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GRDC
Grains Research & Development Corporation

Elevated Carbon Dioxide and Wheat Nutrition

- Lessons From The Australian Grains Free Air Carbon Dioxide Enrichment Experiments

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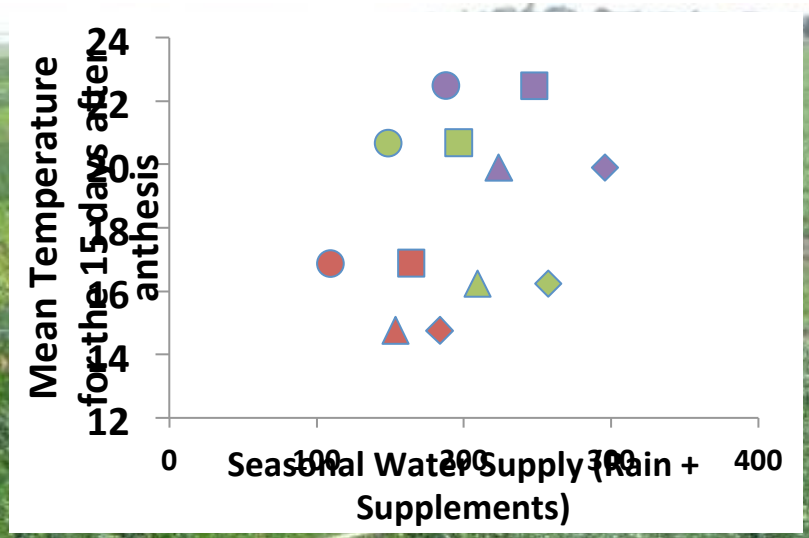
Australian Grains Free Air Carbon Dioxide Enrichment Facility (AGFACE)

- 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

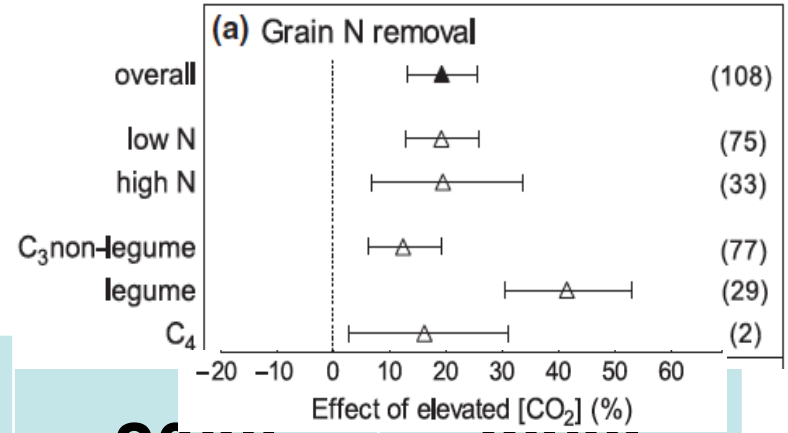
- Experimental treatments
  - FACE CO_2 – ambient (~380 ppm) & 550 ppm
  - Water – rainfed & irrigated (+50 mm)
  - Sowing time – early sown (June 18) & late sown (August 22) – *generates +5°C during flowering*
  - Nitrogen – low and supplemented – *managed in response to water supply (Yitpi only)*
  - **Cultivar - Yitpi and Janz**



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

Experimental Treatments – 2007, 2008, 2009

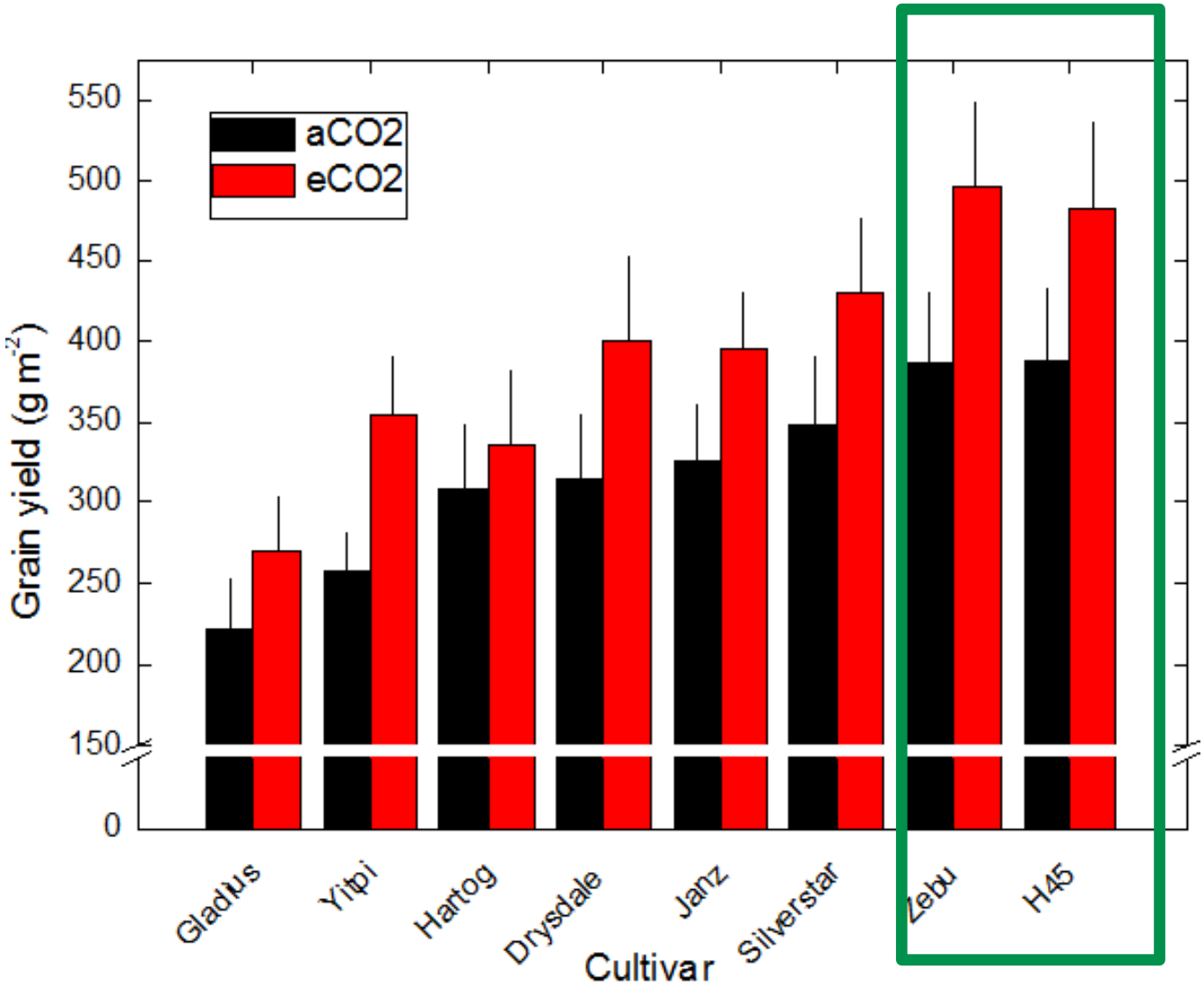
Mean effects of eCO_2 2007-2009



Factor	$[CO_2]$ (µmol/mol)	2007	2008	2009
Grain yield (g m^{-2})	*380+*	258	247	252
+27%	*550*	323	310	332
Grain N content (%) **-5%**	*380+*	2.44	3.16	3.06
	550	2.33	3.04	2.81
N removal g m^{-2}	*380+*	6.30	7.81	7.71
	550	7.53	9.42	9.33

+20% N removal under eCO_2

Yield response to eCO_2 – 2009-2011



Seneweera et al 2013 submitted

Changes in protein quality with eCO_2

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

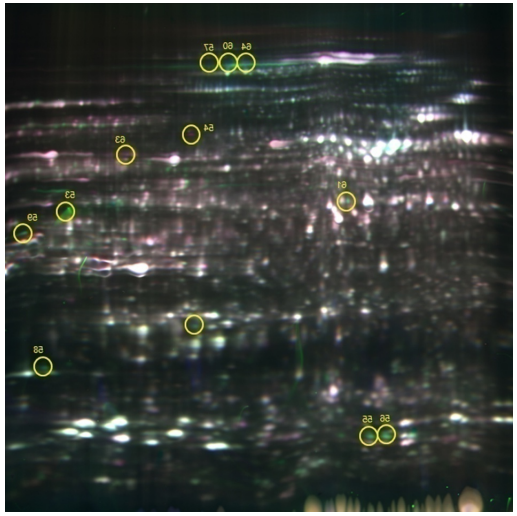
cv Yitpi	$[CO_2]$	Grain N (g/kg)	Grain S (g/kg)	N:S
2008	aCO_2	**26.8**	1.75	**15.1**
	eCO_2	**23.5**	1.66 ns	**14.5**
2009	aCO_2	**27.2**	**1.83**	14.9
	eCO_2	**23.7**	**1.65**	14.4 ns

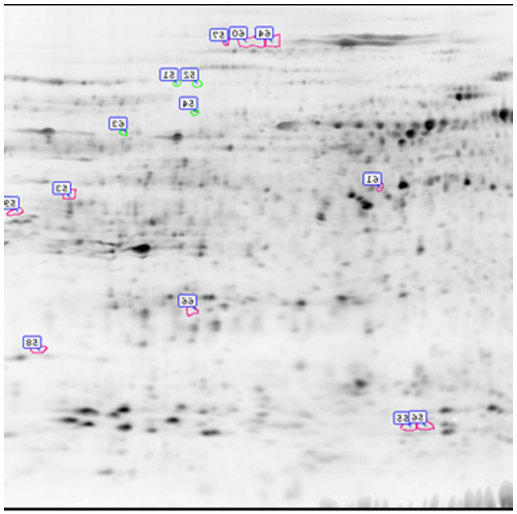
- Increase in flour yield (aCO_2 69.5% v eCO_2 72.3%) (Fernanado et al, 2013 JCS)
- Decrease in estimated bread volume* (aCO_2 169cm^3 v eCO_2 157 cm^3) (Fernanado et al, 2013 JCS)
- EBV is estimated from mixograph data.

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**



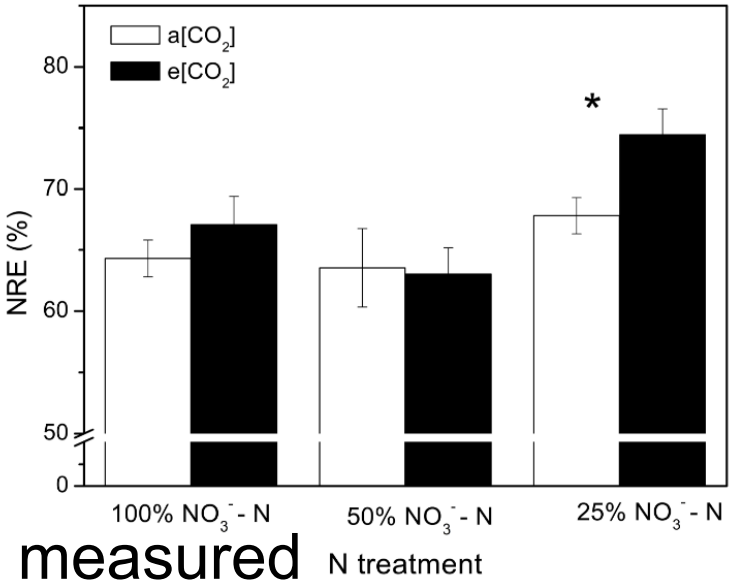


DIGE for MALDI-TOF Mass Spectrometry

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

Grain N recovery and N source

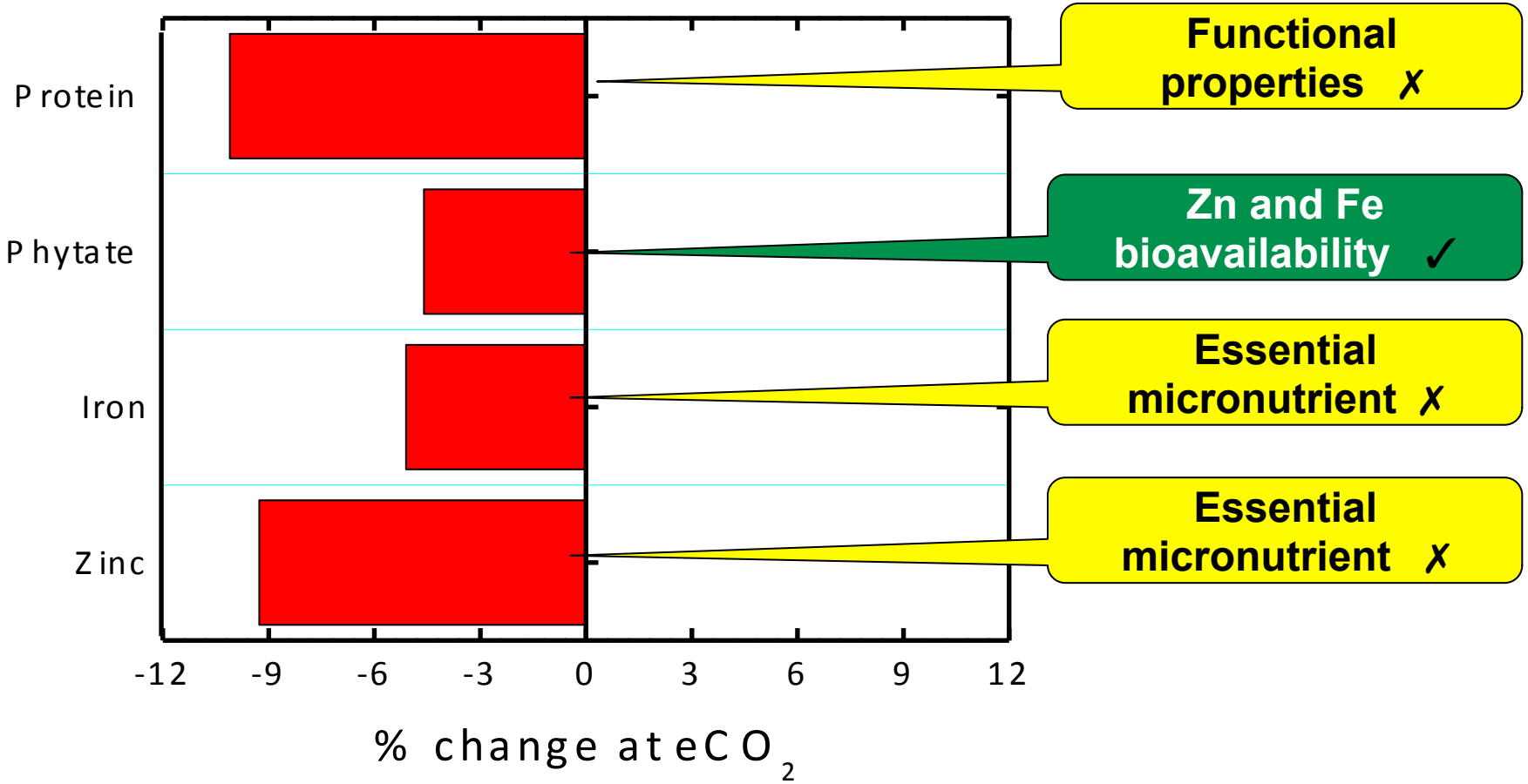
- Glasshouse experiment
- aCO_2 v eCO_2
- Variation in NO_3:NH_4 supply
- Pulse labeled with ^{15}N at anthesis
- N recovery efficiency, NR activity measured
- If N>50% NH_4, higher N recovery under eCO_2



Fernando et al. JCS submitted

- Under ammonium dominant supply, significant response in N recovery
- Competition for energy between photo-reduction & nitrate reduction.

Three years FACE data – from 2 sites – only two varieties.

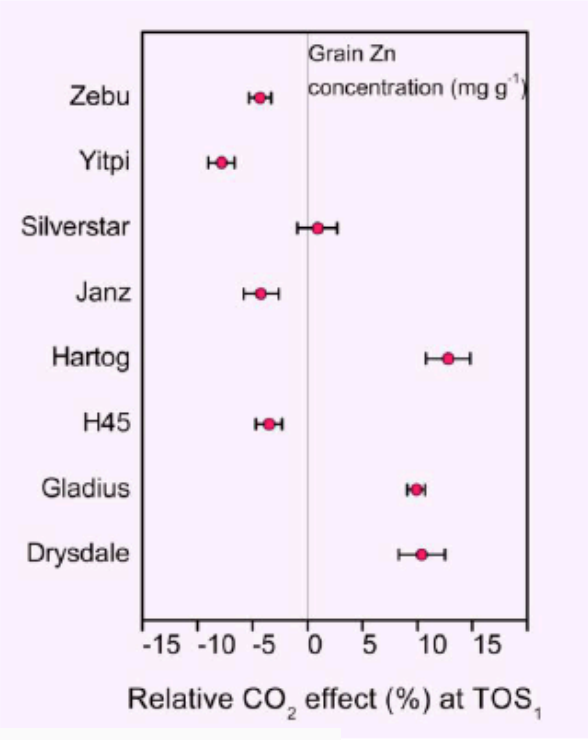


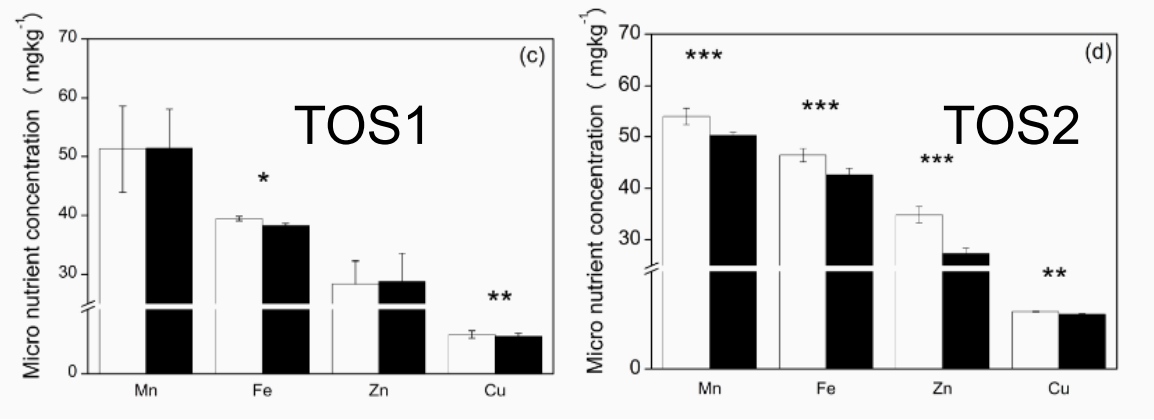
No effect of eCO_2 on Vitamin E (tocopherols) (Posch et al, 2012)

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





Meeting the higher N demand

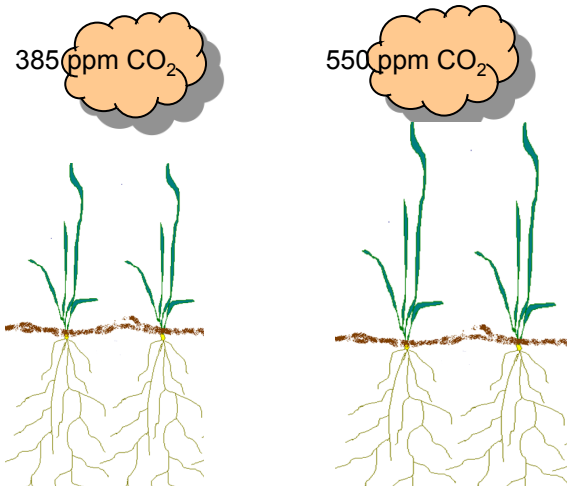
- Higher RLD at anthesis under eCO_2

Year	aCO_2	eCO_2
2007	**1.14**	**1.82**
2008	**2.45**	**3.00**
2009	0.86	0.96

- +27% C input, -6% N input
- Higher C:N ratio in residues – increase N demand for C sequestration

- No difference in N recovery from fertilizer. (Lam et al. 2012)
- No difference in mineralisation.

- Potential for Progressive N Limitation (Luo et al. 2004.)



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….
- So – adequate P is important in reducing the N deficit

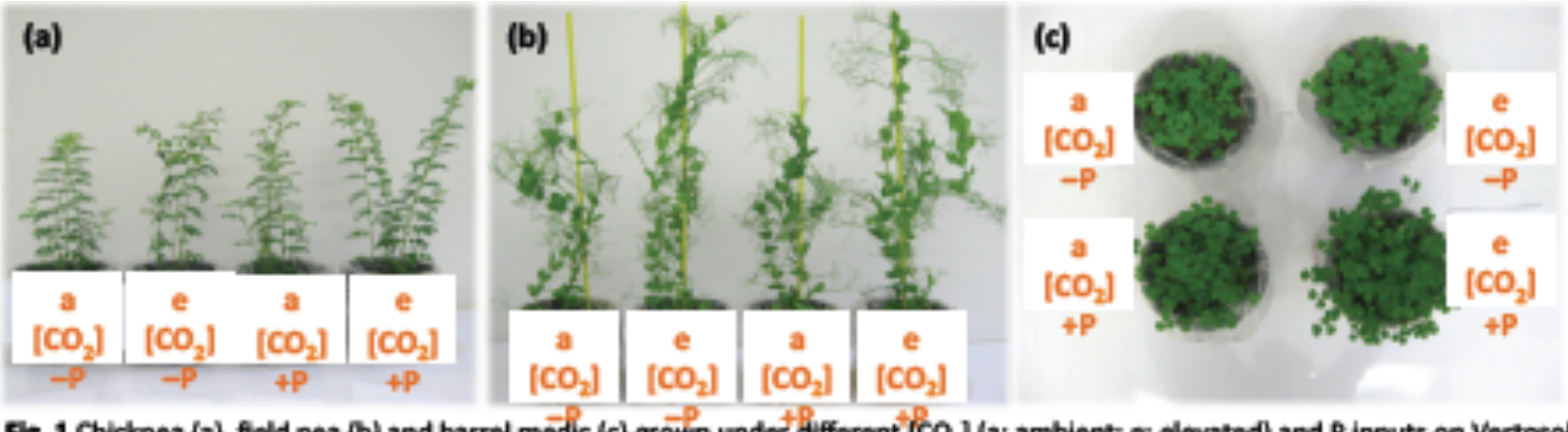


Fig. 1 Chickpea (a), field pea (b) and barrel medic (c) grown under different [CO_2] (a: ambient; e: elevated) and P inputs on Vertosol

Lessons

- Growth and yield responds positively to rising CO_2, with little interaction with temperature and water supply.
- Grain protein content and functional properties are adversely affected – intraspecific variations and alternative N management strategies may provide hope.
- Grain micronutrient content declines, not necessarily all as yield dilution – intraspecific responses of interest.
- N demand will increase – potential for progressive N limitation.
- P supply for pulses/legumes will determine N limitation.
- Revise N management strategies – source/rate/time

Lam et al. 2012 Global Change Biology. Meta-analysis

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