Dual effects of nitrification inhibitors on N$_2$O 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
• N₂O: a greenhouse gas approximately 300 times more potent than CO₂

• Global agriculture contributes around 60% of total anthropogenic N₂O emission (Ciais et al. 2013).

• Nitrification inhibitors are recommended by the IPCC as a potential mitigation option for agricultural N₂O emission.

• Nitrification inhibitors: NH₄⁺ ⇌ NO₃⁻
Nitrification inhibitors decrease $\text{N}_2\text{O}$ emission by 31–48% across diverse agricultural ecosystems.

However the inhibitors prolong the retention of $\text{NH}_4^+$ in soil, and increase $\text{NH}_3$ emission by 20–40% (meta analyses by Akiyama et al., 2010; Qiao et al., 2015)

$\text{NH}_3$ deposition:
- a major threat to environmental quality and ecosystem biodiversity (Erisman et al. 2008)
- indirectly contributes to $\text{N}_2\text{O}$ emission (van der Gon & Bleeker 2005)
• Previous meta-analyses
  – included studies focussed on either N₂O or NH₃
  – expressed the effect as % change, not absolute difference in nitrogen

• No review on studies that simultaneously measure N₂O and NH₃ emissions in the field under the treatment of nitrification inhibitors
Methodology

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

- IPCC emission factor EF$_4$ (indirect N$_2$O emission from NH$_3$ volatilization and deposition):
  - Default: 1%
  - Upper range: 5%
<table>
<thead>
<tr>
<th>Agricultural system</th>
<th>Inhibitor</th>
<th>Direct N\textsubscript{2}O emission</th>
<th>NH\textsubscript{3} volatilization</th>
<th>Overall NI effect on N\textsubscript{2}O emission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>%</td>
<td>Amount (kg N ha\textsuperscript{-1}) (I)</td>
<td>%</td>
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<tr>
<td>Cropping</td>
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<td>–49.9</td>
<td>–0.57</td>
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<td>–0.79</td>
<td>–3.7</td>
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<tr>
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<td>–52.3</td>
<td>–1.36</td>
<td>+3.1</td>
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<tr>
<td>Cropping; pasture</td>
<td>DCD</td>
<td>–46.5</td>
<td>–0.52</td>
<td>+6.1</td>
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<tr>
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<td>–10.6</td>
<td>–0.23</td>
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<tr>
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<td>–1.24</td>
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<tr>
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<td>–2.93</td>
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<td>DMPP</td>
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<td>–4.51</td>
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</table>

Lam et al. 2016, *Global Change Biology*
Knowledge gap

- No study on vegetable production systems (intensive N input)
- Chamber techniques for \( \text{N}_2\text{O} \) (closed) and \( \text{NH}_3 \) (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

NH₃ and N₂O measurements

- open-path Fourier transform infrared (FTIR) spectroscopy
- paddock-scale (4 ha); continuous; non-intrusive
DMPP effect on NH₃ and N₂O emission

**N₂O**
- DMPP: 5.7 kg N ha⁻¹
- + DMPP: 3.6 kg N ha⁻¹
decreased by 37%

**NH₃**
- DMPP: 12.4 kg N ha⁻¹
- + DMPP: 17.2 kg N ha⁻¹
increased by 39%
Nitrification inhibitors effectively decrease N$_2$O emission.

This beneficial effect can be weakened or even reversed by the increase in indirect N$_2$O emission from deposited NH$_3$.

The inclusion of indirect N$_2$O 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
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