N $ha^{-1}$

+ DMPP: 3.6 kg N $ha^{-1}$

decreased by 37%

**$NH_3$**

– DMPP: 12.4 kg N $ha^{-1}$

+ DMPP: 17.2 kg N $ha^{-1}$

increased by 39%

THE UNIVERSITY OF MELBOURNE

# Summary

- Nitrification inhibitors effectively decrease $N_2O$ emission.
- This beneficial effect can be weakened or even reversed by the increase in indirect $N_2O$ emission from deposited $NH_3$.
- The inclusion of indirect $N_2O$ emission is critical for evaluating the effectiveness of nitrification inhibitors in mitigating greenhouse gas emissions from agriculture.

# Recommendations

- Appropriate $NH_3$ mitigation measures should be taken where nitrification inhibitors are used:
  - double inhibitor (combining nitrification and urease inhibitors)
  - $NH_4^+$ based N input: substances with a high affinity for binding onto $NH_4^+$ ions e.g., zeolite and lignite
  - where practical, manure/fertilizers should be incorporated into soil

# Acknowledgements

**Funding bodies**

**Australian Government Department of Agriculture**

**Incitec Pivot Fertilisers**

**Landholder**

**Lamattina, Australia**

**Field and laboratory assistance**

**Trevor Coates, Sima Mazaherinia, Eric Ireland, Rifaath Hussain, Muhammad Shakir**