The effect of nitrification inhibitors on wheat crop performance on coarse-grained soils in Mediterranean environments

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Outline

• Role of nitrification inhibitors (NIs) in agriculture.

• Aims and objectives.
• Study design.

• Laboratory Studies.
• Glasshouse pot trials.
• Field trials.

• Conclusions & future work.

• Acknowledgements.
• Questions.
Role of nitrification inhibitors in agriculture

• N fertilisers essential aspect of modern agriculture.
• For most crops accumulation of N is inefficient <50%.
• N losses detrimental – environmentally & economically.

• Nitrification inhibitors (NI) (e.g. DMPP, DCD, Nitrapyrin) means to limit N losses.
• Inhibits AMO enzyme in ammonia oxidising microorganisms (bacteria & archaea).
• Stops conversion of $\text{NH}_4^+ \rightarrow \text{NO}_2^-$. 
• $\text{NH}_4^+$ less mobile than $\text{NO}_3^-$ → retained in soil.
• Use in agriculture remains uncertain.
Aims and objectives

• GRDC funded project.
• Improving nitrogen use efficiency (NUE) in the Western Australian (WA) wheatbelt.
• Is there a role for NIs in these cropping systems?
• How do NIs influence ammonia oxidiser populations?
• Why WA wheatbelt?

• Provides ≈50% of Australia’s wheat crop (+ considerable canola & barley).
• Mediterranean climate (cool, wet winters → hot, dry summers, 350-500 mm annual rainfall).
• Predominantly coarse-grained soils (deep sands or sand/clay duplex).
• Low organic C (≈1%), acidic (pH 4-6).
Laboratory Incubations

2 Wheatbelt soils

Tenosol
pH = 5.4
Org C = 2.2%
Sand = 85%

Hydrosol
pH = 4.0
Org C = 3.0%
Sand = 90%

4 fertiliser treatments
(100 mg N kg\(^{-1}\) soil)

Laboratory Incubation
(20 °C, 100% field capacity, 100 days)

N species, PNR, AOA/AOB abundances measured
Laboratory soil incubations

Available NH4+ (mg N kg⁻¹ soil)

Day of Incubation

Urea
Urea + DCD
Urea + DMPP
Urea + NPY

PNR (mg NO₃⁻ kg⁻¹ soil h⁻¹)

Day of Incubation

AOB abundance (gene copies g⁻¹ soil)

Day of Incubation

AOA abundance (gene copies g⁻¹ soil)

Day of Incubation
Glasshouse pot trials

2 Wheatbelt soils

- Tenosol
  - pH = 4.8
  - Org C = 1.3%
  - Sand = 78%

- Hydrosol
  - pH = 4.0
  - Org C = 3.0%
  - Sand = 90%

3 N fertilisers - Urea, DMPP, DCD
2 rates (50 & 150 mg N kg⁻¹ soil)

Wheat - *Triticum aestivum* cv. Mace

Grain yield, protein (%) and NUE determined
Glasshouse pot trials

Soil NH$_4^+$ (mg N kg$^{-1}$ soil) over Days after sowing (DAS):
- Urea
- Urea + DCD
- ENTEC Urea (DMPP)

AOB Abundance (gene copies g$^{-1}$ soil) over Days after sowing (DAS):
- Urea
- Urea + DCD
- ENTEC Urea (DMPP)

Grain yield (g plant) for different fertiliser treatments:
- Urea
- Urea + DCD
- ENTEC Urea

Grain Protein (%) for different fertiliser treatments:
- Urea
- Urea + DCD
- ENTEC Urea

Fertiliser Treatment:
- Unfertilised
- 50 mg N kg$^{-1}$
- 150 mg N kg$^{-1}$
Field Trials

6 field trials

Wongan
Tenosol
pH = 5.7
Org C \approx 1.1\%
Sand = 70%

Cunderdin
Sodosol
pH = 6.0
Org C \approx 1.1\%
Sand = 80%

Merredin
Chromosol
pH \approx 4.5
Org C \approx 0.5\%
Sand = 70%

Triticum aestivum cv. Mace – 80 kg ha\(^{-1}\)

2 N fertilisers - Urea, DMPP,
2 rates (30 & 60 kg N ha\(^{-1}\))
Split vs Upfront application
Field Trials – N conservation

![Graph showing N conservation over days for different treatments.](image)

- **PNR (mg NO$_3^-$ kg$^{-1}$ soil hr$^{-1}$)**
  - ON
  - 30N
  - 60N
  - 30N ENTEC
  - 60N ENTEC
  - 60N ENTEC UPFRONT

- **Soil NH$_4^+$ (mg N kg$^{-1}$ soil)**
  - ON
  - 30N
  - 60N
  - 30N ENTEC
  - 60N ENTEC
  - 60N ENTEC UPFRONT

- **% of $^{15}$N label in organic N pool**
  - Urea ENTEC
  - Urea ENTEC
  - Urea ENTEC
  - Urea ENTEC
  - CUN
  - SP
Field Trials – AO abundances

AOB abundance (gene copies g⁻¹ soil)

Day

0.0E+00 2.0E+07 4.0E+07 6.0E+07 8.0E+07

0 50 100 150 200

AOA abundance (gene copies g⁻¹ soil)

Day

0.0E+00 2.0E+07 4.0E+07 6.0E+07 8.0E+07

0 50 100 150 200

0 N AOB

60 N Urea AOB

60 N ENTEC AOB
Field Trials - Crop performance

![Graph showing grain yield benefit (kg ha⁻¹) for different trials and nitrogen applications.](image)
Conclusions
Future work

Wongan Hills 1
<100 kg ha\(^{-1}\) yield benefit

Wongan Hills 2
> 400 kg ha\(^{-1}\) yield benefit
Acknowledgements

• GRDC (CSA00032)
• Kelley Whisson & Karen Treble – CSIRO Agriculture and Food.
• Anna Simonsen – CSIRO Land and Water.
• Shari Dougall – DAFWA Wongan Hills.
• Glen Reithmuller & Greg Shea – DAFWA Merredin.
• Dr David Minkey – WANTFA.
• Michael Blair & Rohan Hungerford – UWA.
• Richard Phillips & Liam Thammavongsa – CSIRO Agriculture and Food.
• Charlie Walker – Incitec Pivot.