Legumes in crop rotations reduce nitrous oxide emissions, compared to fertilized non-legume rotations

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Soil nitrous oxide ($\text{N}_2\text{O}$) emissions . . .

- $\text{N}_2\text{O}$ comes from natural processes in the soil
  - nitrification and denitrification

- What matters is the extra nitrogen that humans add to soil
  - Fertiliser
  - Legume $\text{N}_2$-fixation by rhizobia

- Emission Factor (EF) = \( \frac{\text{N emission}}{\text{N input}} \times 100\% \)
  - 0.3\% of fertiliser N for Australian dryland cereal crops
  - 1.0\% of legume N for Australian dryland pulses
Australia’s northern grains region

Northern grains region:
• 4 M ha cropping
• 7 M tonnes grain/yr
• winter & summer crops
• 500-800 mm AAR
• cracking clay soils

Tamworth; N₂O emissions Trial site
Our Project Objectives

- **Compare soil N$_2$O emissions during various crops**
  - *canola, chickpea, wheat, sorghum, barley*

- **Compare soil N$_2$O emissions across crop rotations**
  - *canola-wheat-barley*
  - *chickpea-wheat-barley*
  - *chickpea-wheat-chickpea*
  - *chickpea-sorghum*

- **Derive soil N$_2$O emissions factors for legume/fertiliser N**
  - *chickpea (+ fababean and fieldpea in separate experiment)*
  - *non-legume crops (canola, wheat, barley, sorghum)*
Project Methods

- Treatments were crop rotations (dryland)

<table>
<thead>
<tr>
<th>Year</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>canola+N</td>
<td>wheat+N</td>
<td>barley+N</td>
</tr>
<tr>
<td></td>
<td>chickpea</td>
<td>wheat</td>
<td>chickpea</td>
</tr>
<tr>
<td></td>
<td>chickpea</td>
<td>wheat+N</td>
<td>barley</td>
</tr>
<tr>
<td></td>
<td>chickpea</td>
<td>sorghum+N</td>
<td></td>
</tr>
</tbody>
</table>

(+N = urea fertiliser applied at sowing)

- 3 replications
- Zero-till, stubble-retained, chemical weed and disease control
- Plots were 12 m x 6 m
- Automatic air-sampling chambers (50 cm x 50 cm x 20 cm)
  - Air samples analysed in-field 7-8 times/day for N₂O, CH₄ & CO₂
- Legume N₂-fixation input measured by ¹⁵N natural abundance
2009 ~ Air sample chambers in chickpea and canola
2010 ~ Air sample chambers in newly sown wheat and winter fallow plots
Gas chromatograph inside field lab
2010 ~ Air sample chambers in wheat and newly sown sorghum
2011 ~ Sorghum ready for harvest, chamber in wheat fallow
Barley (no N)
Fallow
Chickpea
Barley (+ N)

2011 ~ Air sample chambers in barley, chickpea and fallow
Nitrogen inputs

- Urea mid-row banded at sowing;
  - canola (80 kg N/ha), wheat (80 kg N/ha), sorghum (40 kg N/ha), and barley (60 kg N/ha)

- Chickpea $N_2$-fixation (via $^{15}N$ natural abundance)
  - 2009
    - 18% Ndfa = 49 kg N/ha fixed from air
    - low in comparison to 41% Australian average
  - 2011
    - 37% Ndfa = 41 kg N/ha fixed from air
    - low plant biomass due to dry winter
Large emissions in-crop occurred when soils were saturated soon after fertiliser N applied.
Cumulative N\textsubscript{2}O emissions

Cumulative N\textsubscript{2}O emissions (g N/ha)

- Canola+N
- Wheat+N
- Barley+N
- Chickpea
- Sorghum+N
- Barley
- Chickpea

- Wheat Sowing
- Sorghum Sowing
- Wheat Harvest
- Barley & Chickpea Sowing
- Barley & Chickpea Harvest

Daily rainfall (mm)

Large emissions in fallow occurred in saturated soils of plots after an N-rich crop had decomposed.
## Emission factors (by crop)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Total N added (kg N/ha)</th>
<th>N₂O Emission Factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>(during crop growth)</td>
<td>(over 1 year)</td>
</tr>
<tr>
<td>Canola</td>
<td>80</td>
<td>0.37</td>
</tr>
<tr>
<td>Chickpea (2009)</td>
<td>49</td>
<td>0.06</td>
</tr>
<tr>
<td>Wheat (after canola)</td>
<td>80</td>
<td>0.51</td>
</tr>
<tr>
<td>Wheat (after chickpea)</td>
<td>80</td>
<td>0.39</td>
</tr>
<tr>
<td>Sorghum</td>
<td>40</td>
<td>0.92</td>
</tr>
<tr>
<td>Barley</td>
<td>60</td>
<td>0.07</td>
</tr>
<tr>
<td>Chickpea (2011)</td>
<td>41</td>
<td>0.25</td>
</tr>
</tbody>
</table>
## Emission factors (by rotation)

<table>
<thead>
<tr>
<th>Crop rotation</th>
<th>Total N added (kg N/ha)</th>
<th>Total N(_2)O-N emitted (g N/ha)*</th>
<th>N(_2)O Emission Factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>canola+N_wheat+N_barley+N</td>
<td>80 + 80 + 60</td>
<td>1523</td>
<td>0.69</td>
</tr>
<tr>
<td>chickpea_wheat+N_barley</td>
<td>49 + 80 + 0</td>
<td>885</td>
<td>0.69</td>
</tr>
<tr>
<td>chickpea_wheat_chickpea</td>
<td>49 + 0 + 41</td>
<td>614</td>
<td>0.68</td>
</tr>
<tr>
<td>chickpea_sorghum+N_</td>
<td>49 + 40</td>
<td>1028</td>
<td>1.16</td>
</tr>
</tbody>
</table>

* not corrected for background emission
A lifecycle analysis of the first 2-year rotations . . .

- most greenhouse gas emissions were due to fertiliser N
- N₂O emitted directly from the soil accounted for up to 45% of total greenhouse gas emissions
- The remainder was associated with N fertiliser production, transport and application, and urea hydrolysis
Conclusions

- N$_2$O emissions during legume growth were very low.

- In-crop N$_2$O emissions during growth of fertilised crops can be significant if soil is saturated soon after fertiliser is applied.

- N$_2$O emissions during post-harvest fallow can be significant if soil is saturated after residue decomposition of N-rich crops (chickpea, canola).

- Over a multi-year crop rotation, legumes reduced total N$_2$O emissions and total greenhouse gas emissions, but the loss as a proportion of N input was similar to N fertiliser.
Thank you!