Economic Development, Jobs, Transport and Resources

What is the impact of elevated CO_2 and N management on grain quality?

Cassandra Walker Roger Armstrong
Joe Panozzo Glenn Fitzgerald

AGRICULTURE VICTORIA

Rising levels of CO_2

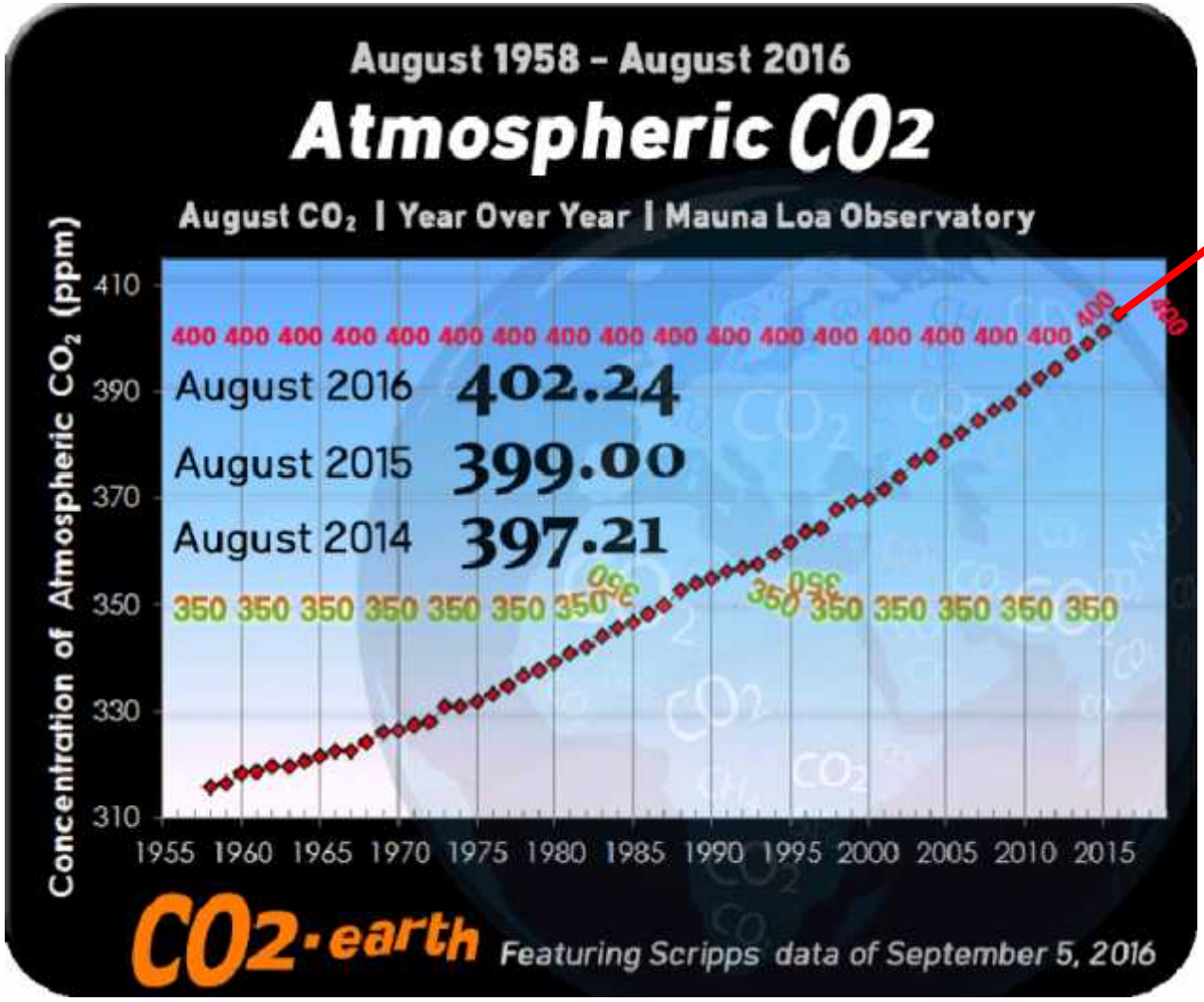


Chart source: CO2now.org

Rising levels of CO_2

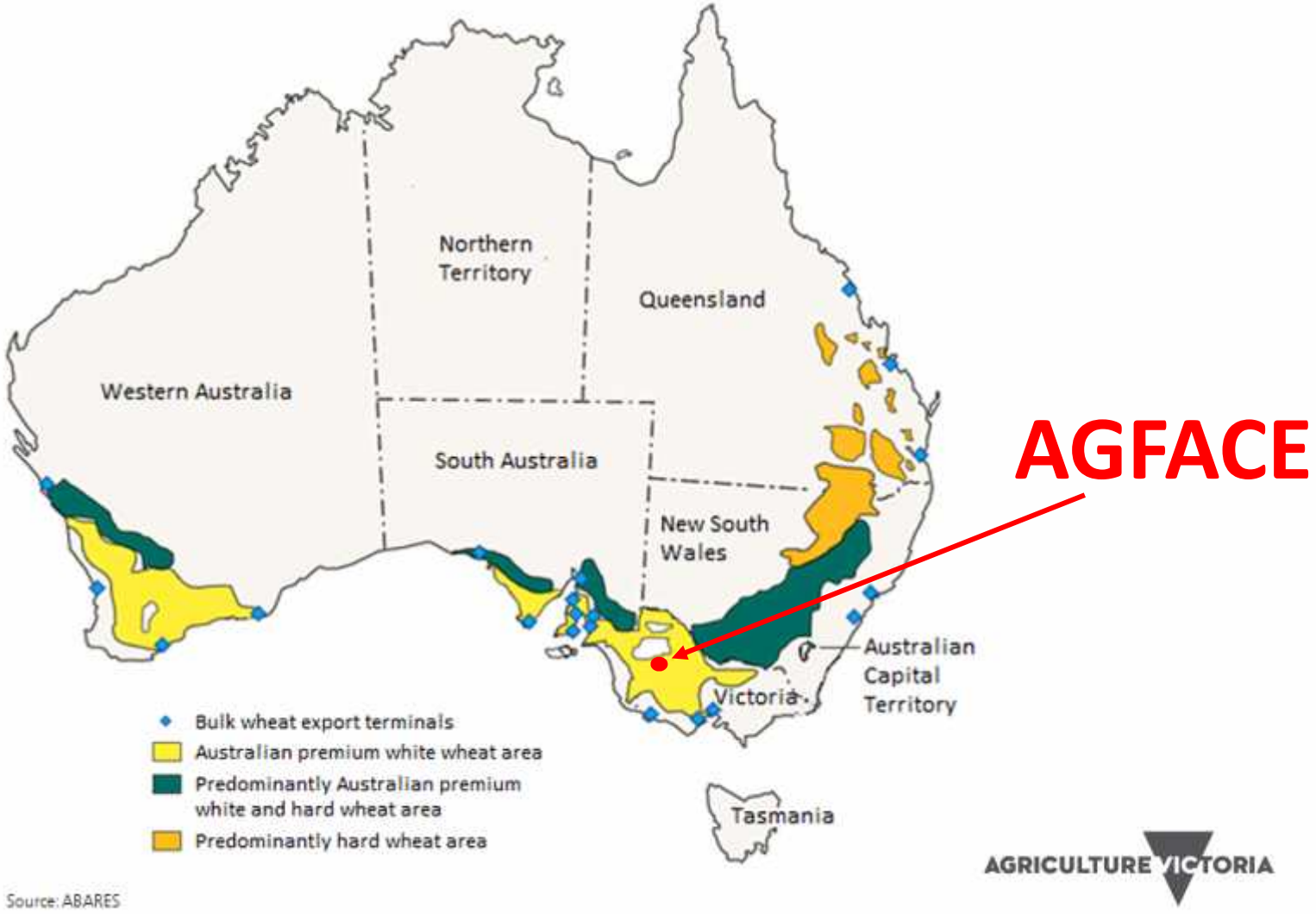
AGFACE:

The "Australian Grains Free Air CO_2 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



Economic Development, Jobs, Transport and Resources

AGRICULTURE VICTORIA

Rising levels of CO_2 and Agriculture

C3 plants response to eCO_2:

- **Reduced need for RuBisCO**
  - → **less leaf, plant and grain nitrogen**
- **Increased Carbon uptake**
  - → **increased biomass and grain yields**
- **Any eCO_2 'fertilisation' effect on plant production is strongly related to the N supply**

AGFACE Research Questions

- **What is the impact of elevated CO_2 (eCO_2) on wheat yield, grain protein content and baking quality?**
- **Can N management strategies be used to overcome the decline in grain protein content under eCO_2?**
- **What are the implications of eCO_2 for plant breeding?**

Impact of eCO_2 → Grain Yield

Global Change Biology

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

Elevated atmospheric [CO_2] can dramatically increase wheat yields in semi-arid environments and buffer against heat waves

GLENN J. FITZGERALD[1], MICHAEL TAUSZ[2], GARRY O'LEARY[1], MAHABUBUR R. MOLLAH[1], SABINE TAUSZ-POSCH[3], SAMAN SENEWEERA[4], IVAN MOCK[1,5], MARKUS LÖW[2], DEBRA L. PARTINGTON[6], DAVID MCNEIL[7] and ROBERT M. NORTON[3,8]

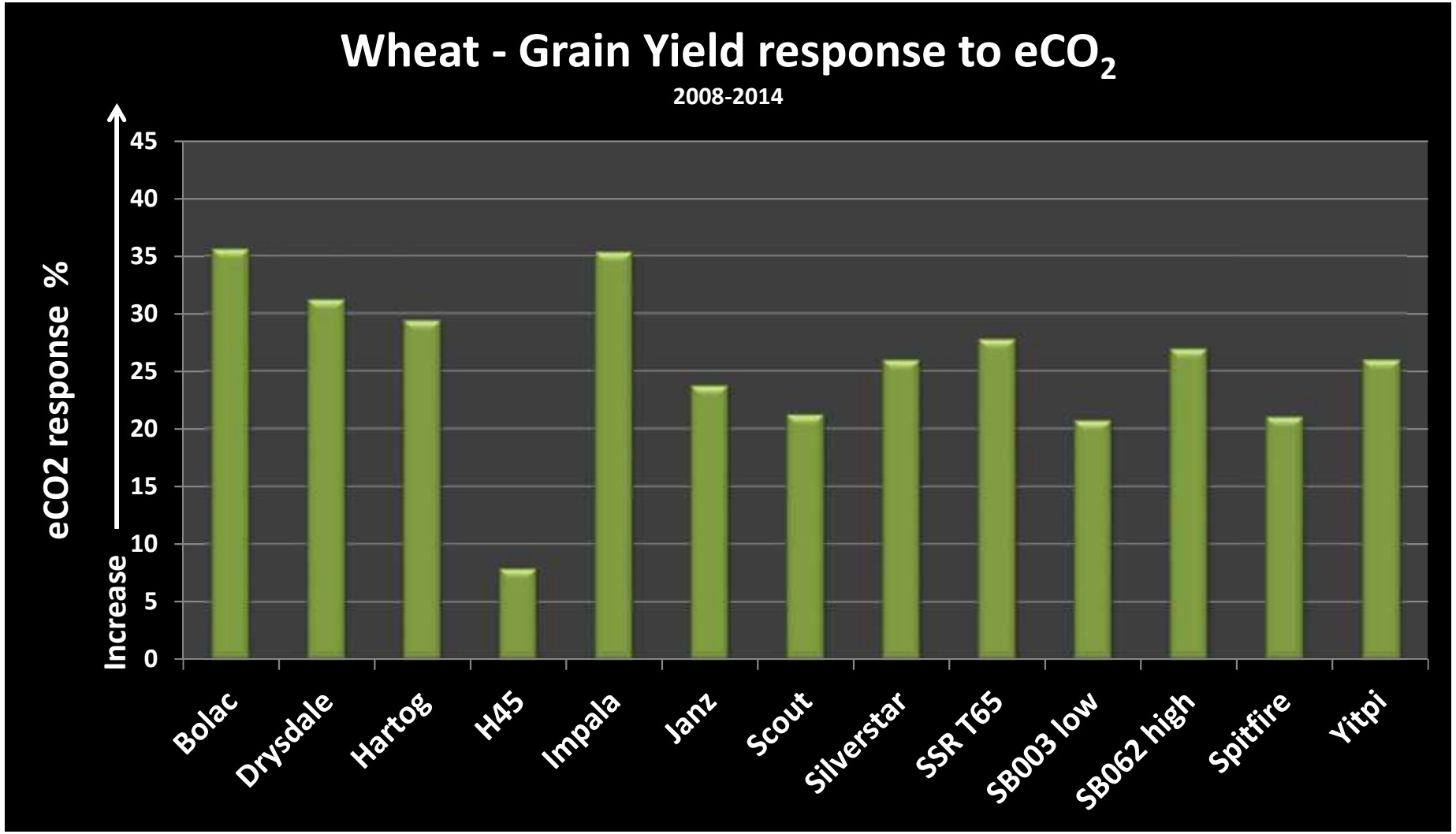
[1]*Victorian Department of Economic Development, Jobs, Transport and Resources, Private Bag 260, Horsham, Vic. 3401, Australia,* [2]*Department of Forest and Ecosystem Science, The University of Melbourne, 4 Water Street, Creswick, Vic. 3363, Australia,* [3]*Faculty of Veterinary and Agricultural Sciences, The University of Melbourne, 4 Water Street, Creswick, Vic. 3363, Australia,* [4]*Centre for Crop Health, University of Southern Queensland, Toowoomba, Qld 4350, Australia,* [5]*Dodgshun Medlin Agricultural Management, 348 Campbell St, Swan Hill, Vic. 3585, Australia,* [6]*Victorian Department of Economic Development, Jobs, Transport and Resources, Hamilton Centre, Mount Napier Road, Hamilton, Vic. 3300, Australia,* [7]*Tasmanian Institute of Agriculture, Private Bag 98, Hobart, Tas. 7001, Australia,* [8]*International Plant Nutrition Institute, 54 Florence St, Horsham, Vic., Australia*

- **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 eCO_2 → Grain Yield

Increased



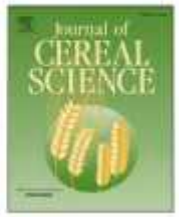
Impact of eCO_2 → Grain Protein Content

Journal of Cereal Science 60 (2014) 461–470

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs



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%**

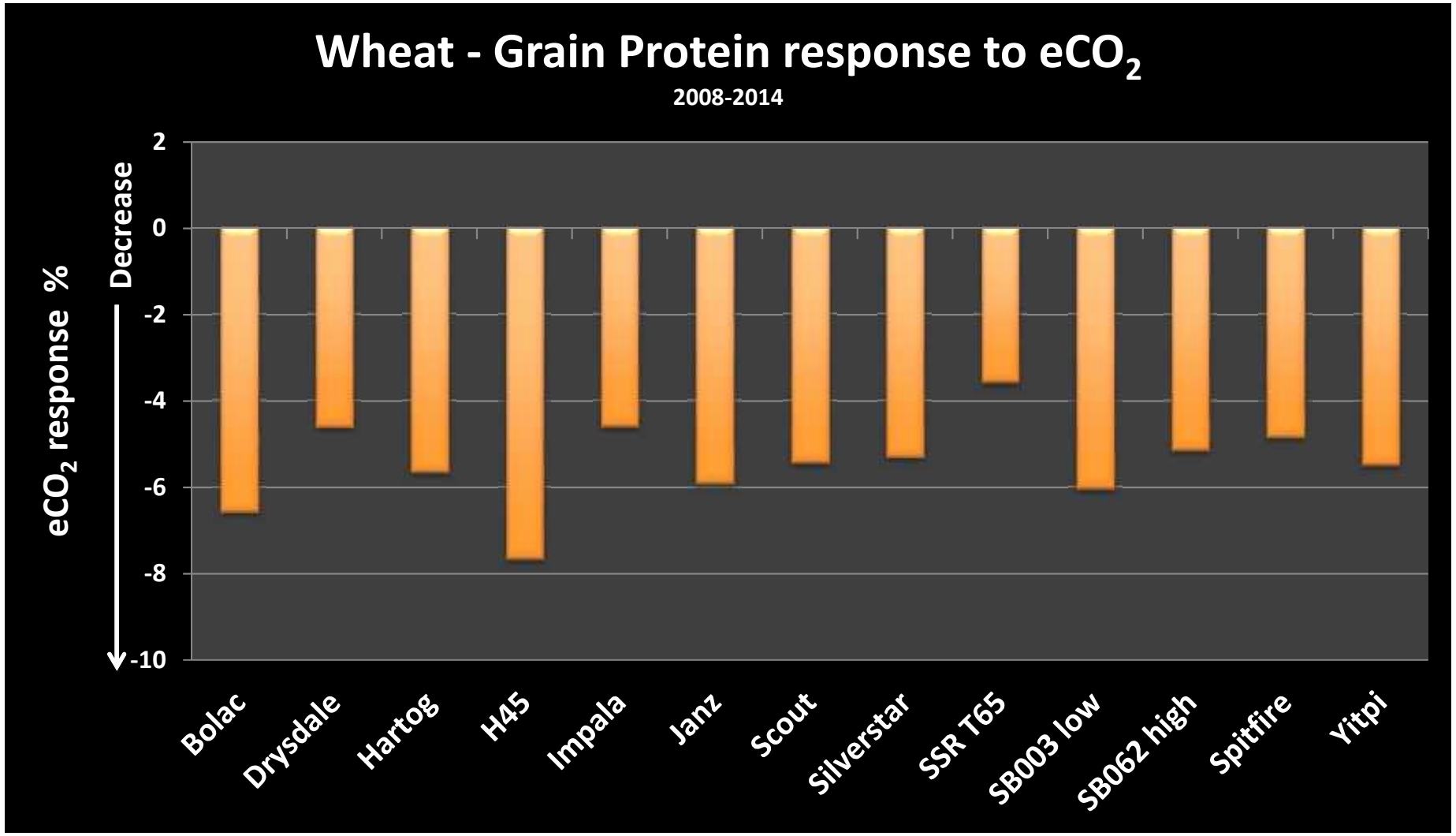
P=0.01

Confirms other researchers findings:

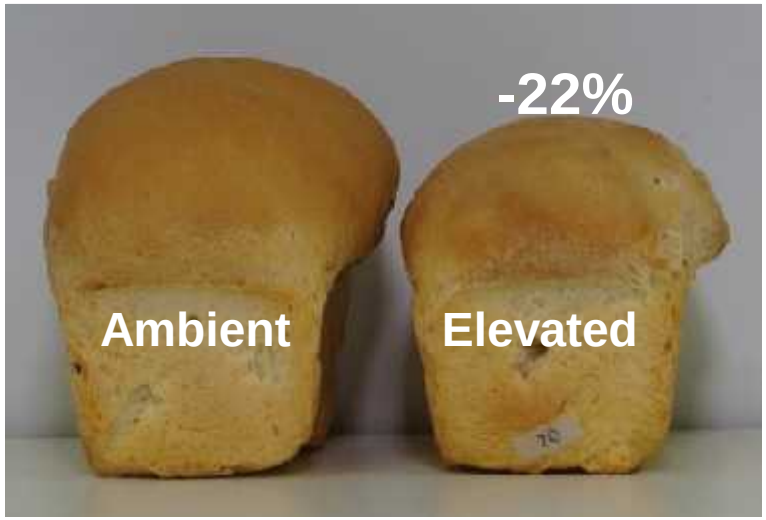
Erbs et al 2010; Hogy et al 2009; Kimball et al 1995; Taub et al 2008; Wieser et al 2008

Impact of eCO_2 → Grain Protein Content

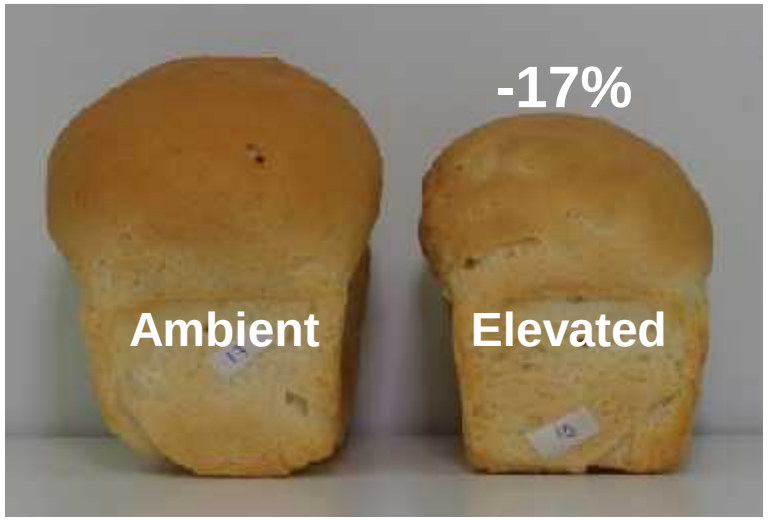
Reduced



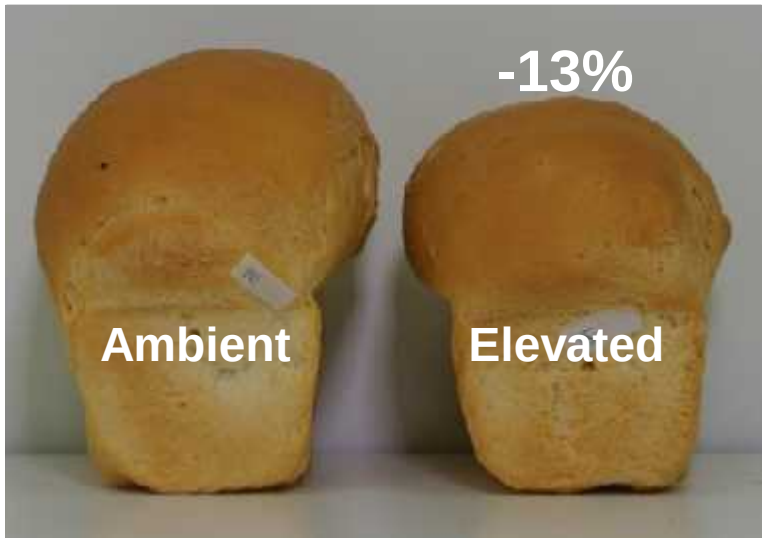
Scout



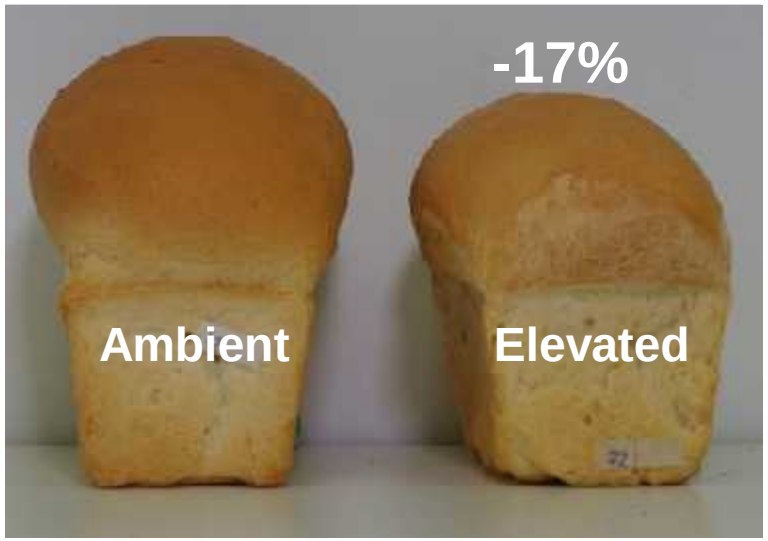
Yitpi



Gladius

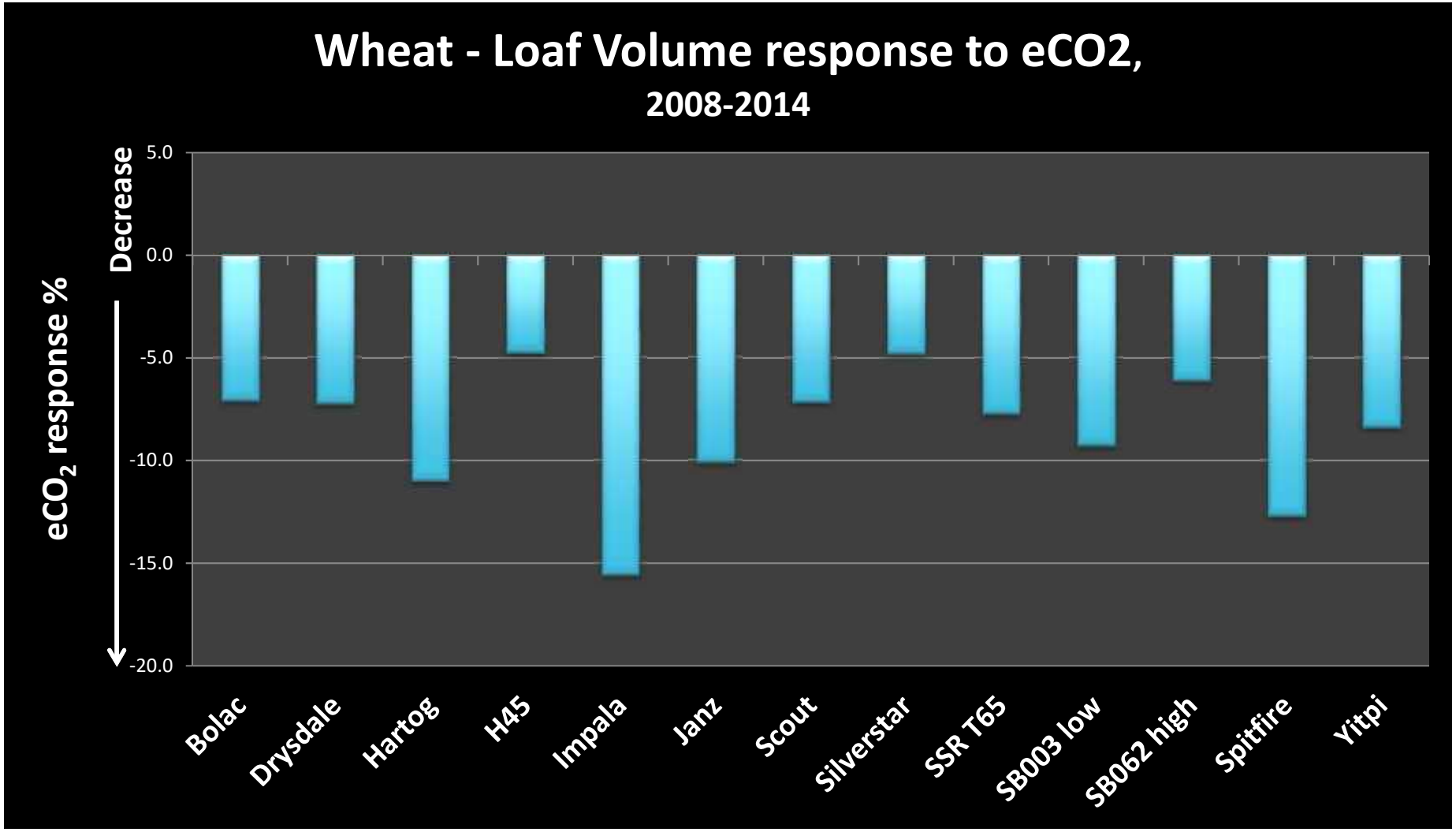


Wyalkatchem



Impact of eCO_2 → Bread Quality

Reduced



Impact of eCO_2 → Bread Quality

Journal of Cereal Science 60 (2014) 461–470

Contents lists available at ScienceDirect

Journal of Cereal Science

journal homepage: www.elsevier.com/locate/jcs

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 eCO_2 → Bread Quality

Reduced Loaf Volume (-9.1%)

- **Partially due to reduced grain protein**
- **Deleterious effects**

  Greater reduction in loaf volume under eCO_2
  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 CO_2 on grain quality…

One Hypothesis is that:

- **N-management strategies can retain grain protein content under eCO_2**

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**

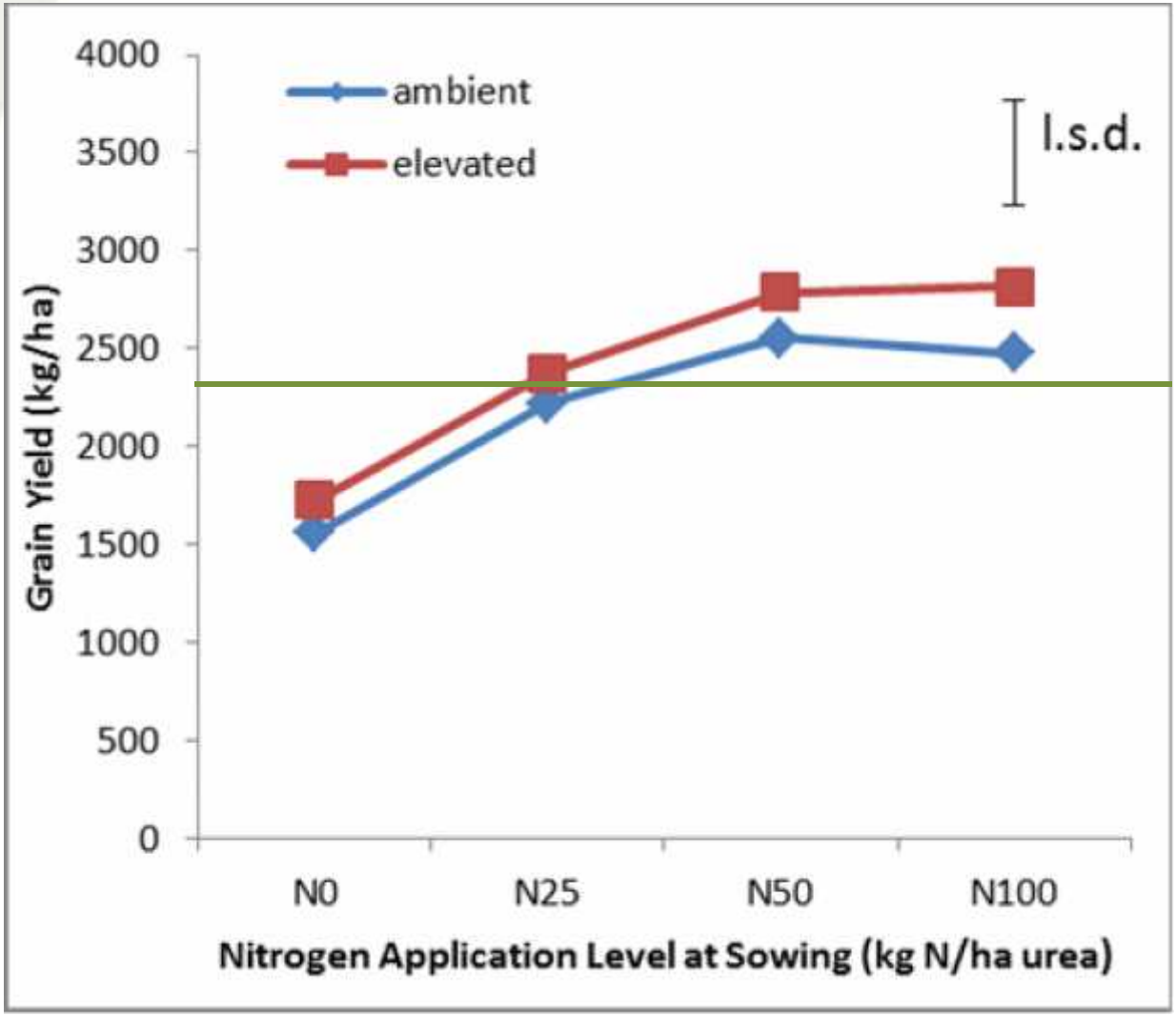
  25 kg N/ha urea equivalent
- **Top dressed urea**

  25 kg N/ha urea equivalent
- **Slow release urea**

  25 kg N/ha urea equivalent

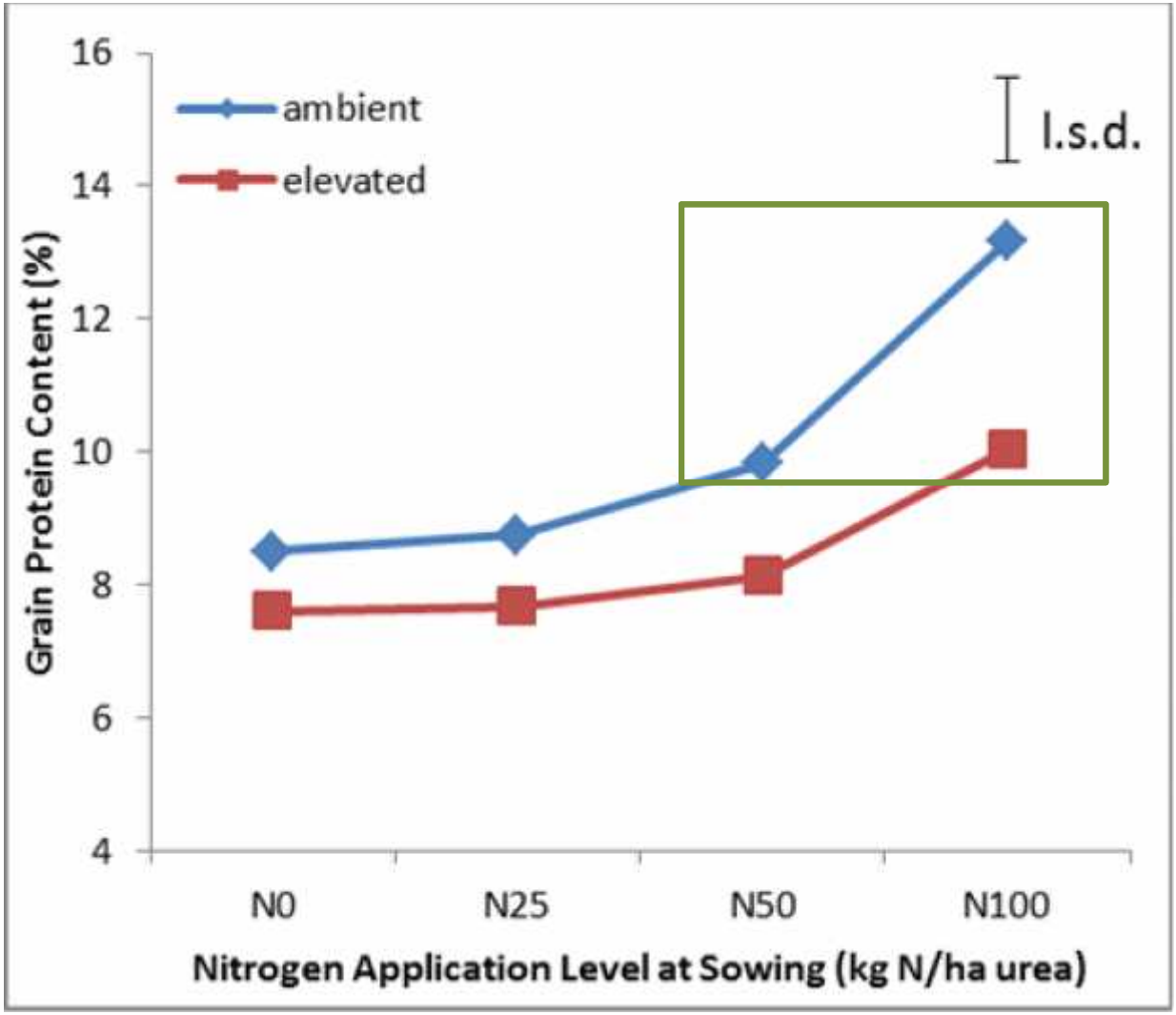
N-FACE

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

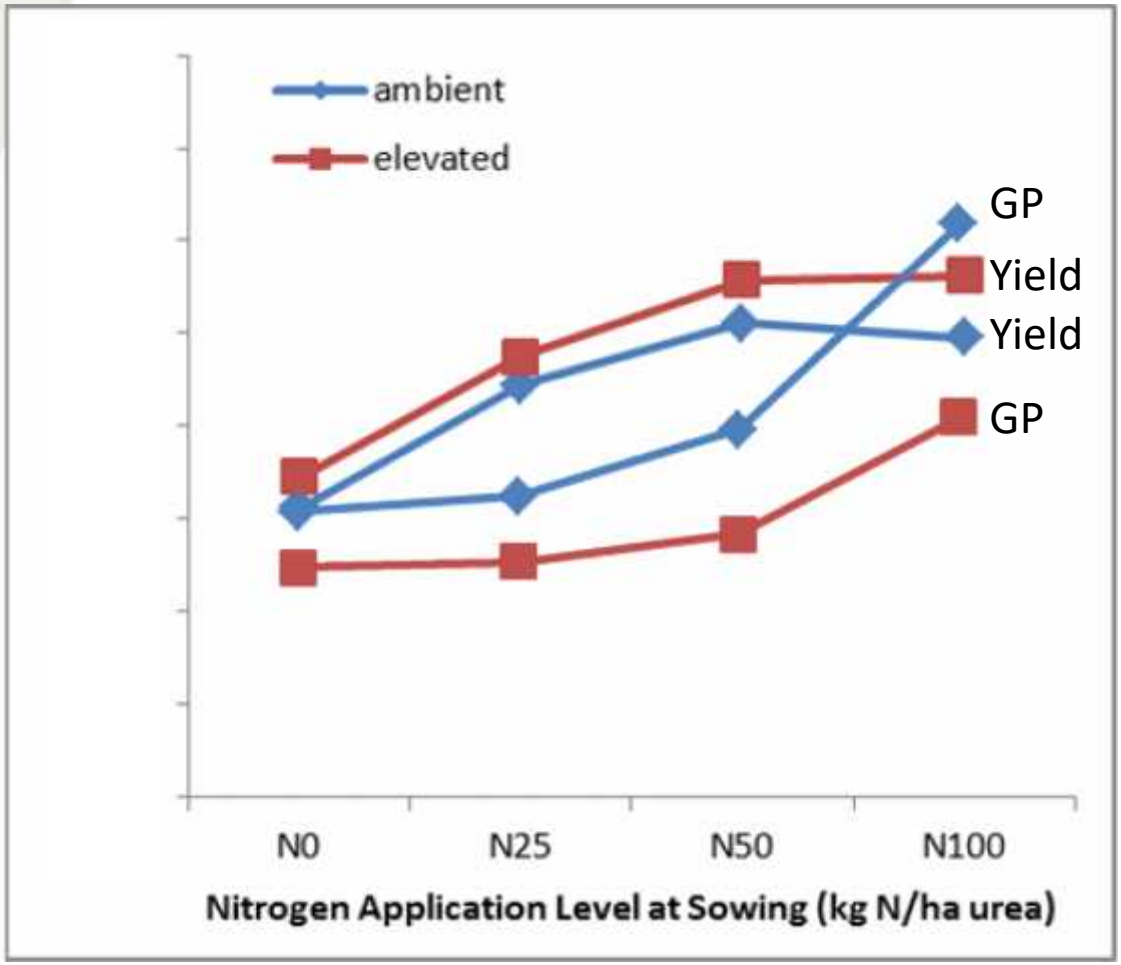


N-FACE

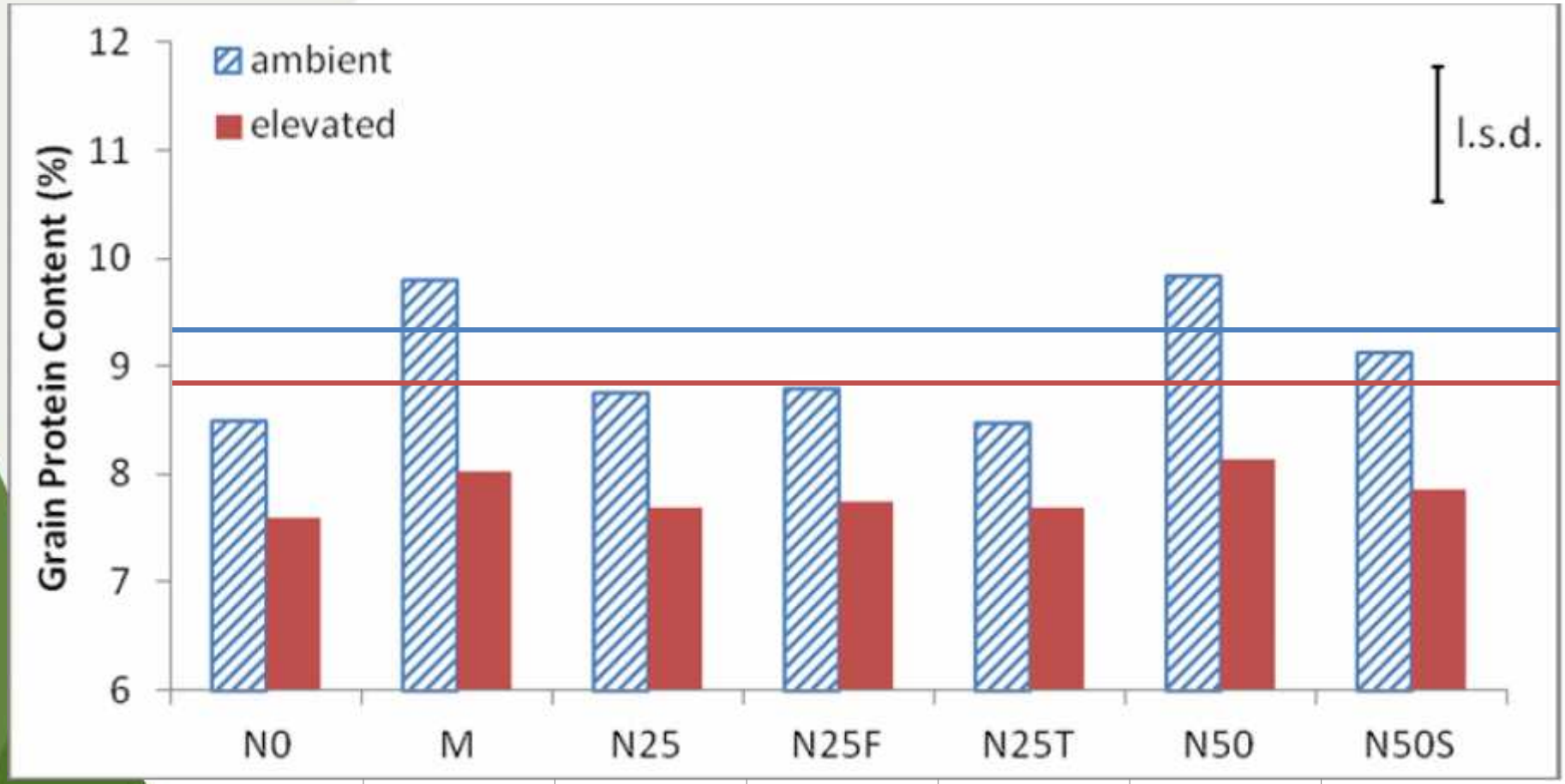
Significant grain protein responses were not observed until 100kg/ha of N fertiliser was applied under eCO_2



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 eCO_2

- **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 CO_2 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 eCO_2 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

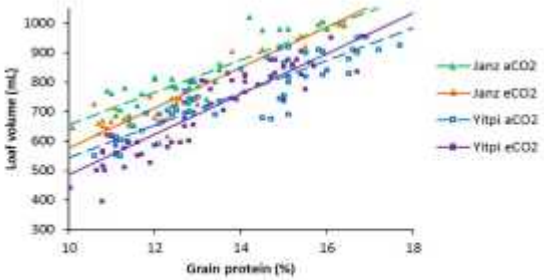
An empirical model of wheat baking quality under elevated CO_2

Malcolm McCaskill[1], Garry O'Leary[2], Joe Panozzo[2], Cassandra Walker[2], Debra Partington[1]

Elevated CO_2 (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 CO_2 level, Janz and Silverstar both had loaf volumes over 100 cm^3 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 CO_2 (eCO2).

Summary of the percentage of cases satisfying the minimum grain protein (GP) level (13%) for the H1 hard wheat pool under ambient (aCO_2) and elevated CO_2 (eCO_2), 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

AGRICULTURE VICTORIA

AGFACE funders

- Cassandra Walker, Ag VIC
- Joe Panozzo, Ag VIC
- Glenn Fitzgerald, Ag VIC
- Michael Tausz, UoMNathan Neumann, Ag VIC
- Garry O'Leary, Ag VIC
- James Nuttall, Ag VIC
- Sabine Tausz-Posch, UoM
- Roger Armstrong, Ag VIC
- Mahabubur Mollah, Ag VIC
- Piotr Trebicki, Ag VIC
- Friday Obanor, CSIRO
- Shu Kee (Raymond) Lam, UoM
- Clayton Butterly, La Trobe
- Caixian Tang, La Trobe
- Chris Korte, Ag VIC
- Debra Partington, Ag VIC
- Simone Dalton, Ag VIC
- Alan Yen, Ag VIC
- Narelle Nancarrow, Ag VIC
- Markus Löw, UoM
- Maryse Bourgault, UoM
- Helale Bahrami, UoM
- Alireza Houshmandfar, UoM
- Allene Macabuhay, UoM
- Rebecca Vandegeer, UoM
- Pramesha Madurangi , UoM
- Shihab Uddin, UoM
- Shahnaj Parvin, UoM
- Osmin Torres-Guttierrez, UoM
- Paul Melloy, CSIRO
- Russel Argall, Ag VIC
- Peter Howie, UoM
- Ash Purdue, Ag VIC
- Sam Henty, UoM
- Jason Ellifson, Ag VIC
- Simone Vassiliadis, Ag VIC

Members at large: Rob Norton, UoM (IPNI), David McNeil, Ag VIC (Uni Tas); Jo Luck, Ag VIC; Saman Seneweera, UoM (USQ); Mark Nicolas, UoM; Jason Brand, Ag VIC; Sukumar Chakraborty, CSIRO; Angela Freeman, Ag VIC; Grant Halloway, Ag VIC; Janine Fitzpatrick, Ag VIC; Justine Ellis, Ag VIC, Jennifer Briggs, Ag VIC; Nimesha Fernando, UoM (Ag VIC), Humaira Sultana, UoM; Chamindathee L Thilakarathne, UoM; Jian Jin, La Trobe; Kyla Finlay, Ag VIC

AGRICULTURE VICTORIA

Australian Government

Department of Agriculture, Fisheries and Forestry

THE UNIVERSITY OF MELBOURNE

Australian Government

Grains Research and Development Corporation

GRDC

GRAINS RESEARCH & DEVELOPMENT CORPORATION

AGRICULTURE VICTORIA

Economic Development, Jobs, Transport and Resources