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Can our new cotton varieties handle our changing climate?

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AT A GLANCE…

- Understanding cotton physiology and growth is important for developing agricultural systems that are resilient to stresses induced by variable and changing climates.
- In recent studies we compared the early-season physiology and growth of old and more recent varieties under current and future climate regimes (including rising CO_2 and temperature).
- Cotton physiology and growth were responsive to changes in CO_2 levels and temperature, but there were some differences in the magnitude of some of these responses between varieties. The modern variety was able to compensate for less early biomass and a more compact growth habit by having higher photosynthetic rates per unit leaf area.
- Understanding physiological attributes of different cotton varieties may assist in breeding varieties increasingly suitable for projected environmental conditions.

FIGURE 1: Physiology responses of DP16 and 71BRF cotton grown in high CO_2 and warmer temperatures were measured

Research was conducted at the Western Sydney University's Hawkesbury Campus.

CURRENT projections for climate change indicate that Australia can expect more heatwaves, changes in rainfall distribution and an increase in the intensity of droughts. Natural atmospheric CO_2 concentration during the past 800,000 years ranged between 170 and 300 parts per million (ppm). But atmospheric CO_2 levels have been steadily increasing over the past 200 years from pre-industrial values of about 280 ppm to over 400 ppm in 2016, and with projections for further increases in the future.

This, in combination with rising air temperatures that drive leaf temperatures above the optimum (28–30°C), and changes in rainfall may have significant impacts on the physiology, growth, and yield of cotton. Understanding the impact is important for developing cotton systems that are resilient to stresses induced by variable and changing climates.

Australia's modern irrigated cotton industry developed in the 1960s in northern NSW and southern Queensland. The expansion of the modern industry was initially based on varieties from the US – but domestic breeding efforts led to the development of varieties better suited to the Australian environment. Modern varieties exhibit improved yield, fibre properties, and disease and insect resistance compared with varieties originating from the US.

Deltapine 16 (DP16) was a widely grown, non-transgenic commercial variety bred by Delta and Pine Land Co. in the southern United States during the 1970s, but is not currently in production. In contrast, Sicot 71BRF was a newer transgenic commercial variety, bred by CSIRO and released in 2008, which went on to dominate the market. Given there have been significant changes in Australian cotton varieties, management and yields, it is important to assess potential beneficial traits in older and more recent varieties in projected CO_2 and temperature conditions to maximise cotton production in future environments.

As part of a range of studies being undertaken to prepare the industry for impacts of climate change, a controlled environment glasshouse experiment was conducted to compare the early-season growth and physiology responses of DP16 and Sicot 71BRF cotton varieties grown in high CO_2 and warmer temperatures (Figure 1). The experiment was conducted in specialised glasshouses located at Western Sydney University specifically constructed for climate change research.

Results

We measured vegetative plant growth (leaves and stems), leaf photosynthesis, stomatal conductance (a measure of the degree of stomatal opening), and night respiration of young, well-watered cotton grown in these differing environmental conditions (temperature= 28/17°C or 32/21°C; and CO_2 concentration= 400 ppm or 640 ppm). Results of the experiment are shown in Table 1 and Figure 2.

TABLE 1: Percentage change in physiology of each cotton variety in response to high CO_2 and warmer temperatures. This shows where there are significant interactions between CO_2 and variety, and CO_2 and temperature.

Physiology measurements	Variety	↑ CO_2	↑ temperature
Photosynthesis	DP16	+28%	0
	71BRF	+43%	0
Stomatal conductance	DP16	0	0
	71BRF	0	+23%
Night respiration	DP16	+27%	0
	71BRF	0	0

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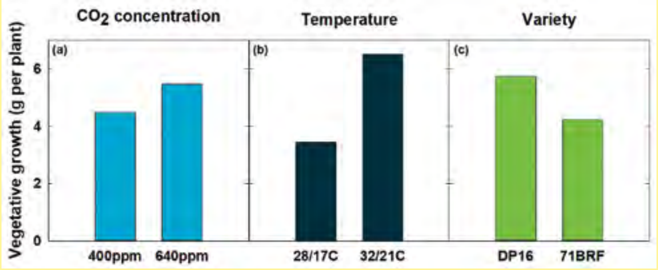
FIGURE 2: the main effects of (a) elevated CO_2, (b) warmer temperature and (c) variety on the early vegetative (leaf and stem) growth of cotton



Research was conducted at the Western Sydney University's Hawkesbury Campus.

In this study, we found that across both varieties, high CO_2 levels increased photosynthetic rates compared with plants grown at current CO_2 levels (Table 1). Leaf photosynthesis of both varieties responded positively to high CO_2, with a significant CO_2 by variety interaction because 71BRF responded more strongly.

In a high CO_2 environment, photosynthesis of 71BRF was 43 per cent greater than plants grown at current CO_2 levels, whereas photosynthesis of DP16 was increased by 28 per cent (Table 1). DP16 plants grown at high CO_2 had 27 per cent higher respiration rates than plants grown at current CO_2 levels, but this trend was not observed for the 71BRF variety.

Stomatal conductance of DP16 and 71BRF responded differently to warmer temperatures. Warmer temperatures increased stomatal conductance of 71BRF by 23 per cent, whereas DP16 did not respond to warmer temperatures. Greater stomatal conductance of 71BRF may have contributed to greater leaf-level water use than DP16, although it is also possible that total plant water use is greater for DP16 given it is a larger plant overall.

High CO_2 increased early vegetative growth (stems and leaves) of cotton by 22 per cent compared with plants grown at current CO_2 levels. Plants grown at warmer temperature (32/21°C) also had 89 per cent greater early vegetative growth than plants grown at 28/17°C.

DP16 had consistently greater vegetative growth than 71BRF (Figure 2). This can be attributed to greater leaf number and size, and thus greater light interception by DP16 plants, despite higher leaf-level photosynthesis per unit leaf area of 71BRF plants (Table 1).

The compact growth habit and higher leaf-level photosynthetic rates and lower respiration rates of 71BRF are potentially advantageous in current Australian production systems due to reduced leaf surface area for water loss by transpiration. In other words, 71BRF compensates for less early biomass and a more compact growth habit by having a higher photosynthesis per unit leaf area.

Conclusion

Future environments are anticipated to produce larger cotton plants with potentially greater requirements for water. Thus, plants with smaller, more compact vegetative growth habits and higher photosynthetic rates (e.g. Sicot 71BRF) may have an advantage over varieties with substantial plant growth and leaf area (e.g. DP16).

Our research continues to focus on understanding the implications of warmer temperatures and higher levels of atmospheric CO_2 on cotton physiology, growth and water use, using a combination of controlled environment glasshouse and field-based experiments. This will be important for optimising management of cotton in Australian production systems into the future.

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