Elevated Carbon Dioxide and Wheat Nutrition– Lessons From The Australian Grains Free Air Carbon Dioxide Enrichment Experiments

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INTRODUCTION

Atmospheric carbon dioxide (CO_2) has been rising since the industrial revolution, and at the present rate will reach about 550 µmol mol^{-1} by 2050. This increase, along with the consequent perturbations of climate will profoundly influence food production and farming systems. Higher CO_2 levels are generally reported to stimulate growth in C3 plants. Uncertainty about how this increase would interact with hotter and drier growing conditions led to the establishment of the Australian Grains Free Air Carbon Dioxide Enrichment (AGFACE) facility in 2007. We provide an overview of the results from the AGFACE research group relating to wheat crop nutrition.

METHODS

The AGFACE facility is at Horsham (36.7519°S, 142.1144°E) in southeastern Australia. The facility has 8 elevated CO_2 FACE rings (~550 µmol mol^{-1}) and 8 control (~385 µmol mol^{-1}) rings with 12 m rings and 12 plots each 4 m by 1.7 m per ring (2007/2008) or 16 m rings wth 24 plots (after 2009). These main CO_2 effects are combined with different water supply (by irrigation), temperature during grain fill (by altering sowing time), nitrogen (by fertilizer) and cultivar. CO_2 was injected over the crop in open-air rings from emergence until maturity in 2007, 2008 and 2009 (Mollah et al. 2009). Growth, yield, water use, grain mineral content and yield have been measured for each of the treatments and these data analysed as a factorial analysis of variance.

RESULTS AND DISCUSSION

Growth and Yield

Elevated CO_2 increased crop biomass at maturity by 22% (2007), 31% (2008) and 32% (2009). Mean grain yield of two common wheat cultivars (Yitpi and Janz) increased on average from 252 g m^{-2} to 322 g m^{-2} when grown under elevated CO_2 (Table 1). Sowing time and additional water affected growth and yield with the later sowing showing no response to higher CO_2 in 2008. In two of three years, kernel weight increased with higher CO_2 although there was no consistent change in other yield components (Norton et al. 2010).

Nutrient demand and supply

When grown under elevated CO_2, plants had lower tissue N content particularly later in growth, but there were few interactions with temperature, water or cultivar. For example, in 2008 leaf N concentration at flowering declined from 3.8% to 3.5% ($p<0.00$) (Norton et al. 2010) although the lower leaf N content may not have compromised photosynthetic capacity as RubisCo activity increased (Thilikarthne et al. 2013). Grain protein at maturity declined significantly in nearly all situations under elevated CO_2 (Table 1). Fernando et al. (2012) showed in one cultivar that protein declined from 15.5% to 13.5%. Despite this, the demand for N increased due to the stimulation of growth, which may be a consequence of reduced plant N causing less remobilisation from the leaves to the grain during grain filling. Over all the experimental treatments, elevated CO_2 increased crop N removal by 20% (Lam et al. 2012).

Table 1. The effect of elevated CO_2 on the grain yield and grain N content of wheat from the AGFACE experiment. All means within a year are significantly different (*$p<0.05$*)

Factor	[CO_2] (µmol/mol)	2007	2008	2009
Grain yield (g m^{-2})	*380*	258	247	252
	550	323	310	332
Grain N content (%)	*380*	2.44	3.16	3.06
	550	2.33	3.04	2.81

Elevated CO_2 did not affect the efficiency at accessing fertilizer N, and in the AGFACE there was no evidence of differences in N mineralisation from crop residues (Lam et al. 2012a). Nitrogen supply from biological N fixation did increase under elevated CO_2 but this response was dependant on an adequate P supply to the legume (Lam et al. 2012b). The relative value of legume derived N to subsequent cereals may be reduced under elevated CO_2. However, compared to N fertilizer application, legume incorporation will be more beneficial to grain yield and N supply to subsequent cereals under future climates (Lam et al. 2013).

Concentration of grain S, Ca, Zn and Fe decreased in wheat grown under elevated CO_2. This could not be fully explained by "yield dilution and the N:S ratio also declined (Fernando et al. 2012) and preliminary results indicate that this affects baking quality, as well as protein quantity. The reduction in grain protein was correlated with Fe, Zn, and S concentration, so that elevated CO_2 is likely to exaggerate worldwide Fe and Zn malnutrition for those on grain-based diets, although lower grain phytate concentrations may offset some of this decline (Fernando et al. 2012).

CONCLUSIONS

This research identified that nutrient management strategies will need review under elevated CO_2. The pattern of growth, and therefore the temporal pattern of nutrient demand mean new combinations of the nutrient source, rate, time, and place will be needed.

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