Understanding the variability in performance of the nitrification inhibitor 3,4-Dimethylpyrazole phosphate in Australian agricultural soils.

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Role of Nitrification Inhibitors

Nitrification Inhibitor

Ammonia monooxygenase (Amo) enzyme

NH$_4^+$, NH$_3$

X

NO$_2^-$

NO$_3^-$

Nitrate

Nitrification (aerobic)

Leaching loss

Denitrification (anaerobic)

Nitrous oxide

N$_2$, N$_2$O

Nitrification Inhibitors

Ammonium

Nitrate

Denitrification

Leaching loss
Background: Why Focus on Nitrification inhibitors?

- Reduce N₂O emissions
- Reduce nitrate leaching
- Improve nitrogen use efficiency

Australia's National GHG inventory (2014) (total CO₂-e)

93% = agricultural soils
= 18% of agricultural emissions

Fertiliser inputs significant contributor to N₂O
Background: Why Focus on 3,4-Dimethylpyrazole phosphate?

- Commercially available in Australia
- Potential for use across broad range of climates

BUT

- Inconsistent results observed
- Reasons for this are unclear

3,4-Dimethylpyrazole phosphate
How to address this? Experimental Methodology

- Laboratory Incubation experiment
- 30 soils, < 2 mm
- Treatments
  - Control (no N)
  - Fertiliser (NH$_4^+$-N)
  - Fertiliser + DMPP

- 100 μg NH$_4^+$-N / g soil + 50 μg NO$_3^-$-N / g soil
- 25°C, 60% WFPS, 28 days,
- Mineral N (2 M KCl 1:5) and N$_2$O collected
Results: Nitrification rate

Example of mineral N dynamic

Horsham soil (cropping): 23% clay, 34% silt, 44% sand, pHw 8.5, OC 0.82%, N 0.08%
## Results: Nitrification rate

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Range</th>
<th>Average ± standard error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>-4.61-26.89</td>
<td>1.37±0.99&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>1.33-25.45</td>
<td>6.47±0.93&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMPP</td>
<td>-0.43-22.02</td>
<td>4.00±0.78&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

### Average net-nitrification rate (14 days)

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</thead>
<tbody>
<tr>
<td>Fertiliser</td>
<td>-1.44-12.63</td>
<td>4.82±0.55&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMPP</td>
<td>-4.86-8.02</td>
<td>2.39±0.45&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- Addition of fertiliser increases nitrification rate
- DMPP nitrification rate = control (no fertiliser)
- **Average 38% reduction in fertiliser induced nitrification rate with DMPP (range 9-100%)**
Results: Soil properties and DMPP efficacy to reduce nitrification

$f_{\text{Vnit}_{\text{max}}}$: fraction of nitrification achieved with DMPP relative to the fertiliser only treatment

Other soil properties

- Clay (-ive) \((P<0.05)\)
- Mn (-ive) \((P<0.1)\)
- DTPA Cu (+ive) \((P<0.01)\)

\(R^2 = 0.282\)

\(P<0.01)\)
Results: \( \text{N}_2\text{O} \) emissions

Example of \( \text{N}_2\text{O} \) emission

Horsham soil (cropping): 23% clay, 34% silt, 44% sand, pHw 8.5, OC 0.82%, N 0.08%
### Results: N₂O emissions

#### Cumulative N₂O emissions (28 days)

(µg N₂O-N/g soil)

<table>
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<tr>
<th>Treatment</th>
<th>range</th>
<th>Average ± standard error</th>
<th>Log₁₀</th>
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<tbody>
<tr>
<td>Control</td>
<td>0.01-1.1</td>
<td>0.06±0.30</td>
<td>-1.20±0.64&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Fertiliser</td>
<td>0.07-7.74</td>
<td>0.62±0.28</td>
<td>-0.59±0.45&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMPP</td>
<td>0.01-6.96</td>
<td>0.49±0.26</td>
<td>-0.92±0.64&lt;sup&gt;ab&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

#### Cumulative Net-N₂O emissions (28 days)

(µg N₂O-N/g soil)

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<tr>
<td>Fertiliser</td>
<td>-0.10-9.54</td>
<td>0.71±0.39</td>
<td>-0.57±0.48&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>DMPP</td>
<td>-0.01-10.75</td>
<td>0.52±0.35</td>
<td>-1.17±0.78&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

- Addition of fertiliser increases N₂O emissions
- DMPP nitrification rate = control (no fertiliser)
- **Average 55% reduction in fertiliser induced N₂O emissions with DMPP (range 0-100%)**
Results: Soil properties and DMPP efficacy in reducing $\text{N}_2\text{O}$ emissions

Other soil properties
- Mn (+ive) $(P<0.05)$
- DTPA Zn (+ive) $(P<0.05)$
- DTPA Fe (-ive) $(P<0.01)$

$R^2 = 0.2696$  
$(P<0.01)$
Conclusions on DMPP efficacy and soil properties

- Effective tool for reducing nitrification and N$_2$O emissions across Australian agricultural soils
- High range of responses
- OM significantly (P<0.01) affected the DMPP inhibition of nitrification
- pH significantly (P<0.01) affected the DMPP inhibition of N$_2$O emissions
- Further investigation of the importance of properties other than organic matter and pH, and the role of soil trace elements and metals for their interactions with the inhibitor.
- The significant of the soil microbial community requires investigation
  - e.g. Bacterial versus archaeal responses