Crop N & P demand under Climate Change

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acknowledgements to:
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ANZFIC, Coolum Beach, Queensland, October 2013.
Outline

• Climate change and crop responses
• Impact on plant demand
• Impact on soil supply
• Reviewing the 4Rs for future management.

• Overlay of
  – Increased demand for food
  – Need for higher resource use efficiency
  – Resource pricing and demand
  – Changing soil nutrient status
  – Government policy
Global CO$_2$ emissions and projections

Carbon dioxide + nitrous oxide + methane = GHG
CO$_2$ drives plant growth & yield (C3 plants)

- Photosynthesis – takes in carbon dioxide, gives out oxygen.
- Transpiration – to get CO$_2$, the plant has to open its leaf pores which lets out water.
- So – higher CO$_2$ = better

- NO PROBLEM
Impacts of increased CO$_2$ from other experiments

- Ainsworth & Long 2005 New Phytologist
BUT
Projected climate – 2050 - A1B - Australia

Elevated CO₂ improves photosynthesis and plant water use efficiency, but, high temperature and lower rain fall have a negative impact on crop growth and productivity in most parts of Australia.
Australian Grains Free Air Carbon Dioxide Enrichment Facility (AGFACE)

- Located at Horsham in southeastern Australia – 36°S.
- Aim to answer the fundamental question of how the supply of N and water interact with higher temperatures under elevated CO$_2$ in relatively low yield potential situations i.e. 1 to 4 t/ha.

Experimental Treatments –
- FACE CO$_2$ – ambient (~380 ppm) & 550 ppm
- Water – rainfed & irrigated (+50 mm)
- Sowing time – early sown (June 18) & late sown (August 22)
- Generates +5°C during flowering
- Nitrogen – low and supplemented
- Managed in response to water supply (Yitpi only)
- Cultivar – Yitpi and Janz

4 replicates
Each ring 12 m
16 m in 2009 et seq.
Spread over 5 ha site

Mean Temperature for the 15 days after anthesis

Seasonal Water Supply (Rain + Supplements)

Mean effects of eCO₂ 2007-2009

Very few interactions with eCO₂ were significant.

(a) Grain N removal

- C₃ non-legume
- Legume
- C₄

Effect of elevated [CO₂] (%)

+20% N removal under eCO₂
Implication – N demand

• 20% increase in N demand – irrespective of temperature and rainfall changes
  – REVIEW THE RIGHT RATE

• Most increase is after stem elongation (temperature).
  – REVIEW THE RIGHT TIME/RATE – MORE LATER?

• The protein content decline occurs with bigger yield stimulation – changes in N metabolism
  – Down-regulation of photosynthetic proteins
  – Lower protein/N content in leaves
  – Less N for remobilization to grain.
  – LATE FOLIAR N (HIGH EFFICIENCY)
  – NEW MORE INTERNALLY N-EFFICIENT WHEAT TYPES, NON-DOWNREGULATING
Yield response to eCO$_2$ – 2009-2011

Seneweera et al 2013 submitted
Grain N recovery and N source

- If N>50% NH$_4$$_4$, higher N recovery under eCO$_2$
- Under ammonium dominant supply, significant response in N recovery
  - SHIFT TO AMMONIUM BASED N-SOURCES
  - ENHANCE AMMONIUM ACCESS (eg DMPP)
Changes in protein quality with eCO₂

- Change in grain N:S ratio (Fernando et al., 2012)

<table>
<thead>
<tr>
<th>cv Yitpi</th>
<th>[CO₂]</th>
<th>Grain N (g/kg)</th>
<th>Grain S (g/kg)</th>
<th>N:S</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>aCO₂</td>
<td>26.8</td>
<td>1.75</td>
<td>15.1</td>
</tr>
<tr>
<td></td>
<td>eCO₂</td>
<td>23.5</td>
<td>1.66 ns</td>
<td>14.5</td>
</tr>
<tr>
<td>2009</td>
<td>aCO₂</td>
<td>27.2</td>
<td>1.83</td>
<td>14.9</td>
</tr>
<tr>
<td></td>
<td>eCO₂</td>
<td>23.7</td>
<td>1.65</td>
<td>14.4 ns</td>
</tr>
</tbody>
</table>

- Increase in flour yield (aCO₂ 69.5% v eCO₂ 72.3%) (Fernanado et al, 2013 JCS)

- Decrease in estimated bread volume* (aCO₂ 169 cm³ v eCO₂ 157 cm³) (Fernanado et al, 2013 JCS)
  - EBV is estimated from mixograph data.
Grain proteome response to eCO$_2$

**Green = > 1.5 Fold Up-regulated in Control (4 spots)**

**Pink = > 1.5 Fold Down-regulated in Control (10 spots)**

<table>
<thead>
<tr>
<th>Spot ID</th>
<th>Protein Name</th>
<th>Protein coverage</th>
<th>Fold change</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i). Up-regulated proteins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>61</td>
<td>Serpin-Z1C</td>
<td>29%</td>
<td>&gt;1.7</td>
</tr>
<tr>
<td>66</td>
<td>1-Cys peroxiredoxin PER1</td>
<td>42%</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>63</td>
<td>Not identified</td>
<td></td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>(ii). Down-regulated proteins</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>64</td>
<td>HMW Glutenin, subunit</td>
<td>5%</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>60</td>
<td>HMW Glutenin, subunit</td>
<td>5%</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>57</td>
<td>HMW Glutenin, subunit</td>
<td>5%</td>
<td>&gt;1.6</td>
</tr>
</tbody>
</table>

The gluten protein concentration was significantly reduced (more than 20%) at elevated CO$_2$. DIGE for MALDI-TOF Mass Spectrometry
Effect on eCO$_2$ on micronutrient concentration – intraspecific variation

Fernando et al. 2013 JAFC (in review)

Wheat cultivars differentially responded to increased atmospheric [CO$_2$] in terms of grain Zn, Fe, Mn and Cu, and flour rheological properties
Three years FACE data – from 2 sites – grain quality.

Functional properties ×

Zn and Fe bioavailability ✓

Essential micronutrient ×

Essential micronutrient ×

No effect of eCO$_2$ on Vitamin E (tocopherols) (Posch et al, 2012)
Effect of eCO$_2$ on pulses/legumes
(Lam et al. 2012, CPS)

- Glasshouse experiments +/-P; aCO$_2$, eCO$_2$ – 3 species
- Legumes responded to eCO$_2$ if P was supplied.
- No differences in %Ndfa due to [CO$_2$]
- N fixed increased due to growth stimulation
- Net negative N balance in pulses irrespective,….
- Adequate P is important reducing the N deficit.

![Images of chickpea, field pea, and barrel medic plants grown under different CO$_2$ and P conditions](Fig. 1)
Conclusions about eCO$_2$ and nutrition

• Supply capacity
  – No increased efficiency of accessing N from fertilizer
  – More roots at a higher density access more soil N
  – Higher OM input but same C:N ratio
  – May lead to N immobilization – likely that N limitation will occur

• Potential for input
  – Fertilizer N rate/source/time
  – P supply at least maintained to ensure N input from legumes.
Summary

• Higher yields will demand higher input of ALL nutrients.

• Grain quality is adversely affected – intraspecific differences and alternative rate, source and timing strategies may provide hope.

• Grain micronutrient content declines may be addressed if protein does not decline.

• N demand will increase – potential for progressive N limitation – higher N rates.

• P supply for pulses/legumes will determine the severity of N limitation.
Acknowledgements

AGFACE Team:
University of Melbourne:
M Tausz, N Fernando, L Thilakarathne, S Posch, M Nicolas, S Barlow, R Lam, H Sultana, P Howie, S Seneweera.

Victorian State Department of Primary Industries (DPI):

Collaborators:
R Norton (IPNI), S Myers (Harvard Medical School), J Stangoulis (Flinders University), A Makino, (Tohoku University), J Conroy (University of Western Sydney), A. Mosier, E. Lin, X Han (CAAS)

Funding:
Australian Commonwealth Department of Agriculture, Fisheries and Forestry.
Grains Research and Development Corporation.
Victorian Department of Primary Industries.
The University of Melbourne.
International Plant Nutrition Institute.

http://www.piccc.org.au/AGFACE