IPNI
INTERNATIONAL PLANT NUTRITION INSTITUTE

Australian Government
Department of Agriculture, Fisheries and Forestry

State Government Victoria
Department of Primary Industries

THE UNIVERSITY OF MELBOURNE

GRDC
Grains Research & Development Corporation

Crop N & P demand under Climate Change

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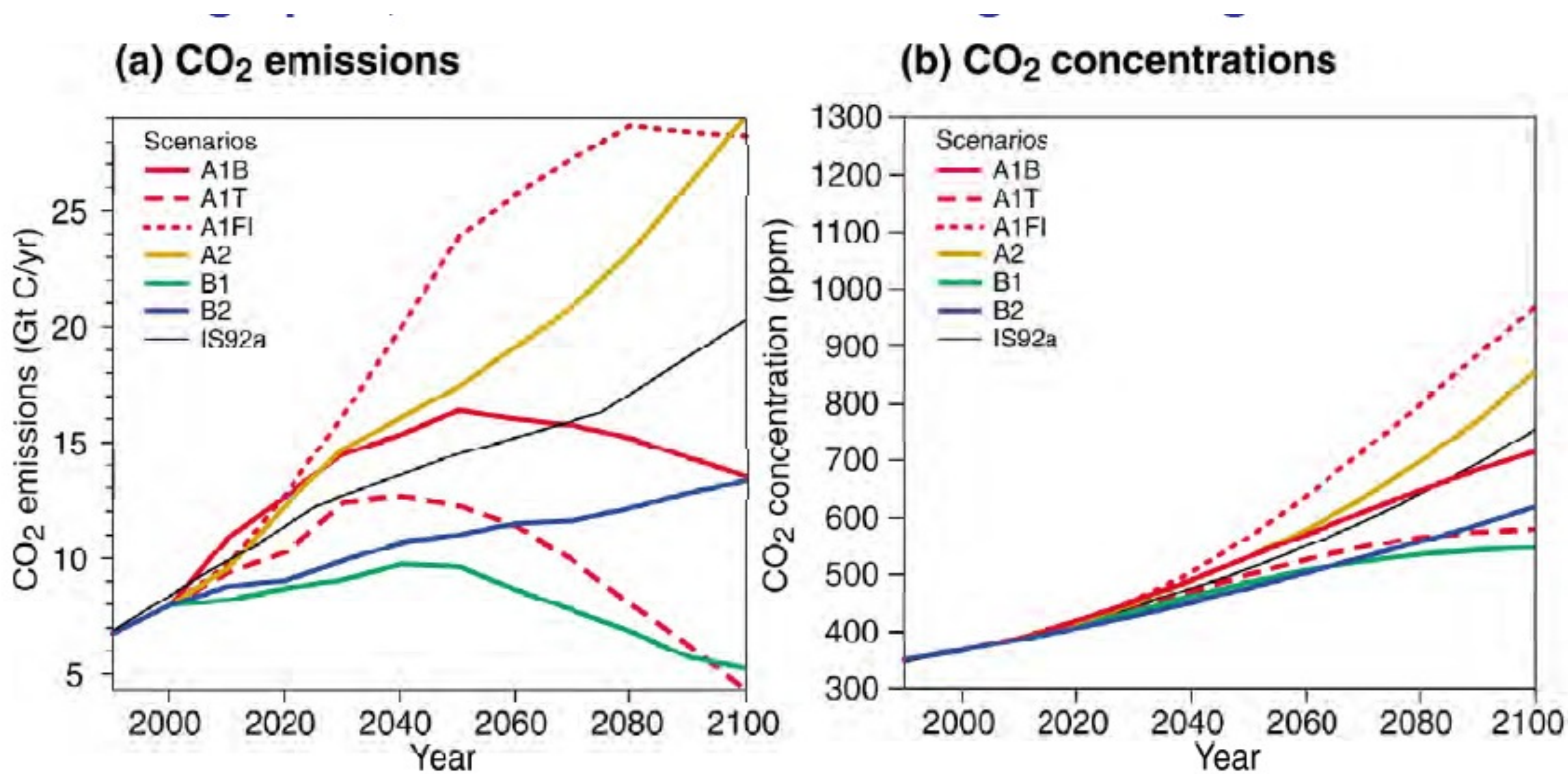
ANZFIC, Coolum Beach, Queensland, October 2013.

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

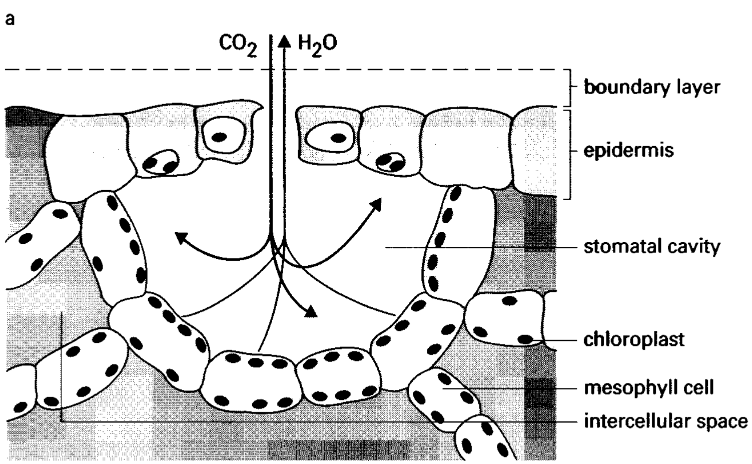
Global CO_2 emissions and projections

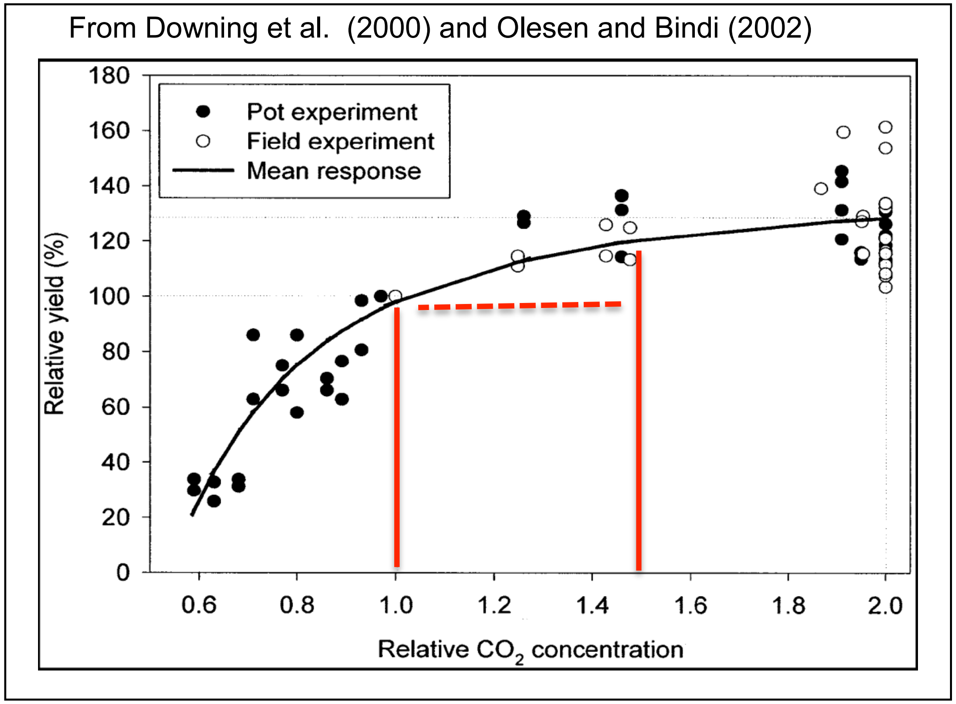


Carbon dioxide + nitrous oxide + methane = GHG

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

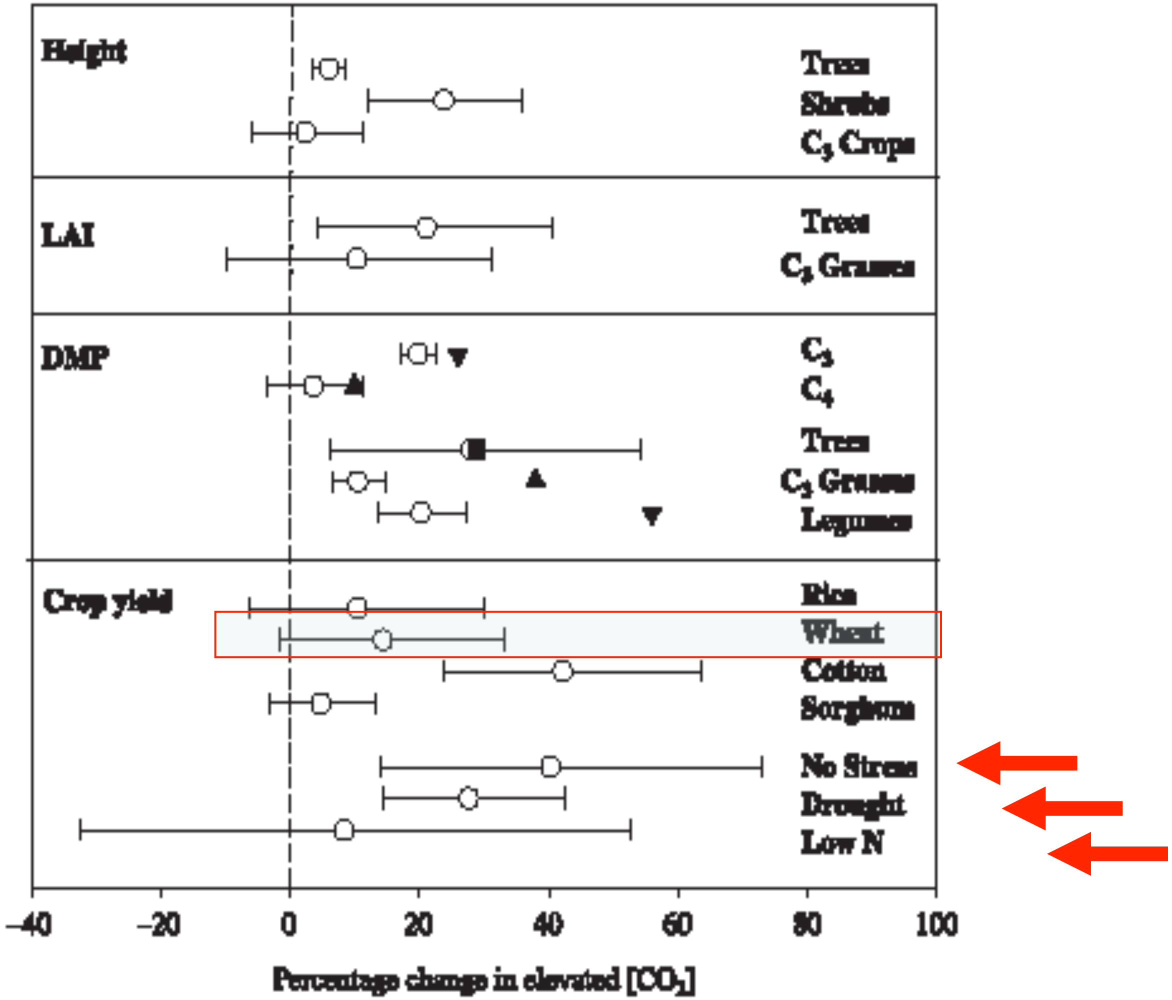


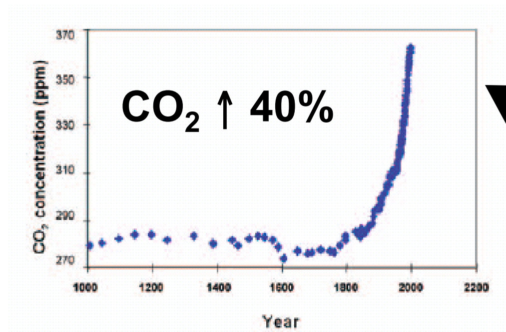
Fig. 8 Comparative responses to elevated [CO_2] of different functional groups and experimental conditions on growth and yield variables. Results from: ○, this meta-analysis; ■, a meta-analysis of tree species (Curtis & Wang, 1998); ▲, a meta-analysis of C_4 grasses (Wand *et al*., 1999). ▼, comparative results from a meta-analysis of 79 crop and wild species (Jablonski *et al*., 2002). Number of species, FACE experiments and individual observations for each response are given in Appendix 2.

- Ainsworth & Long 2005 New Phytologist

BUT

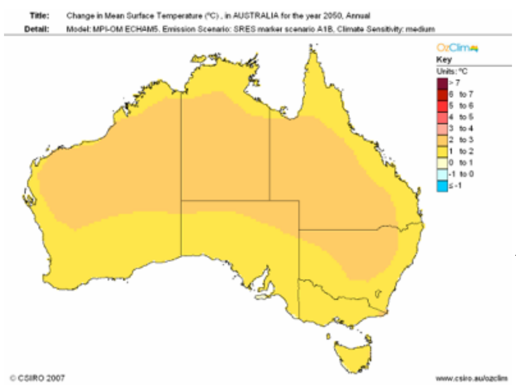
Projected climate – 2050 - A1B -Australia

CO_2

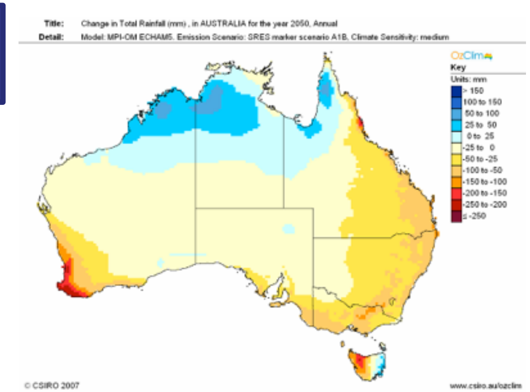


Temperature

Water



Interactions



1-2°C warmer

50mm lower

Elevated CO_2 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.

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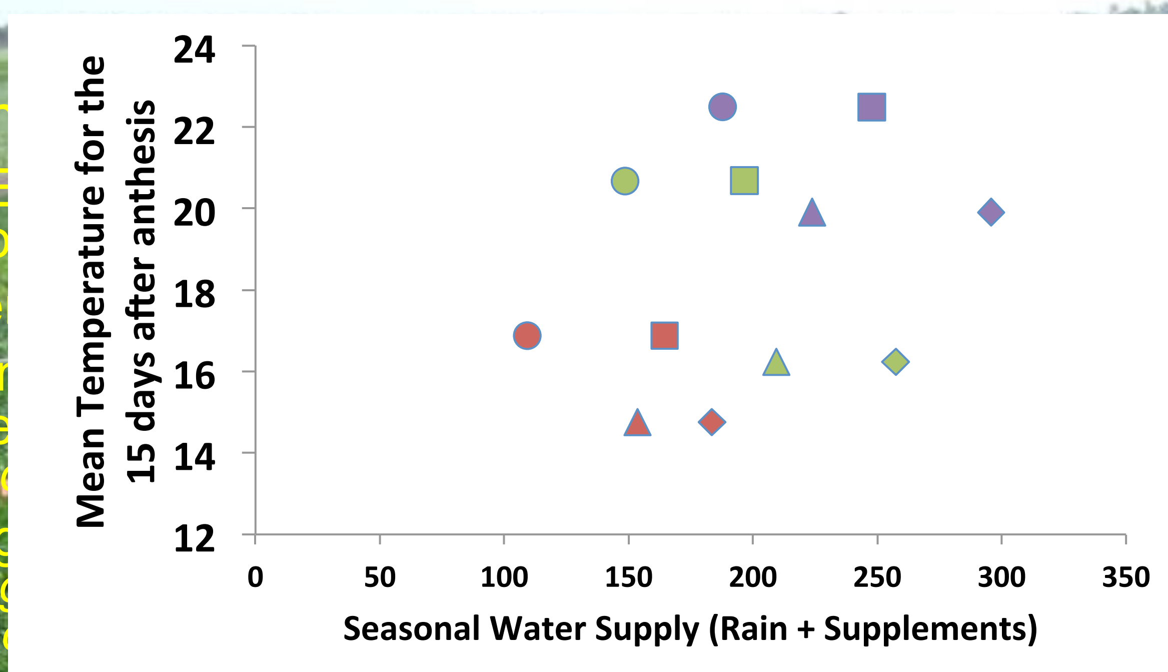
Australian Grains Free Air Carbon Dioxide Enrichment Facility (AGFACE)

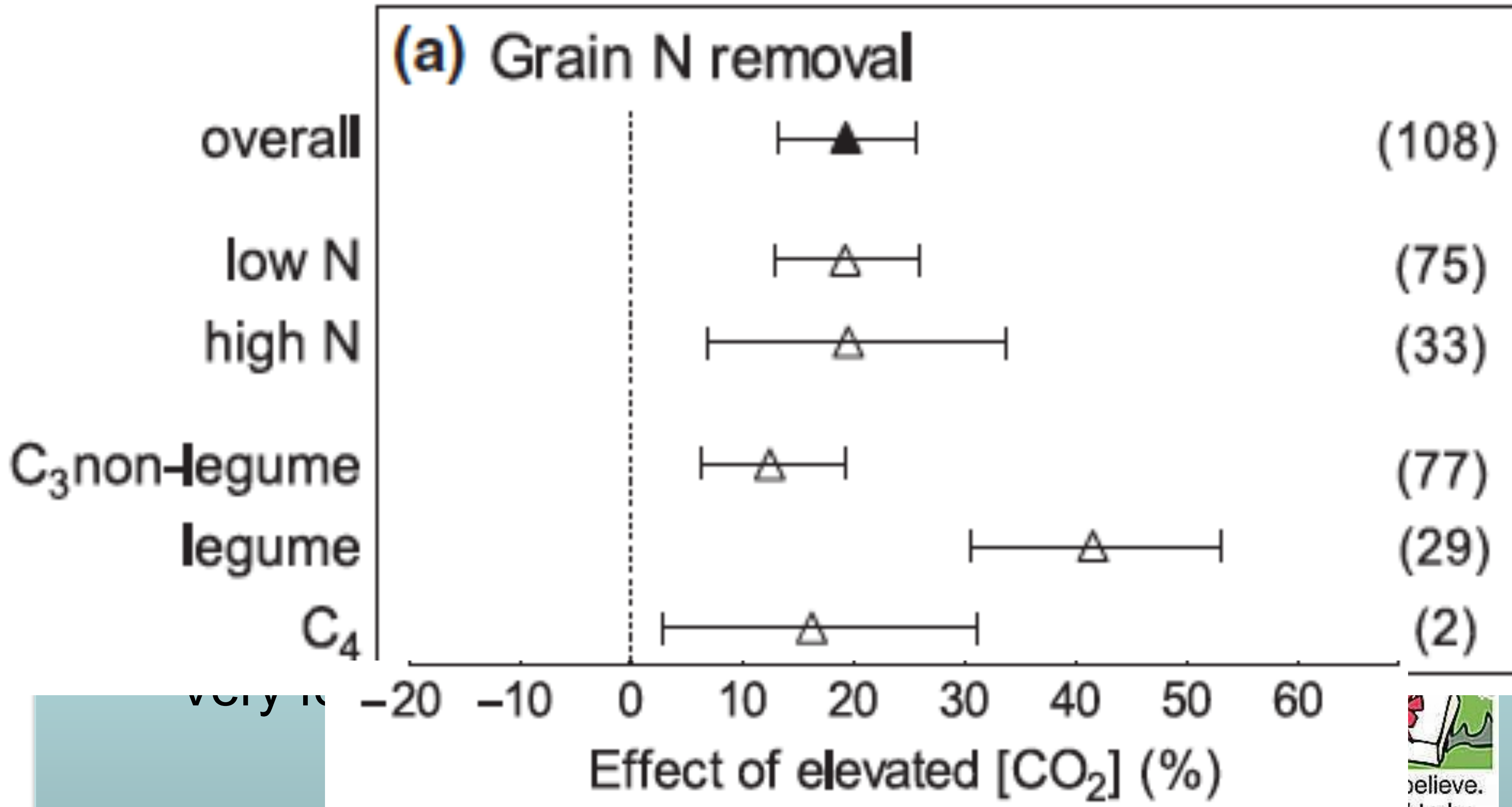
- Located at Horsham in southeastern Australia – 36°S.
- Aim to answer the fundamental question of how the supply of N and water interact with higher temperatures under elevated CO_2 in relatively low yield potential situations *ie* 1 to 4 t/ha

- Experim
  - FACE
    550 p
  - Wate
  - Sowi
    & late
    +5°C ... ates
  - Nitrog ... g 12 m
    manag ... 2009 *et seq.*
    (Yitpi ... over 5 ha site
  - **Cultivar - Yitpi and Janz**



Experimental Treatments – 2007, 2008, 2009

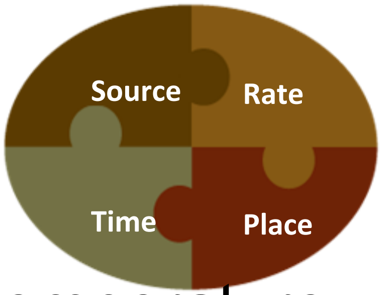
Mean effects of eCO_2 2007-2009



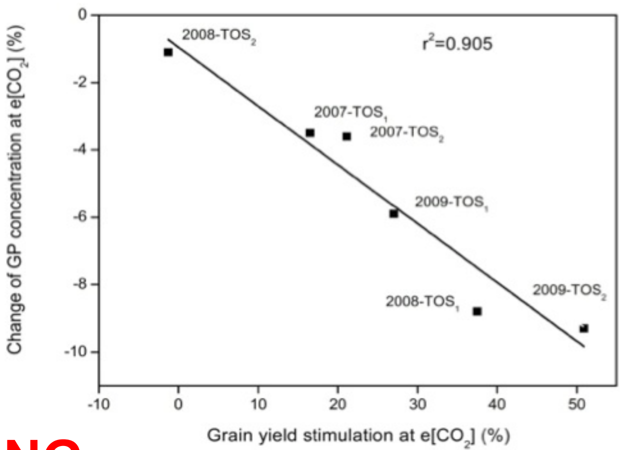
true, it usually is.”

+20% N removal under eCO_2

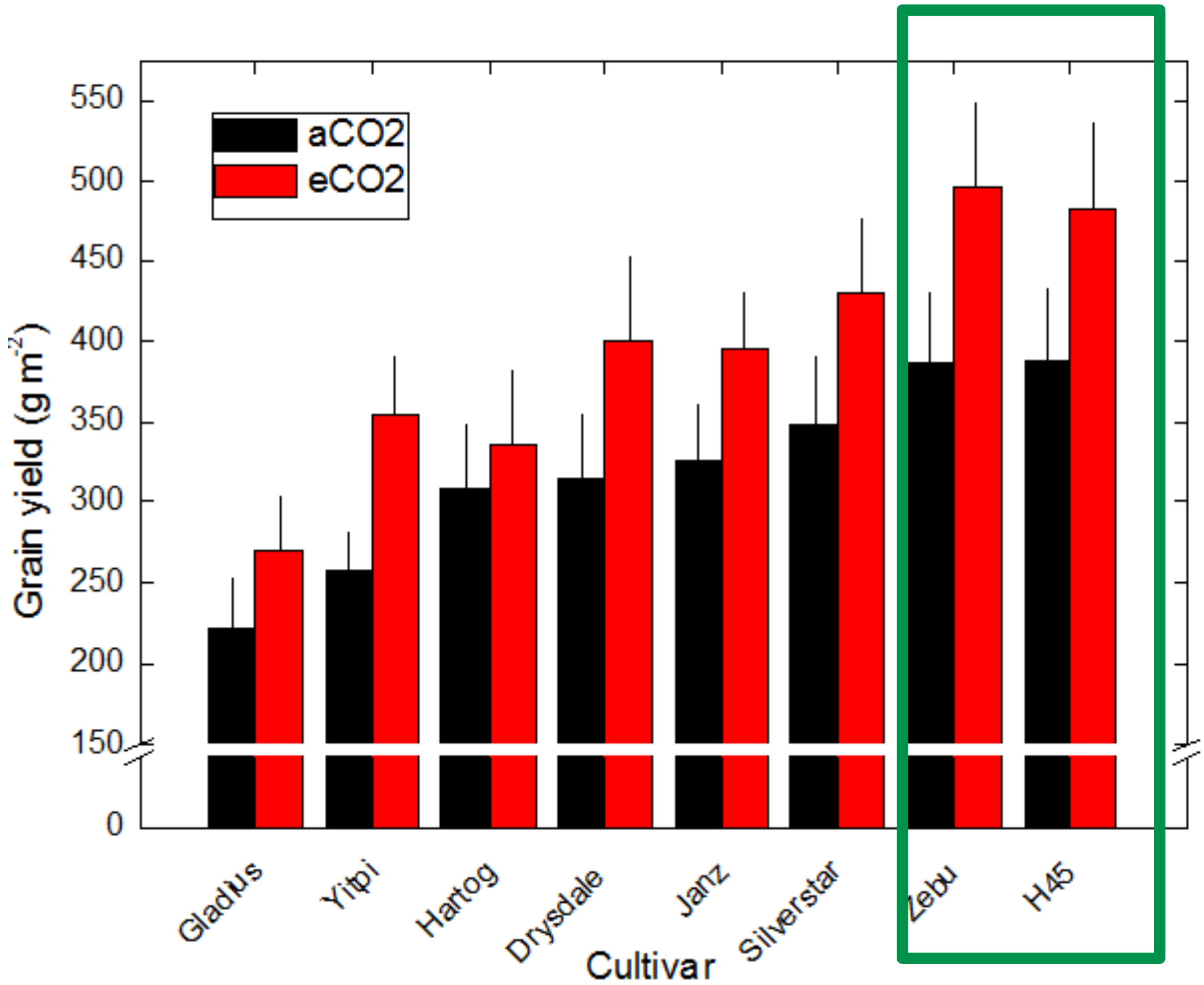
Implication – N demand



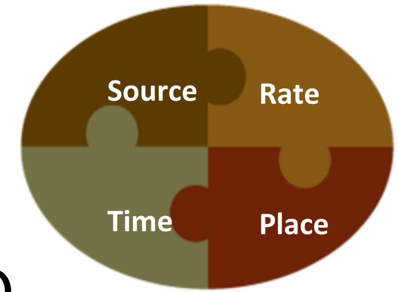
- 20% increase in N demand – irrespective of temperature and rainfall changes
  - **REVIEW THE RIGHT RATE**
- Most increase is after stem elongation (temperature).
  - **REVIEW THE RIGHT TIME/RATE – MORE LATER?**
- The <u>protein content</u> decline occurs with bigger yield stimulation – changes in N 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

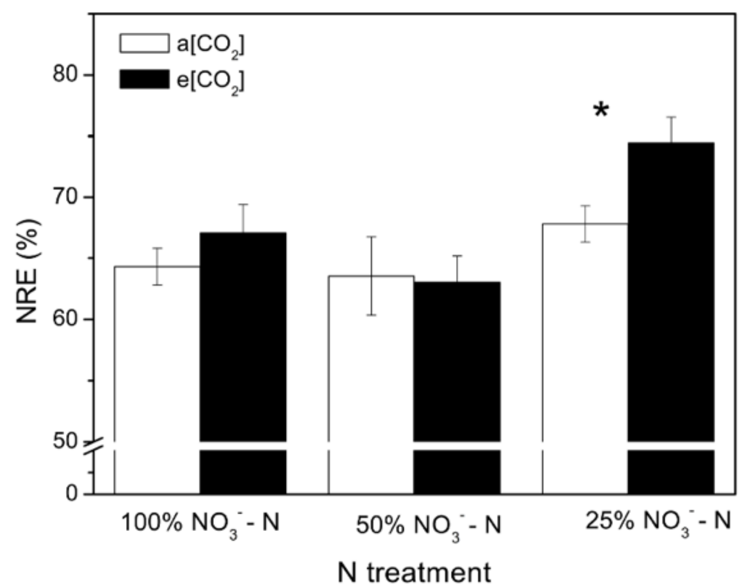


Seneweera et al 2013 submitted



Grain N recovery and N source

- If N>50% NH_4, 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)**

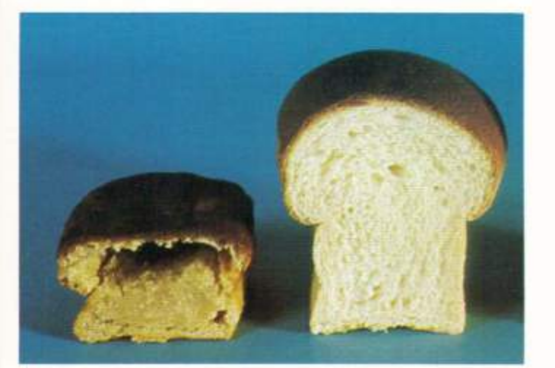


Fernando et al. JCS submitted

Changes in protein quality with eCO_2

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

cv Yitpi	$[CO_2]$	Grain N (g/kg)	Grain S (g/kg)	N:S
2008	aCO_2	**26.8**	1.75	**15.1**
	eCO_2	**23.5**	1.66 ns	**14.5**
2009	aCO_2	**27.2**	**1.83**	14.9
	eCO_2	**23.7**	**1.65**	14.4 ns



Bread loaf on left was baked with flour made from sulphur-deficient grain.

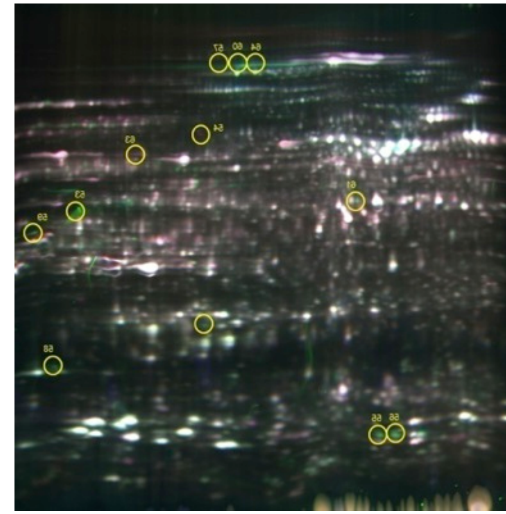
- Increase in flour yield (aCO_2 69.5% v eCO_2 72.3%)
  (Fernanado et al, 2013 JCS)
- Decrease in estimated bread volume* (aCO_2 169cm^3 v eCO_2 157 cm^3) (Fernanado et al, 2013 JCS)
- EBV is estimated from mixograph data.

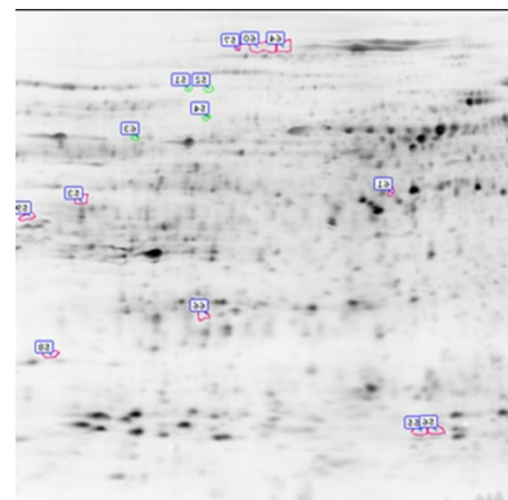
Grain proteome response to eCO_2

Green = > 1.5 Fold Up-regulated in Control (4 spots)
Pink = > 1.5 Fold Down-regulated in Control (10 spots)

Spot ID	Protein Name	Protein coverage	Fold change
(i). Up-regulated proteins			
61	Serpin-Z1C	29%	>1.7
66	1-Cys peroxiredoxin PER1	42%	>1.5
63	Not identified		>1.5
(ii). Down-regulated proteins			
64	**HMW Glutenin, subunit**	**5%**	**>1.5**
60	**HMW Glutenin, subunit**	**5%**	**>1.5**
57	**HMW Glutenin, subunit**	**5%**	**>1.6**

The gluten protein concentration was significantly reduced (more than 20%) at elevated CO_2.





DIGE for MALDI-TOF Mass Spectrometry

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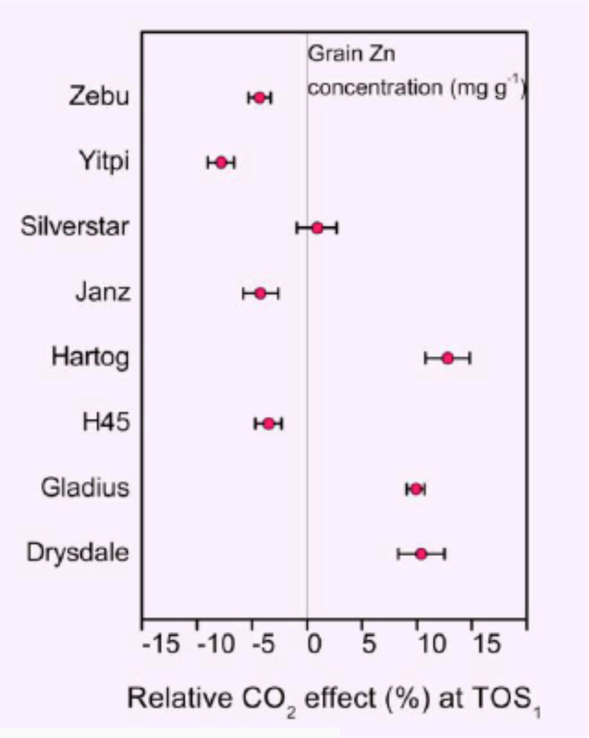
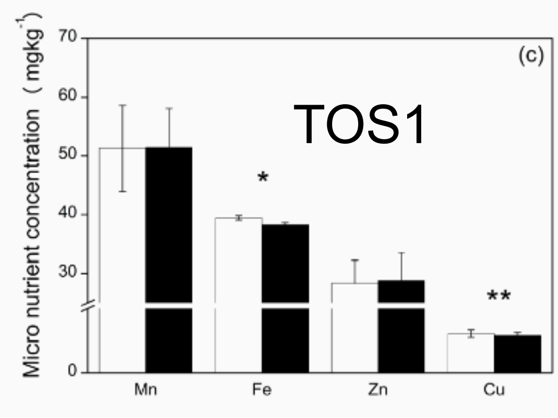
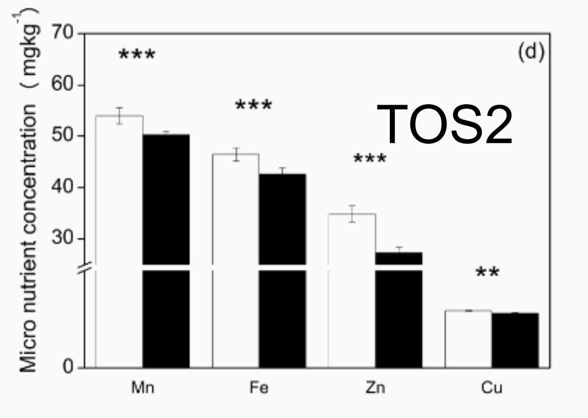
Effect on eCO_2 on micronutrient concentration – intraspecific variation

Fernando et al. 2013 JAFC *(in review)*

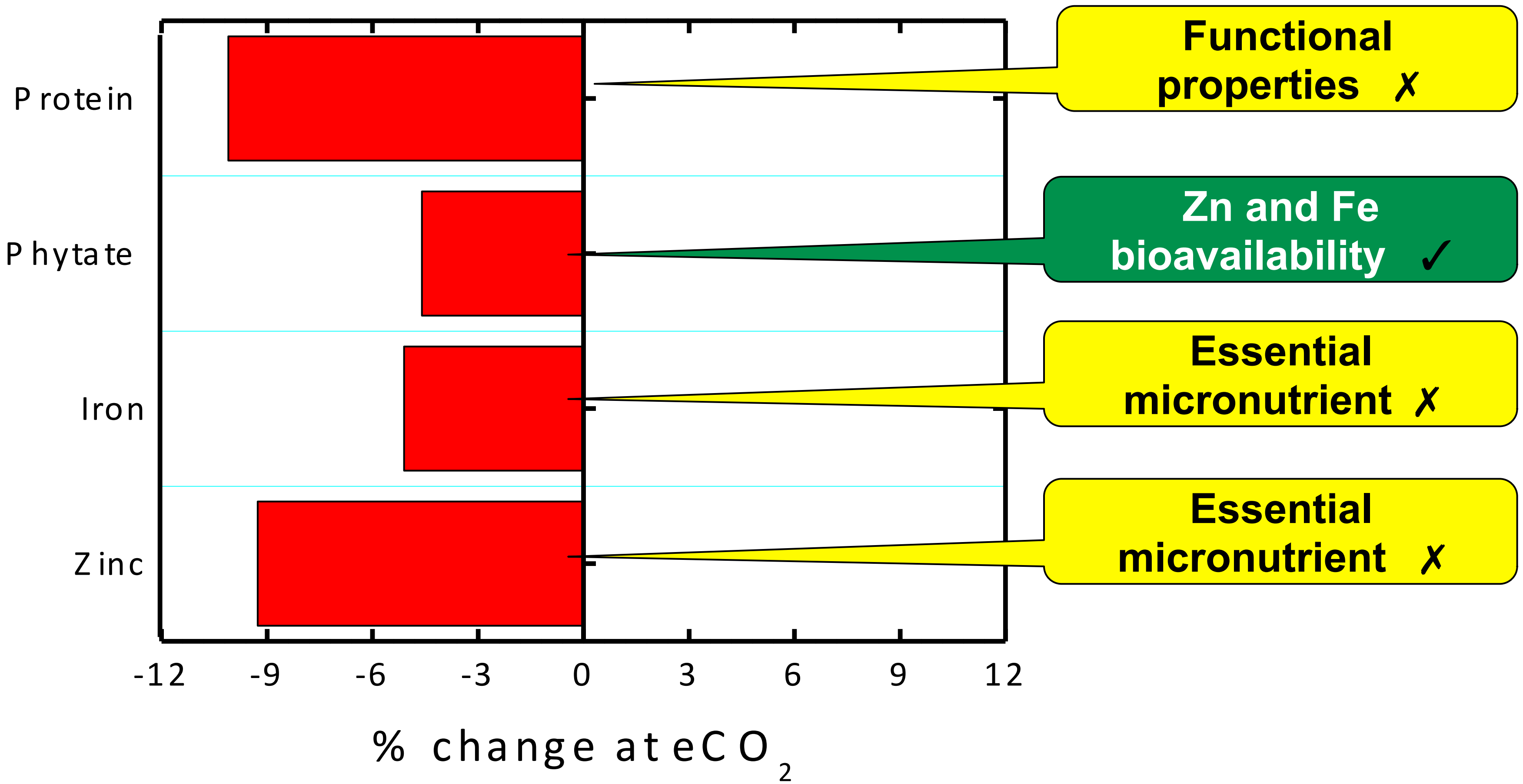


Wheat cultivars differentially responded to increased atmospheric $[CO_2]$ in terms of grain Zn, Fe, Mn and Cu, and flour rheologicial properties





Three years FACE data – from 2 sites – grain quality.



No effect of eCO_2 on Vitamin E (tocopherols) (Posch et al, 2012)

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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.**

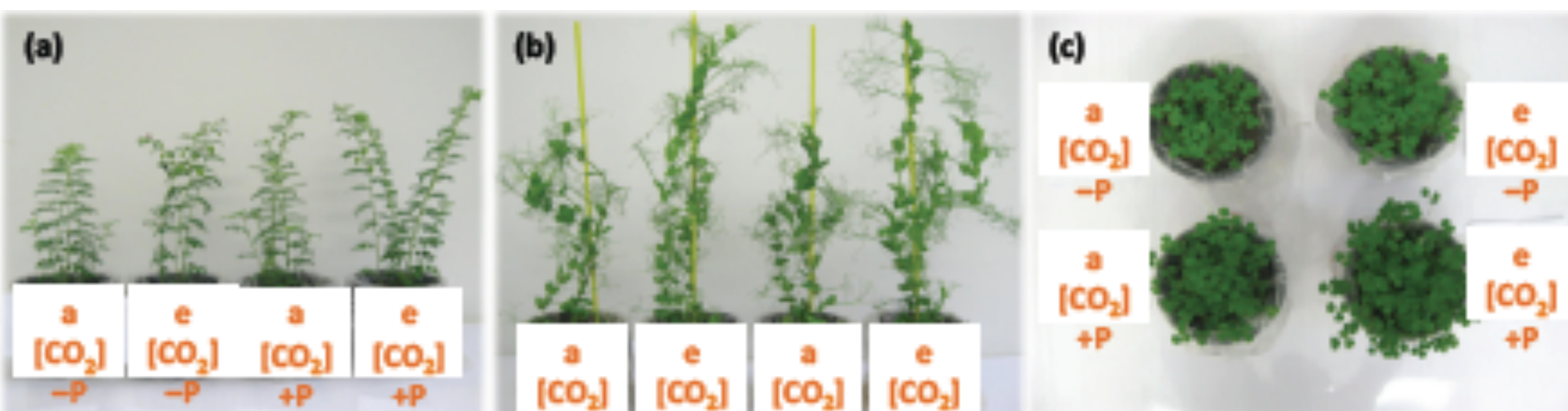
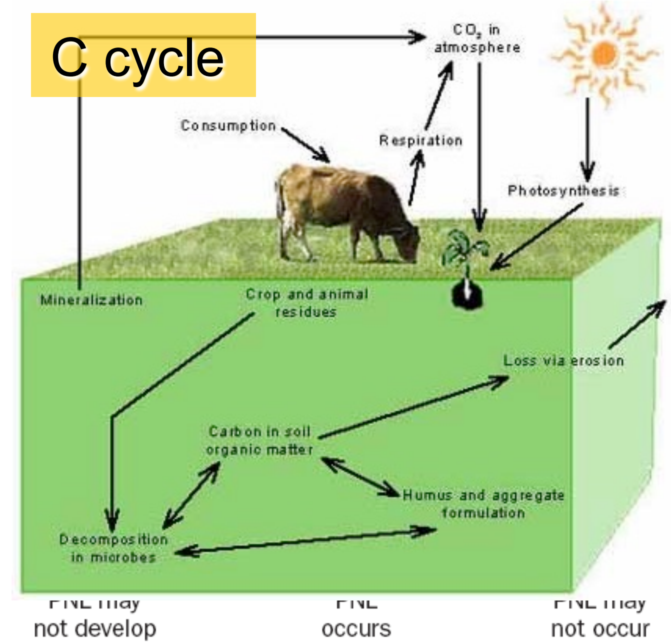
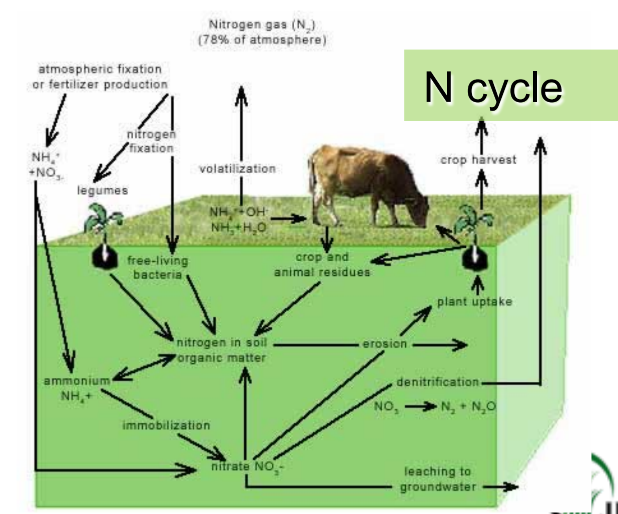


Fig. 1 Chickpea (a), field pea (b) and barrel medic (c) grown under different $[CO_2]$ (a: ambient; e: elevated) and P inputs on Vertosol

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.





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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

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