Climate Change and Wheat Crop Responses—*FACEing the Future*

By Rob Norton, Glenn Fitzgerald, and Michael Tausz

Climate change, with higher temperatures and lower rainfall is challenging us now and will continue to do so in the future. However, some of the adverse effects of changing weather patterns may be reduced through the beneficial effects of higher carbon dioxide (CO_2), even in low yielding environments. There are traits in current varieties that could provide keys to develop varieties better adapted to a warm, hot, and carbon-rich future.

The past decade has seen difficult seasonal conditions in many areas, including southeastern Australia. This region has seen a string of below average rainfall years, coupled with warmer temperatures. Weather records held by the Bureau of Meteorology show that since the 1970s, the decade leading up to 2010 has seen around 60 mm less annual rainfall in the rainfed cropping regions of South Australia, Victoria, and southern New South Wales **(Figure 1)**.

It is predicted that changes in greenhouse gases such as CO_2 will continue to increase temperatures and interfere with weather patterns (Carter et al., 2007). Predictions for much of the grain producing regions of southern Australia suggest that by 2050, rainfall will decline by around 5 to 10% and temperature will rise by 1 to 2°C (CSIRO, 2011).

Farmers have adapted to these changes through careful crop selection and management, adopting flexible programs to deal with uncertain seasons. A recent survey of growers in the Victorian Mallee showed that farmers have changed their management practices by a combination of increasing pasture or fallow frequency, reducing plant density, selecting shorter season crops, and increasing residue retention. As well, fertilizer N management is focused on rainfall which alters the yield potential and so the nutrient demand. Such changes are really risk management strategies to deal with drier and warmer seasons.

But the real question is will this be enough to adapt to a future climate and keep farm business productive and profitable?

Role of Carbon Dioxide

Carbon dioxide is part of the cause of global warming, but rising levels also have a positive effect. This trace gas, which makes up around 0.04% of the atmosphere, is used by plants as the building block of sugars and other plant materials in the process of photosynthesis. Research supports this view and has documented crops like wheat (C3 plants) showing increased growth and yield (up to 30%) in their varieties. However, other plants such as sorghum (C4 plants) do not show this response as their carbon capture mechanisms are much more efficient than C3 plants. Elevated CO_2 also causes the pores in the leaf (stomata) of both C3 and C4 plants to close—a mechanism that allows plants to conserve water.

The outcome of these responses is that wheat crops should show high water use efficiency when grown under the higher CO_2 expected in the future. Present research on this topic also shows that temperature and water availability could affect the response expected to high CO_2. The actual impact of

Common abbreviations and notes: N = nitrogen; FACE = Free Air Carbon Dioxide Enrichment.

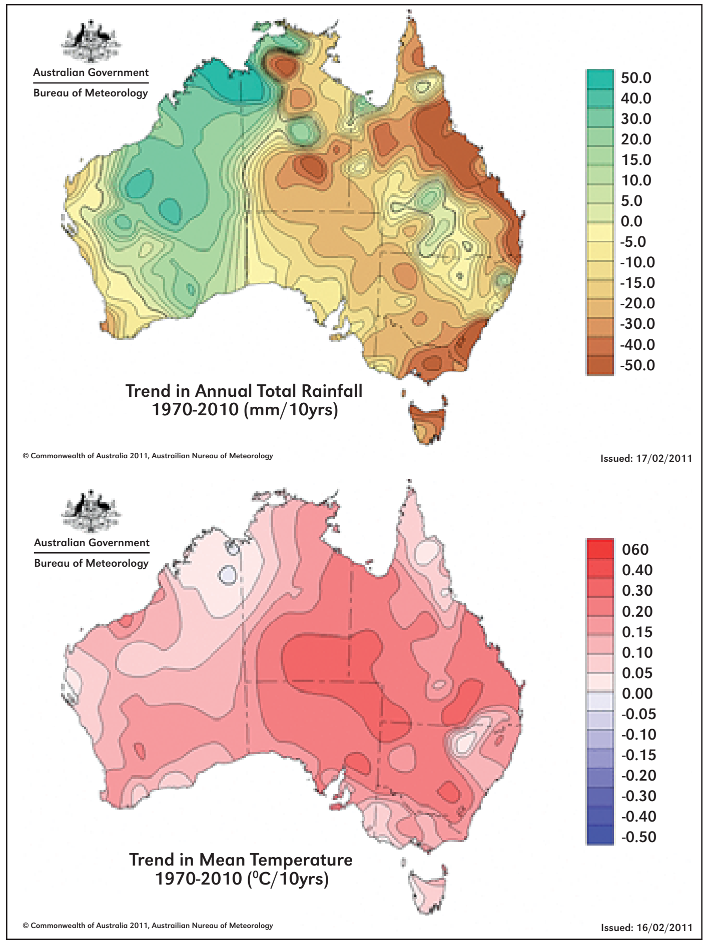

Figure 1. Decadal changes in annual total rainfall (top) and mean temperature (bottom) for South Australia for the period 1970 to 2010.
(Source: Bureau of Meteorology – http://www.bom.gov.au/cgi-bin/climate/change/trendmaps.cgi, last accessed August 2011).

higher temperatures and reduced water availability may in fact reduce any growth benefit from the high CO_2. This research investigates how crops will respond to a future climate that is warmer, drier, but has more CO_2 in the air.

FACE Study Sites

In 2007, the University of Melbourne and the Victorian Department of Primary Industries with support from the (then) Greenhouse Office and Grains Research Development Corporation commissioned the Australian Grains Free Air Carbon Dioxide Enrichment (AGFACE) facility to test the interaction of water, temperature, and CO_2. Two facilities were established, one at Horsham in the Wimmera and the other at Walpeup in the Mallee.

Figure 2. One of the eight free-air CO_2 enrichment rings in the field at Walpeup, Victoria. Eight normal plot areas well spaced from these rings were used as comparisons.

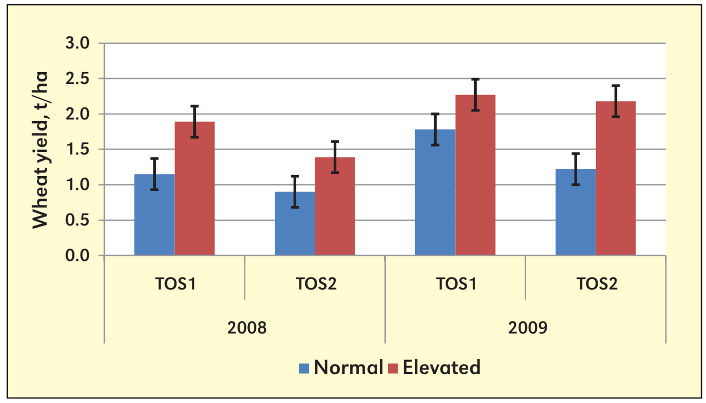

Figure 3. Mean wheat grain yield response to elevated CO_2 (550 ppm versus 385 ppm) with two sowing times (TOS1 and TOS2) at Walpeup in 2008 and 2009. Standard error for yield is 0.22 t/ha.

At these FACE sites, the crop is grown in the open air and normal soil, and the CO_2 level is raised by fumigating those treatments through distributors around the area's perimeter **(Figure 2)**. Every 2 seconds, the level of CO_2 is measured and adjusted to a target of 550 ppm. This compares to the current day time level of 385 ppm in the field.

At Walpeup, the rings were sown with wheat at normal sowing rates, but at two different sowing times—either at the traditional time in mid-May, or late-June to force crop growth from the later sowing into relatively warmer conditions during grain fill. Growth, yield, quality, N dynamics, and water use were all measured on the experiments in 2008 and 2009.

Results

Crops grown under high CO_2 gave, on average, about a 50% increase in yield. This increase occurred irrespective of the sowing time or year **(Figure 3)**. The May to November rainfalls were a dry 148 mm in 2008 and a more normal 264 mm for 2009. The harvest index of these crops—the proportion of growth that goes to grain—was not reduced with high CO_2 so the plants were actually operating more efficiently with the extra carbon available to them in the atmosphere.

The yield response suggests that CO_2 will help reduce the impact of higher temperatures and lower rainfalls, even in the low rainfall regions of Australia. However, higher yields come with lower grain protein content which is part of a physiological adaptation to having more CO_2. The plant invests less N in proteins associated with photosynthesis so that when grain filling starts, there is less N to move to the grain. Our sites were well-fertilized with N, but the grain protein contents still slipped from 15.3% (2008) and 15.5% (2009) under normal conditions to 13.4% (2008) and 13.5% (2009) under elevated CO_2. Reductions in grain mineral content and changes in other aspects of grain quality were also noticed.

The research has moved to investigate strategies to adapt wheat to produce high quality grain. In 2009 and 2010 at Horsham, a range of varieties were evaluated for their comparative growth, yield, and quality. To date, even with the small number of varieties tested, there are differences that will help develop better adapted types.

What we have reported here is only a small part of a large multi-discipline research project that seeks to identify and develop strategies to cope with impacts of climate change in the grains industry. Other research at the FACE site is on soil nutrient cycling processes, responses of legumes, and pest and disease impacts. The data are also being used to calibrate crop simulation models to develop adaptation strategies needed for the warm, dry, and carbon-rich world which seems to await us. BC

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