

What is the impact of elevated CO₂ and N management on grain quality?

Cassandra Walker Roger Armstrong
Joe Panozzo Glenn Fitzgerald



Rising levels of CO₂

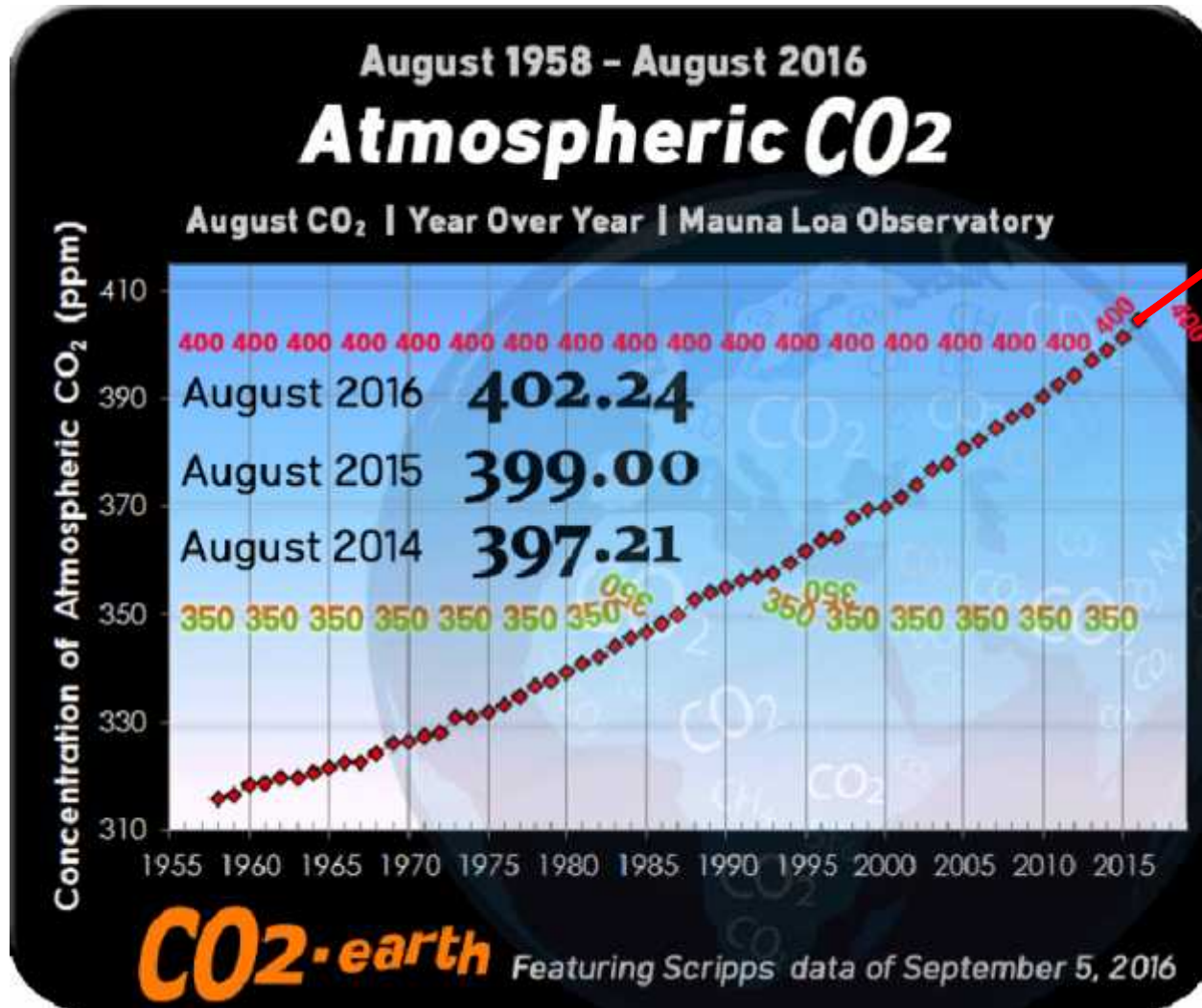


Chart source:
CO2now.org

Rising levels of CO₂

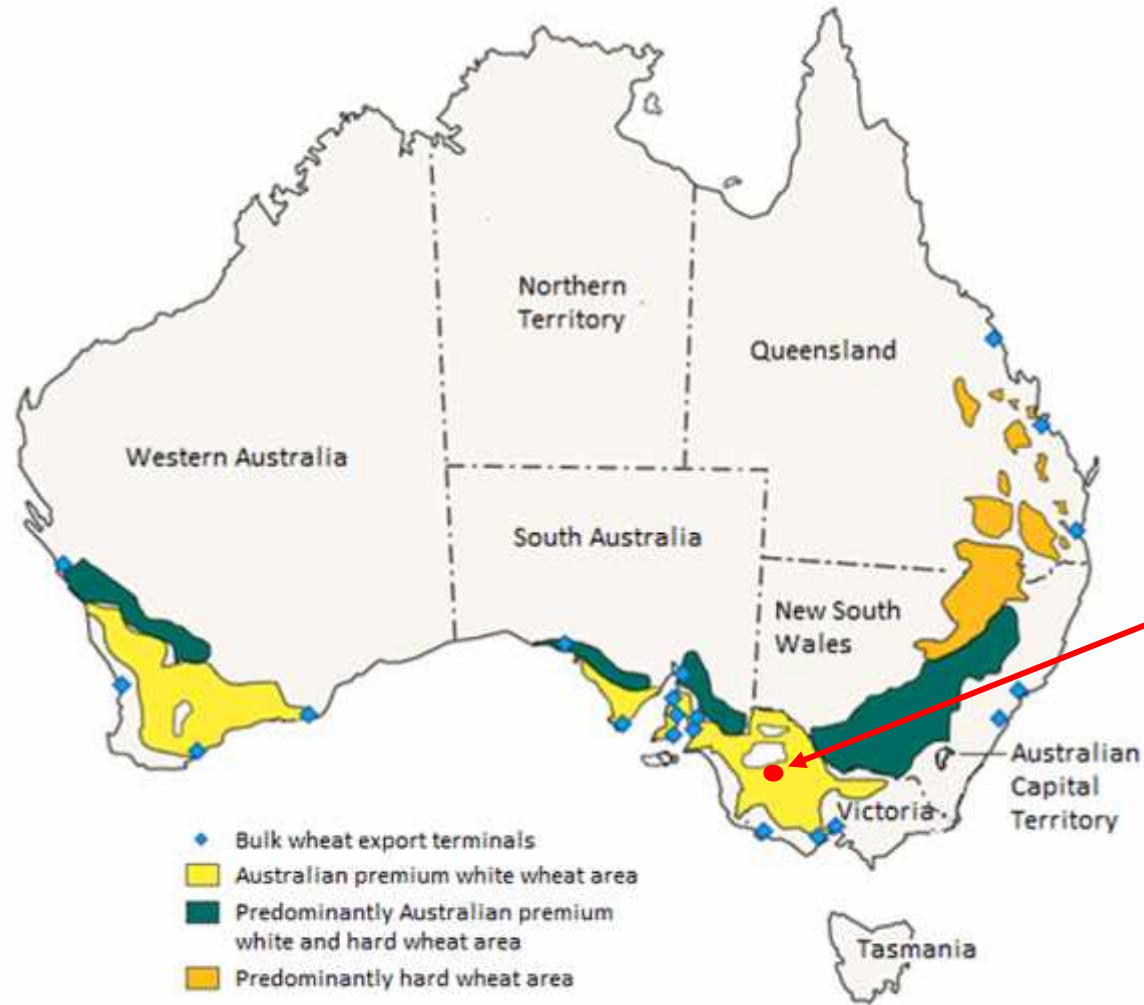
AGFACE:

The “Australian Grains Free Air CO₂ Enrichment” facility
Field Laboratory without walls, testing ambient levels
against the projected levels of 550ppm at 2050



Australian Grain Belt

Australian wheat ~ \$5.5 billion annually



AGFACE

Rising levels of CO₂ and Agriculture

C3 plants response to eCO₂:

- **Reduced need for RuBisCO**
less leaf, plant and grain nitrogen
- **Increased Carbon uptake**
increased biomass and grain yields
- **Any eCO₂ 'fertilisation' effect on plant production is strongly related to the N supply**

AGFACE Research Questions

- **What is the impact of elevated CO₂ (eCO₂) on wheat yield, grain protein content and baking quality?**
- **Can N management strategies be used to overcome the decline in grain protein content under eCO₂?**
- **What are the implications of eCO₂ for plant breeding?**

Impact of eCO₂ Grain Yield

Global Change Biology

Global Change Biology (2016) 22, 2269–2284, doi: 10.1111/gcb.13263

Elevated atmospheric [CO₂] can dramatically increase wheat yields in semi-arid environments and buffer against heat waves

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- **Grain yield increase**
effect positive 21.3%

Confirms other researchers findings:

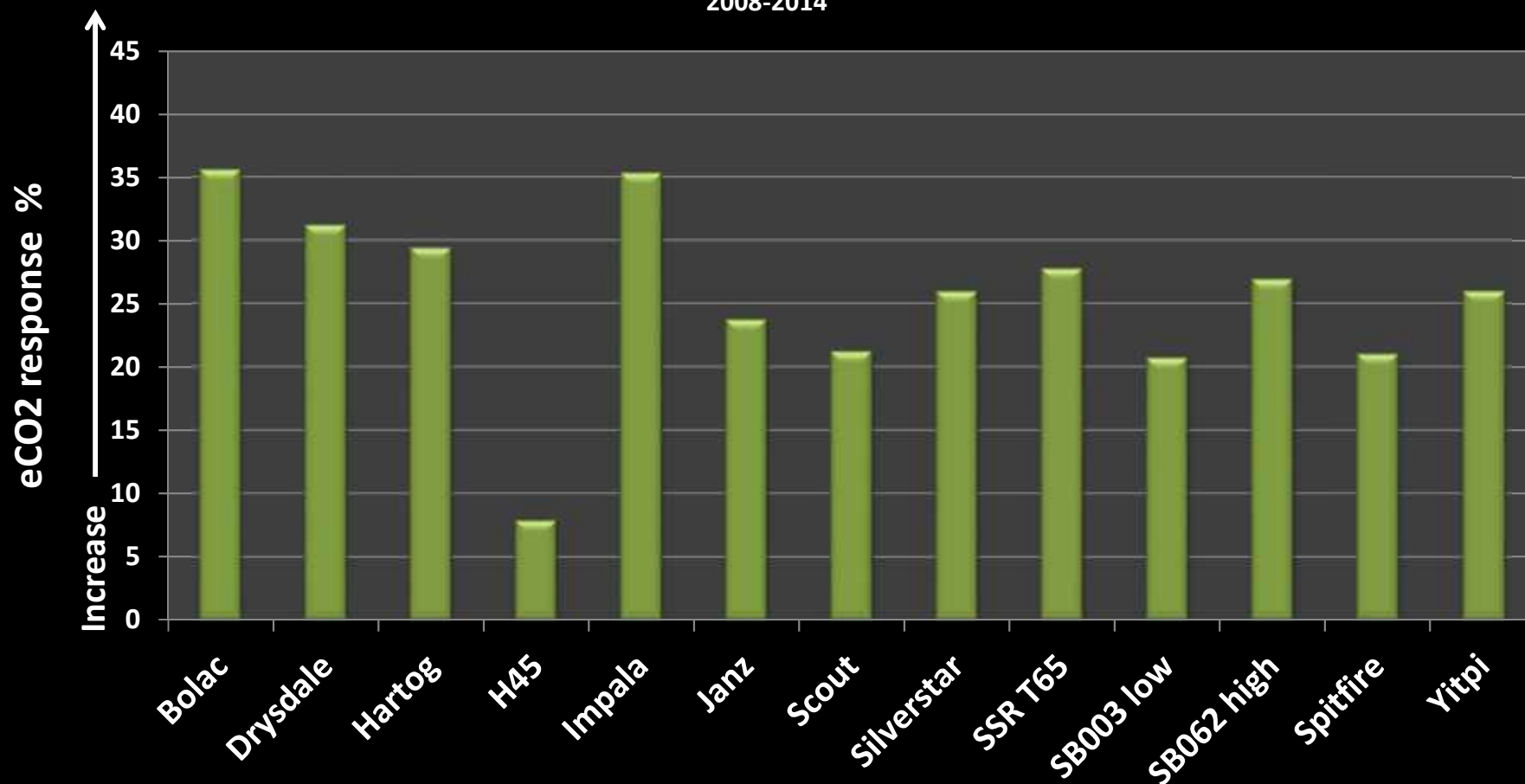
Hogy et al 2009; Kimball et al 1995; Taub et al 2008

Impact of eCO₂ Grain Yield

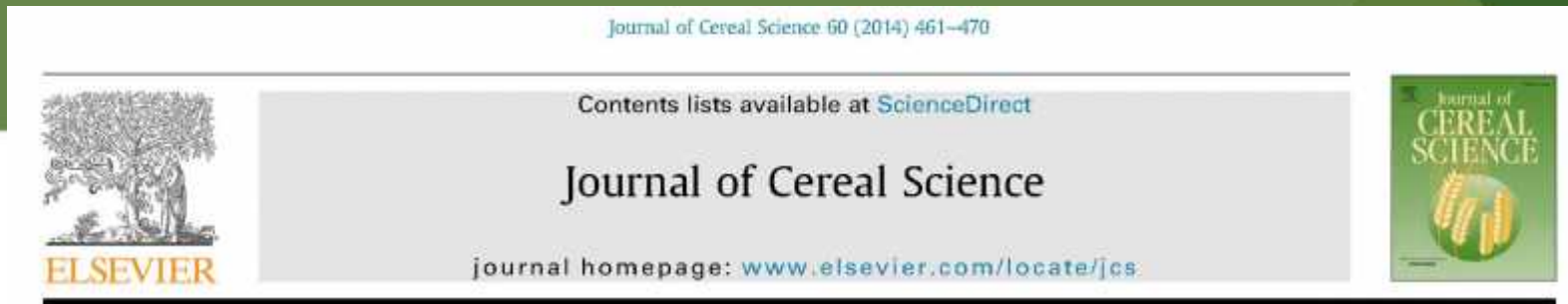
Increased

Wheat - Grain Yield response to eCO₂

2008-2014



Impact of eCO₂ Grain Protein Content



Elevated carbon dioxide changes grain protein concentration and composition and compromises baking quality. A FACE study



J.F. Panozzo ^{a,*}, C.K. Walker ^a, D.L. Partington ^b, N.C. Neumann ^a, M. Tausz ^c,
S. Seneweera ^d, G.J. Fitzgerald ^a

- **Grain protein decrease (-0.4-2.2%)
effect negative 6.6%**
P=0.01

Confirms other researchers findings:

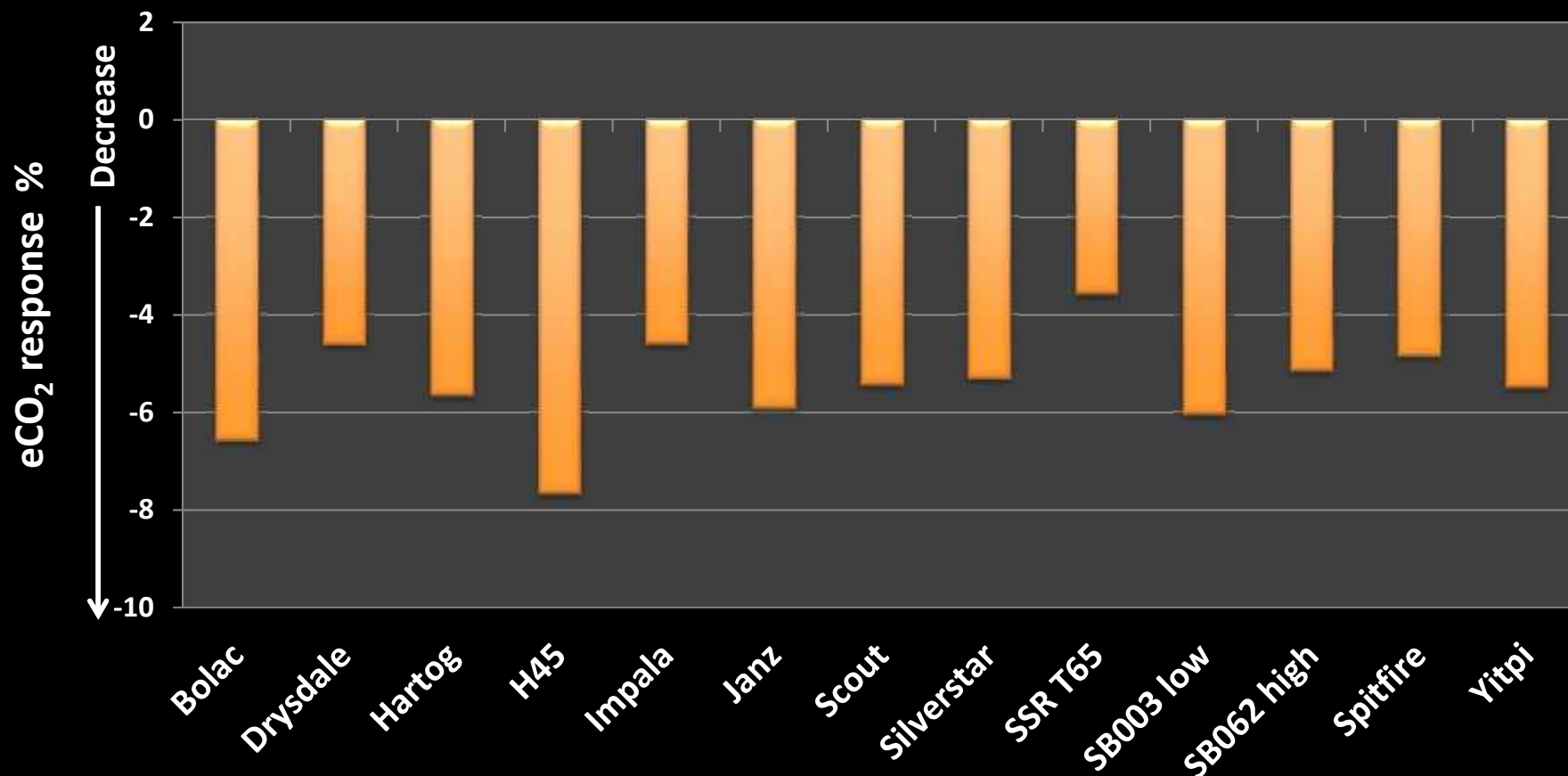
Erbs et al 2010; Hogy et al 2009; Kimball et al 1995; Taub et al 2008; Wieser et al 2008

Impact of eCO₂ Grain Protein Content

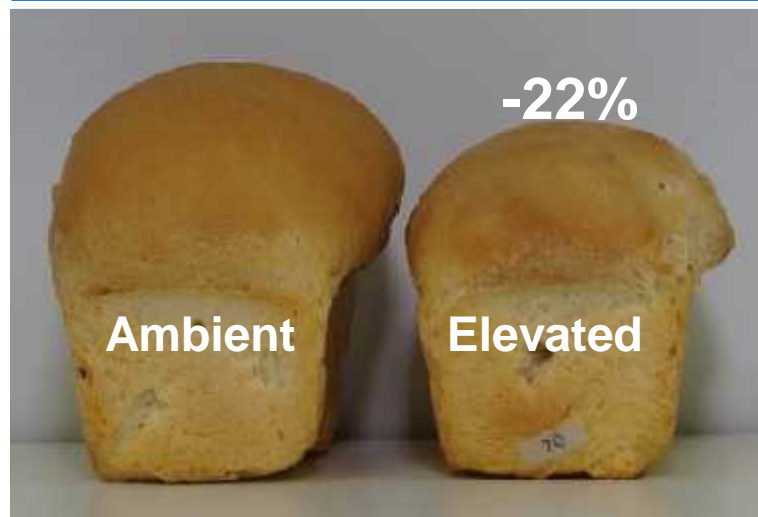
Reduced

Wheat - Grain Protein response to eCO₂

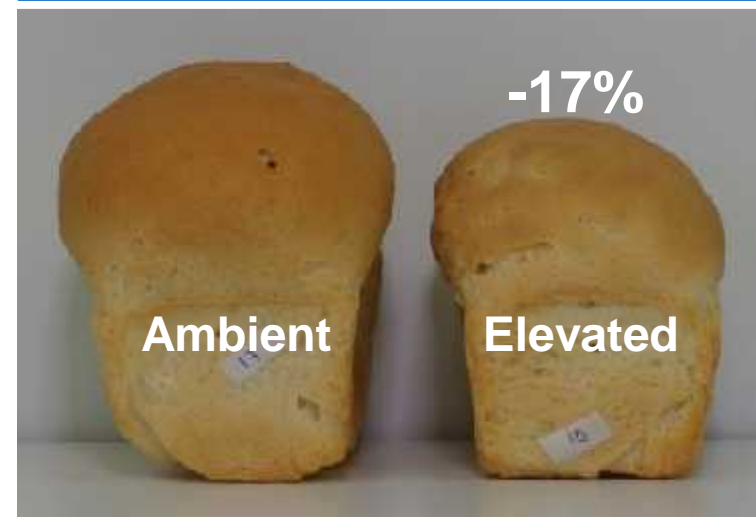
2008-2014



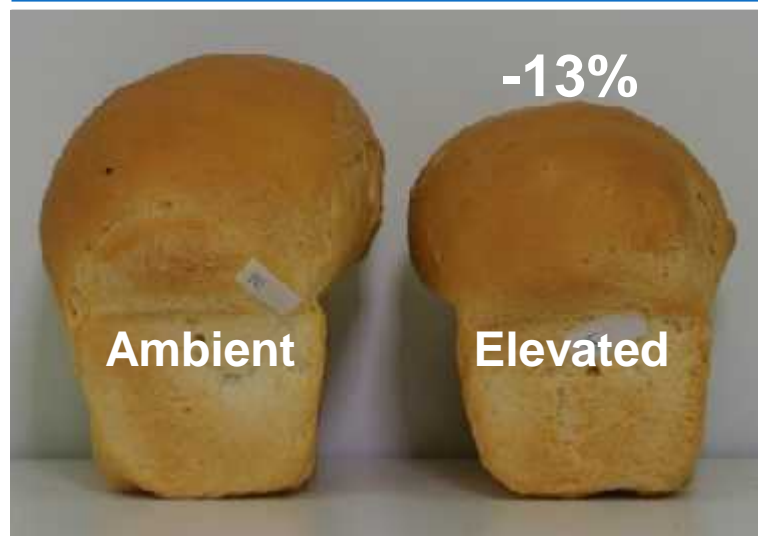
Scout



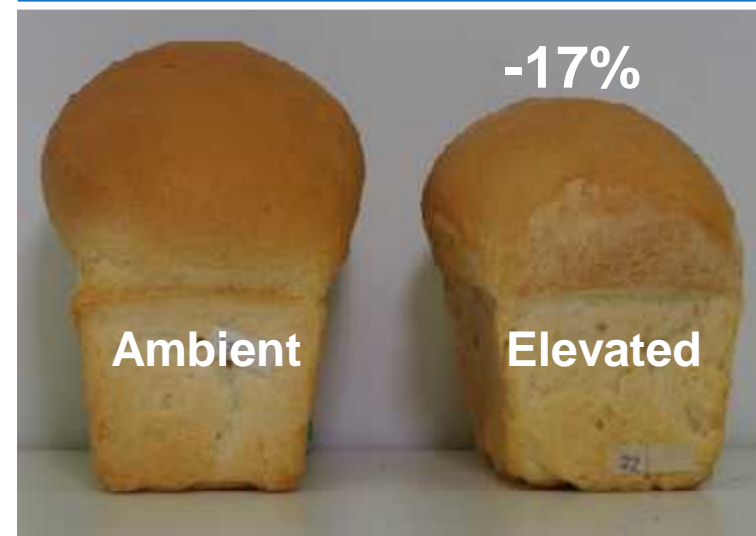
Yitpi



Gladius



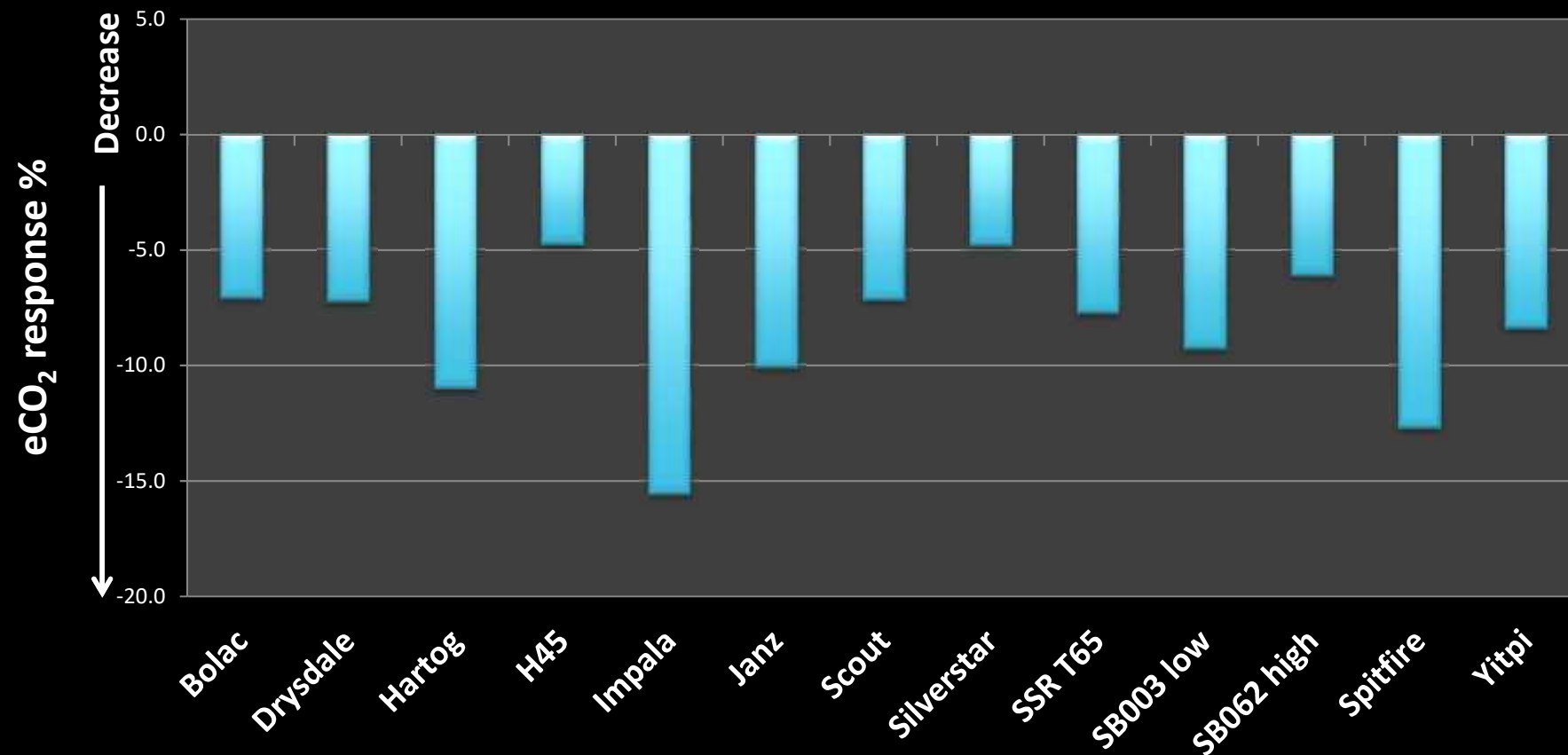
Wyalkatchem



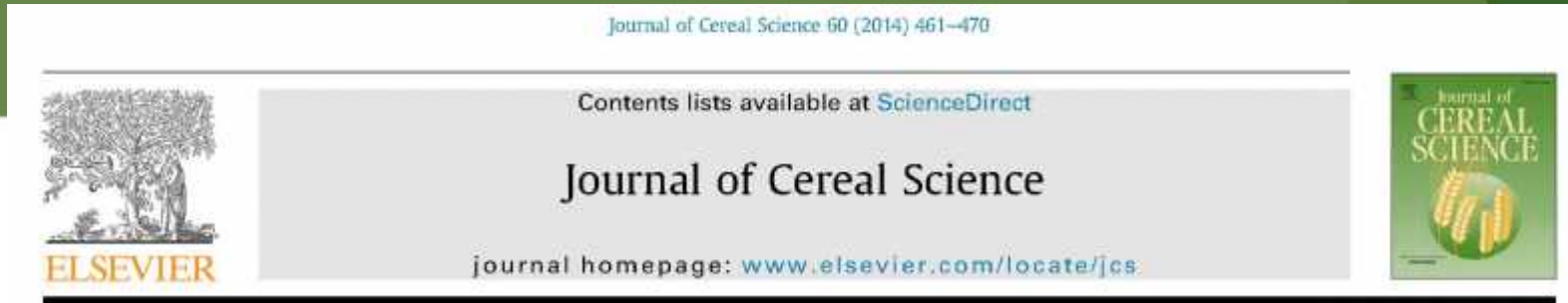
Impact of eCO₂ Bread Quality

Reduced

Wheat - Loaf Volume response to eCO₂, 2008-2014



Impact of eCO₂ Bread Quality



Elevated carbon dioxide changes grain protein concentration and composition and compromises baking quality. A FACE study



J.F. Panozzo ^{a, *}, C.K. Walker ^a, D.L. Partington ^b, N.C. Neumann ^a, M. Tausz ^c,
S. Seneweera ^d, G.J. Fitzgerald ^a

- **Loaf Volume decrease (-20-180cm³)
effect negative 9.1%**

P=0.001

Impact of eCO₂ Bread Quality

Reduced Loaf Volume (-9.1%)

- **Partially due to reduced grain protein**

- **Deleterious effects**

Greater reduction in loaf volume under eCO₂
Loaf Vol -9.1% Grain Protein Content -6.6%

- **Weaker Rheology Properties**

- moulding issue
- dough structure collapses

Nitrogen-FACE

So what strategies can we apply to reduce the negative impact of elevated CO₂ on grain quality...

One Hypothesis is that:

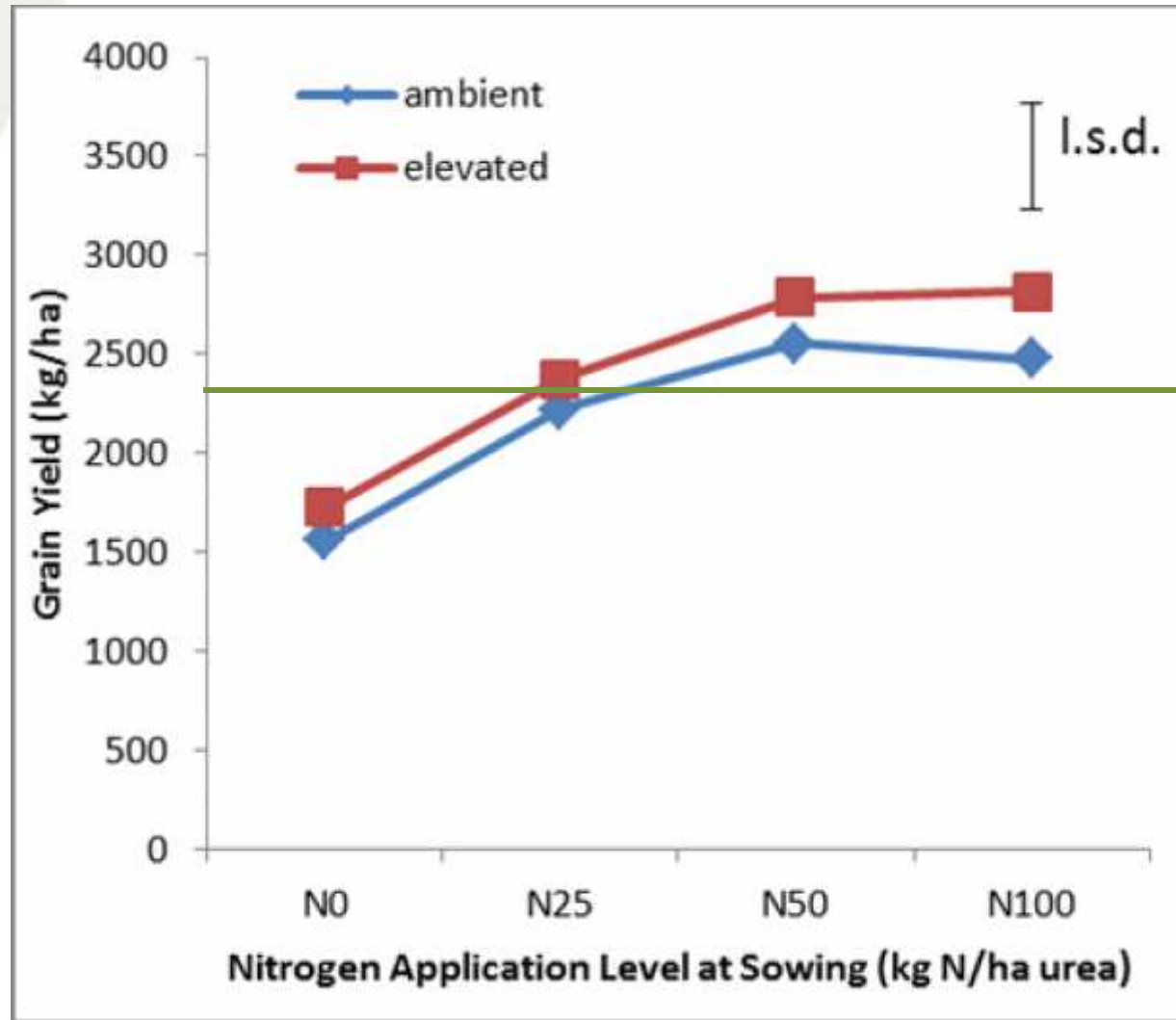
- **N-management strategies can retain grain protein content under eCO₂**

N-FACE - N management strategies

- **Rates of Urea at Sowing: 25, 50, 100 kg/ha**
- **A legume sown in the previous season**
Medic sown previous season and stubble incorporated pre-sowing
- **A foliar spray during anthesis**
25 kg N/ha urea equivalent
- **Top dressed urea**
25 kg N/ha urea equivalent
- **Slow release urea**
25 kg N/ha urea equivalent

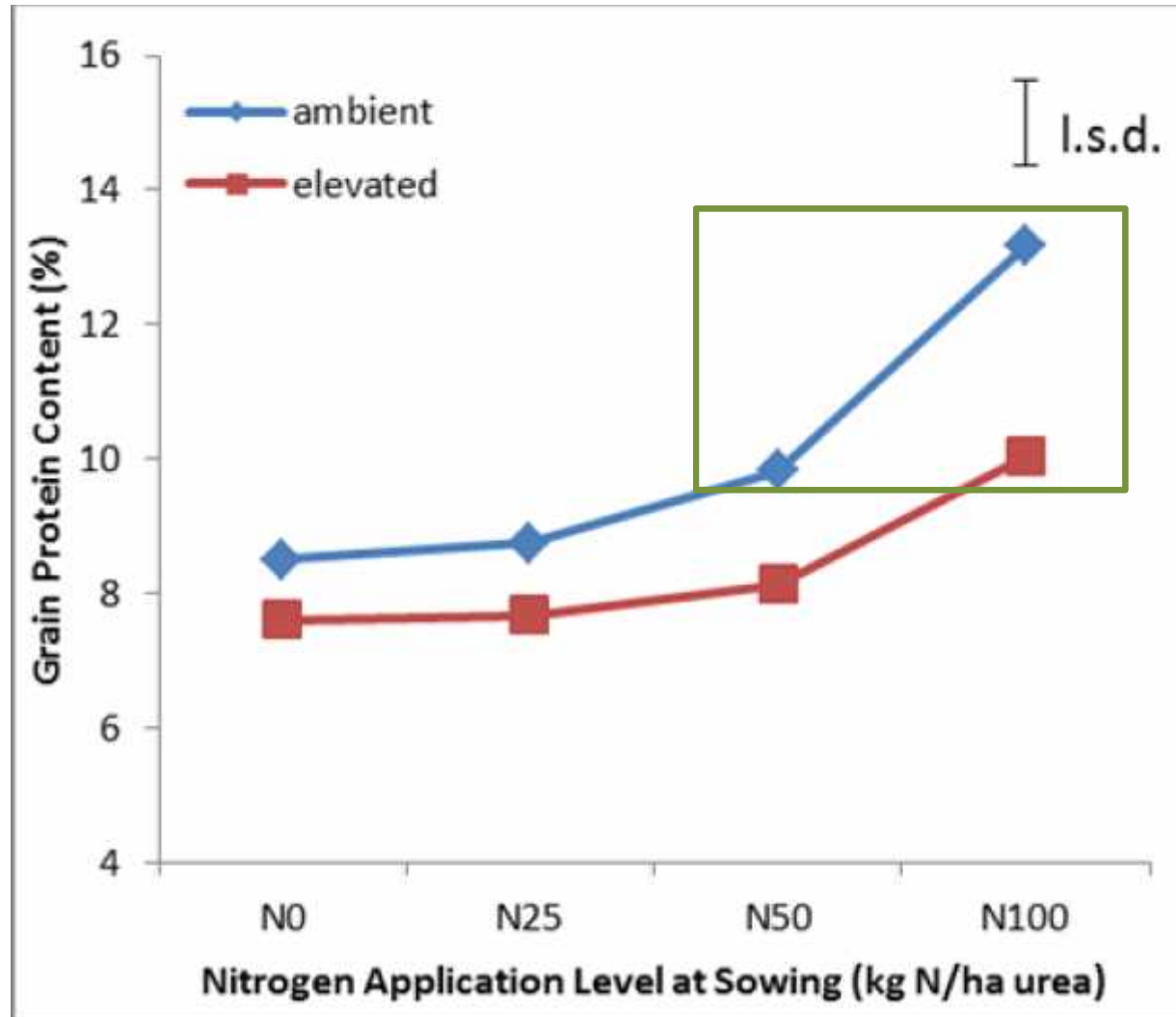
N-FACE

Significant grain yield responses were observed by increasing rate of N fertiliser

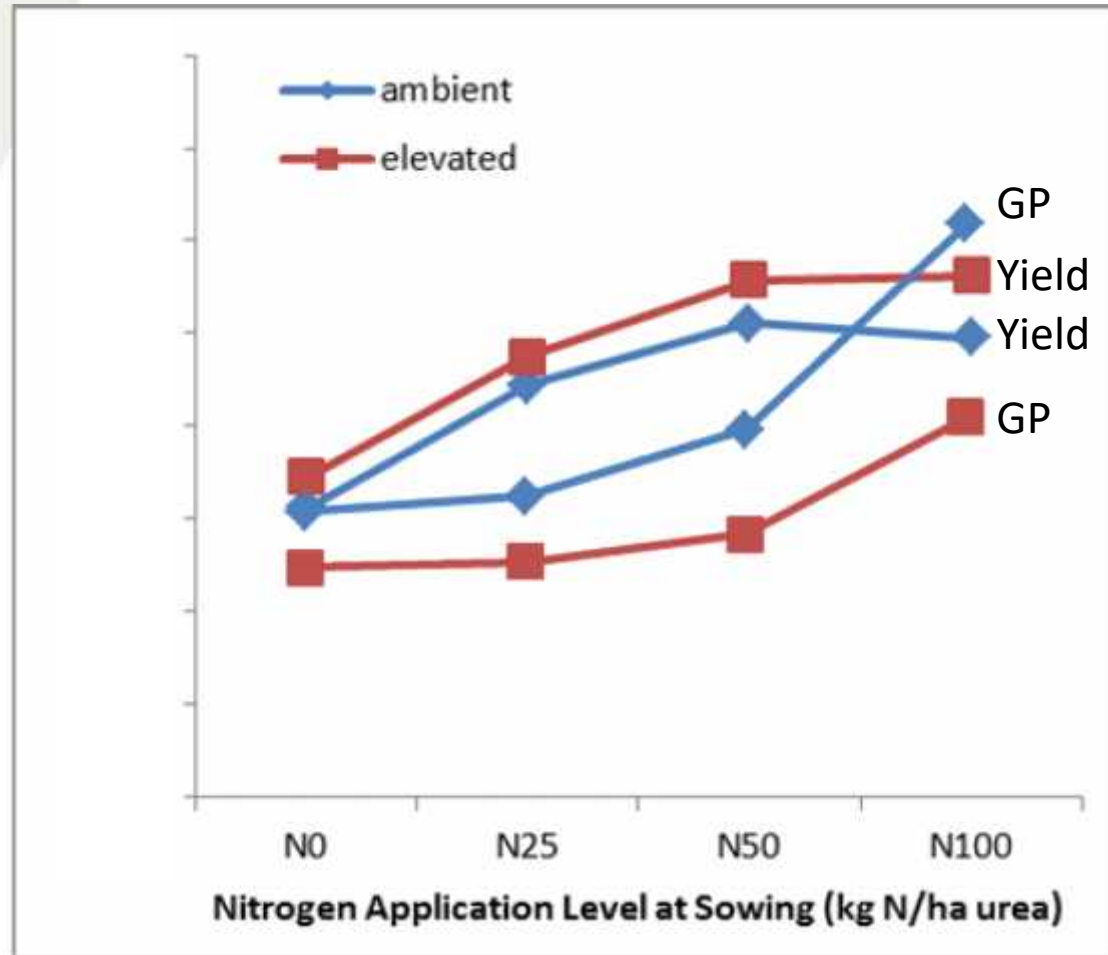


N-FACE

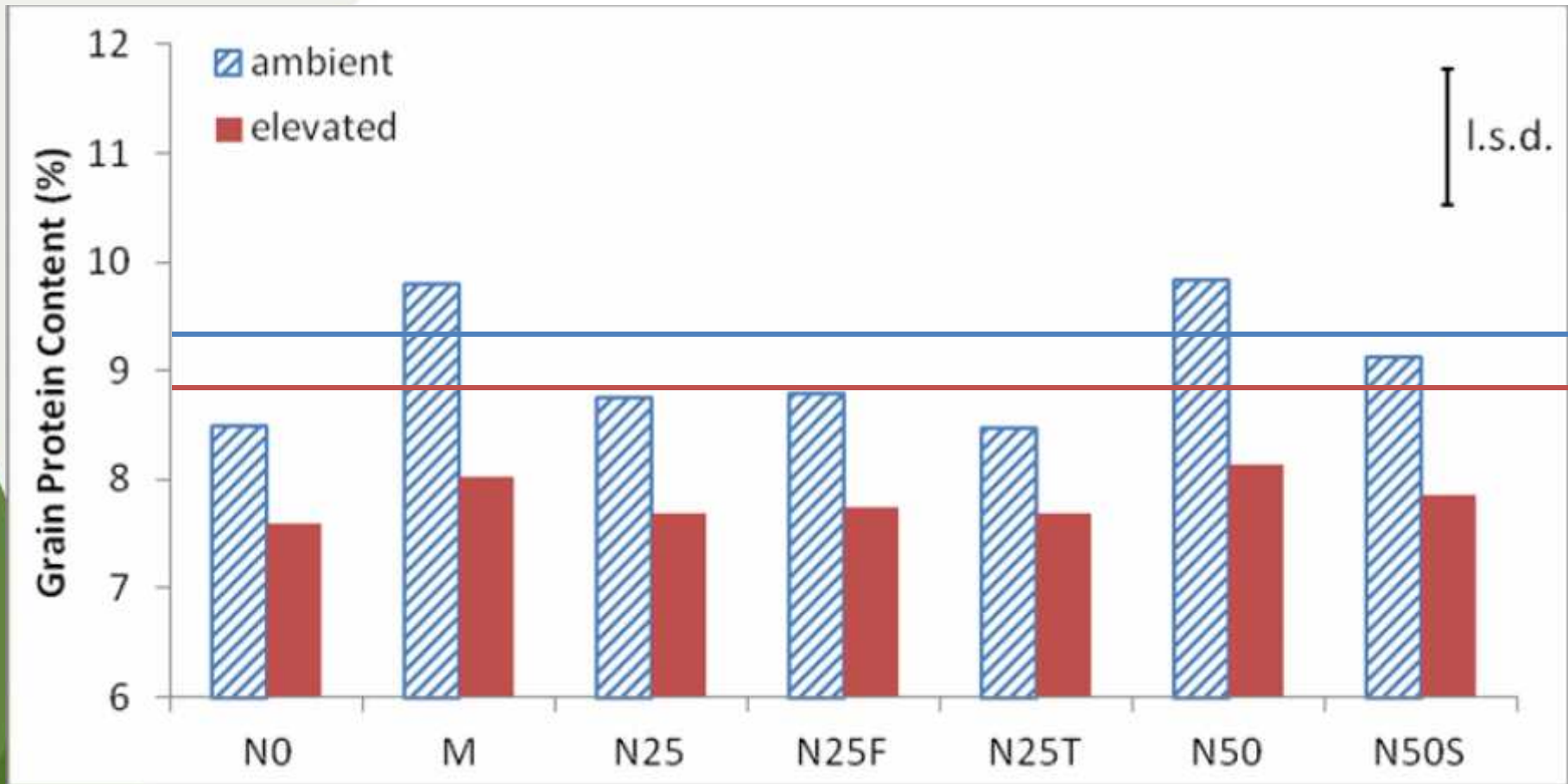
Significant grain protein responses were not observed until 100kg/ha of N fertiliser was applied under eCO₂



Grain Yield Response vs Grain Protein Response



N-FACE



No fertiliser input

Medic sown previous season

25 kg N/ha urea

25 kg N/ha urea; 4 x 6.25 kg N/ha on foliar (anthesis)

25 kg N/ha urea; 4 x 6.25 kg N/ha N topdressed (anthesis)

50 kg N/ha urea

50 kg N/ha polymer coated (slow release) urea

AGFACE Observations, under eCO₂

- **Higher grain yield and biomass**
Grain yield response > N25 _{P=0.05}
- **Decreased grain protein content**
Grain protein response > N100 _{P=0.05}
N management strategies did not increase Grain Protein Content
Applying N → Vegetative growth demand ‘took preference’, once yield potential was achieved the grain quality increase

AGFACE

As CO₂ increases how can we overcome the reduction in grain quality to meet our nutritional and market needs?

- **Bakers add more gluten**
 - increases cost
 - the gluten composition under eCO₂ is compromised
- **Genetic selection**
 - Stronger selection on grain protein achievement, in particular the gluten proteins required to obtain an acceptable loaf volume

Poster Presentation - Modelling

AGRICULTURE VICTORIA

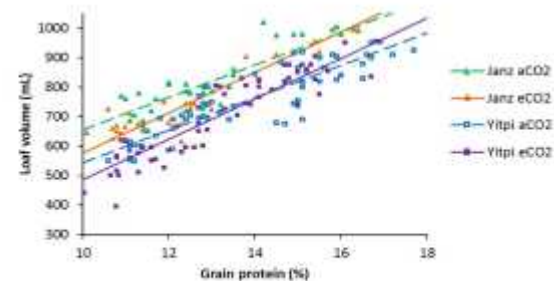
An empirical model of wheat baking quality under elevated CO₂

Malcolm McCaskill¹, Garry O'Leary², Joe Panozzo², Cassandra Walker², Debra Partington¹

Elevated CO₂ (eCO₂) is associated with lower grain protein concentration for wheat, and an inferior baking quality. To extend the functionality of process-based models of wheat growth and nitrogen uptake, an empirical model for bread making quality (loaf volume) was developed from five years of data from the free air carbon dioxide enrichment experiment at Horsham, Victoria, for three bread-wheat cultivars – Janz, Silverstar and Yitpi.

Results

- A regression-based model accounted for 82% of variation in loaf volume.
- Significant terms were grain protein concentration, eCO₂, cultivar and a cultivar x eCO₂ interaction.
- At a given protein concentration and CO₂ level, Janz and Silverstar both had loaf volumes over 100 cm³ larger than Yitpi.
- Fewer samples met the current minimum grain protein percentage (13%) for acceptance into the hard-wheat H1 pool under eCO₂.
- The greatest impact of eCO₂ on acceptance into H1 pool was on Silverstar.



Relationship between grain protein concentration and loaf volume for cultivars Janz and Yitpi under ambient (aCO₂) and elevated CO₂ (eCO₂).

Summary of the percentage of cases satisfying the minimum grain protein (GP) level (13%) for the H1 hard wheat pool under ambient (aCO₂) and elevated CO₂ (eCO₂), mean GP concentration, loaf volume predicted at a GP concentration of 13%, standard errors of differences (SED) and the statistical probability level of significance (P).

Cultivar	n	Percentage of samples in H1 hard wheat pool		Grain protein concentration (%)			P	Loaf volume (cm ³)			P
		aCO ₂	eCO ₂	aCO ₂	eCO ₂	SED		aCO ₂	eCO ₂	SED	
Janz	75	76	62	13.57	13.14	0.15	< 0.01	820	780	13	<0.01
Silverstar	43	64	24	12.09	11.53	0.01	<0.001	830	840	16	ns
Yitpi	118	81	71	13.98	13.33	0.13	<0.001	710	690	10	<0.1

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