

Part 3 – Final Report

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Climate change will affect cotton through rising atmospheric CO₂ levels, higher temperatures, lower humidity (higher Vapour Pressure Deficit (VPD)) and reduced water availability. Currently, predictions for rising temperature based on extreme climate projects are smaller than existing differences in temperature between seasons and across cotton regions. Therefore, opportunities exist to harness current understanding of cotton system adaptation to climate variability to plan for projected climate change. Although some research had previously been conducted on the main effects of rising CO₂ and temperature, VPD, and reduced water, there had been virtually no research that had addressed the real-world interaction of rising CO₂, temperature, VPD and reduced water. Therefore, the development of the National Facility for Cotton Climate Change Research has been a crucial aspect of investigating the response of field-grown cotton in Australian production systems to projected climate change.

Objectives

2. List the project objectives and the extent to which these have been achieved, with reference to the Milestones and Performance indicators.

Four in-field climate change chambers have been constructed and operational for three consecutive cotton seasons (Milestone 1.1). The chambers have been used for field-based research during the 2014-15, 2015-16 and 2016-17 cotton seasons (Figure 1).



Figure 1. Four chambers in the field during the 2014-15 cotton season to investigate the integrated effects of projected climate change in Australian production systems.

CSIRO has employed Kris Karpinski, who is skilled in the use of electronic equipment and field-based work (Milestone 2.1). Kris has provided technical and operational support over three cotton seasons with regard to investigating the interactive effects of climate change as part of the “Cotton Production in a Future Climate- Postdoctoral Fellow” project (Milestone 2.2). Furthermore, the National Facility for Cotton Climate Change Research has attracted a number of other researchers to undertake climate change research projects (Milestone 3.1). This includes researchers at Western Sydney University (PhD student Linh Nguyen), USDA (Paxton Payton), and collaborative research between Robert Sharwood (ANU), Warren Conaty, Susan Jaconis and Katie Broughton in combined growth, physiology, 2,3-5, triphenyltetrazolium chloride (TTC) analyses and Rubisco work. Additionally, as part of a collaborative CSIRO summer student project during the 2016-17 cotton season, Rose Baulch has recently completed a study “*Plant growth and development; an assessment of cotton development in elevated CO₂ and heat environments under standard farming management practices*”. Leaf samples have also recently been collected by Sharon Downes’ team to test for any changes in resistance of *Helicoverpa* under elevated atmospheric CO₂ and warmer temperatures.

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

Chamber design and operation

Four chambers were constructed as part of the National Facility for Cotton Climate Change Research. The 4 x 4 x 3 metre chambers were constructed of galvanised steel attached to a 1cm thick transparent plastic segment in the front and back. The chambers were enclosed with two layers of transparent plastic (F-CLEAN®; inside 80 µm thick and outside 100µm thick; 94% light transparent), which were inflated during the experiments. The chambers are portable, which enables standard crop and field rotations, and a different experimental configuration each cotton season.

Temperature inside the chambers were controlled by a Wadsworth EnviroSTEP controller, which operates an air conditioner unit (Vicot VRPA072A5; Figure 2) to maintain air temperature inside the chambers on average 2-4°C higher than ambient air temperature. Throughout the project, the temperature control systems have been fine-tuned and sensors were re-calibrated to improve day/night performance.



Figure 2: Side-on view of one of the chambers connected to the air conditioning unit during the 2014-15 cotton season.

Food grade CO₂ was injected into the chambers using perforated tubing located above the crop canopy, to maintain the desired CO₂ concentration (targets for ambient CO₂ were 400 ppm and for elevated CO₂ were 550ppm). The concentration of CO₂ and H₂O inside each chamber was monitored at 9 positions within the chamber and the injection of CO₂ was regulated using a Li-cor 840A CO₂/H₂O Gas Analyser.

Software (LabVIEW 2013, National Instruments; Figure 3) was used to monitor environmental conditions within each chamber on a real-time basis, and was used to set controls for variables such as atmospheric CO₂ and air temperature inside the chambers.

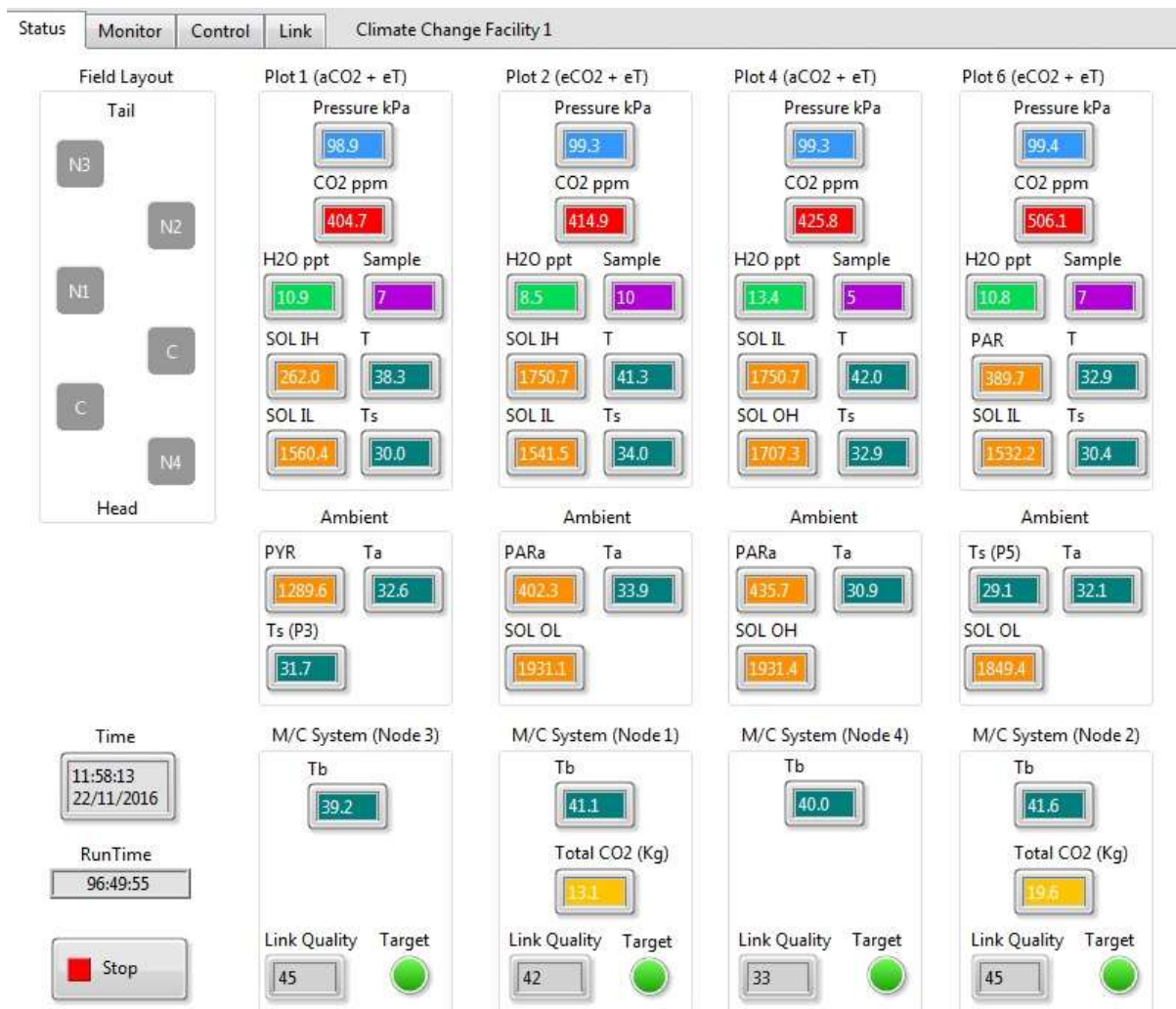


Figure 3: LabVIEW software allows the monitoring of chamber environmental conditions and sensors in real-time.

Drip irrigation was set up in the chambers and control plots, and the system was calibrated each year. Following rainfall events, the area inside the chambers were irrigated with the equivalent quantity of water to match precipitation in all of the treatments.

A generator system was used as a temporary back-up system for power outages. Although the generator did not run the air-conditioner systems, it was adequate to power fans inside the chambers and, with the chamber doors open, minimising extreme higher temperatures during power failures.

Results

4. Detail and discuss the results for each objective including the statistical analysis of results.

The chambers have successfully been used in field based climate change research on cotton for three consecutive years. Control of atmospheric CO₂ and air temperature (Figure 4) has been adequately controlled throughout each experiment.

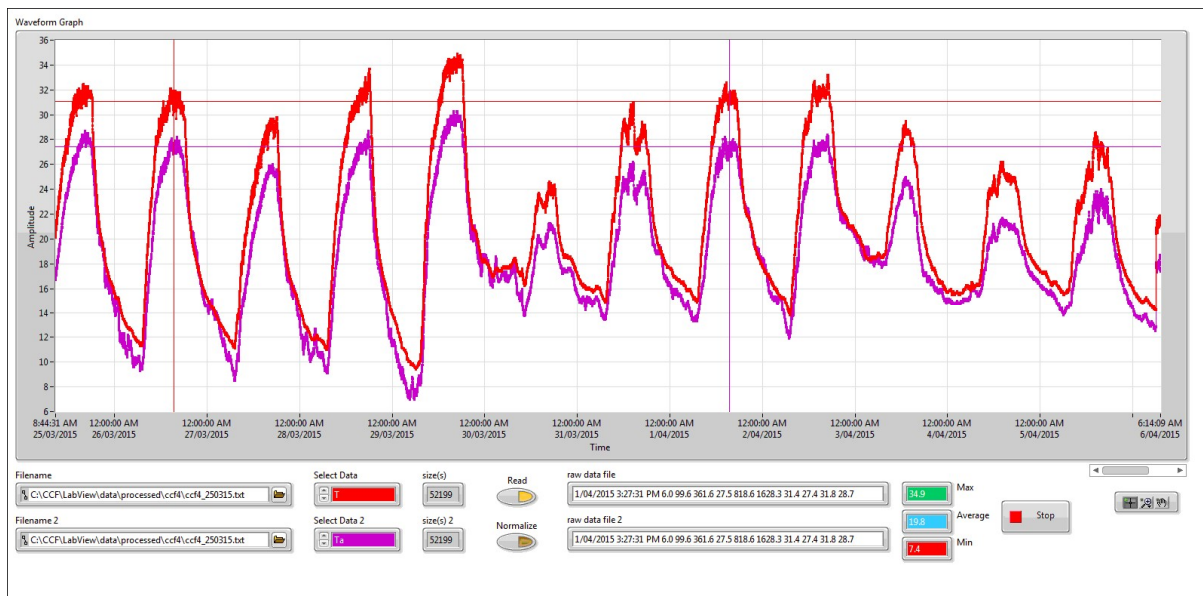


Figure 4: Air temperature inside one chamber (red) compared with ambient temperature outside the chamber (purple) for 11 days during the experiment period during the 2014-15 cotton season.

After conducting the initial experiments in the 2014-15 cotton season, a number of improvements were made to the systems during the course of the project. These included:

- Installing back-up UPS units for all monitoring systems, Wi-Fi gateway and control computer to mitigate frequent power interruptions.
- Implementing additional CO₂ delivery systems for the two ambient CO₂ chambers to compensate for CO₂ consumption by the cotton plants and thus maintain atmospheric CO₂ concentration at 400ppm (Figure 5). This included additional CO₂ warning mechanisms to ensure the safety of personnel working in the chambers.
- Installation of Wi-Fi antennae reflectors to increase signal strength, coverage and network reliability.
- Installation of additional hardware to enable monitoring of important environmental variables such as air temperature, soil temperatures, solar radiation, and photosynthetically active radiation. These have been interfaced to the individual chamber monitoring systems.

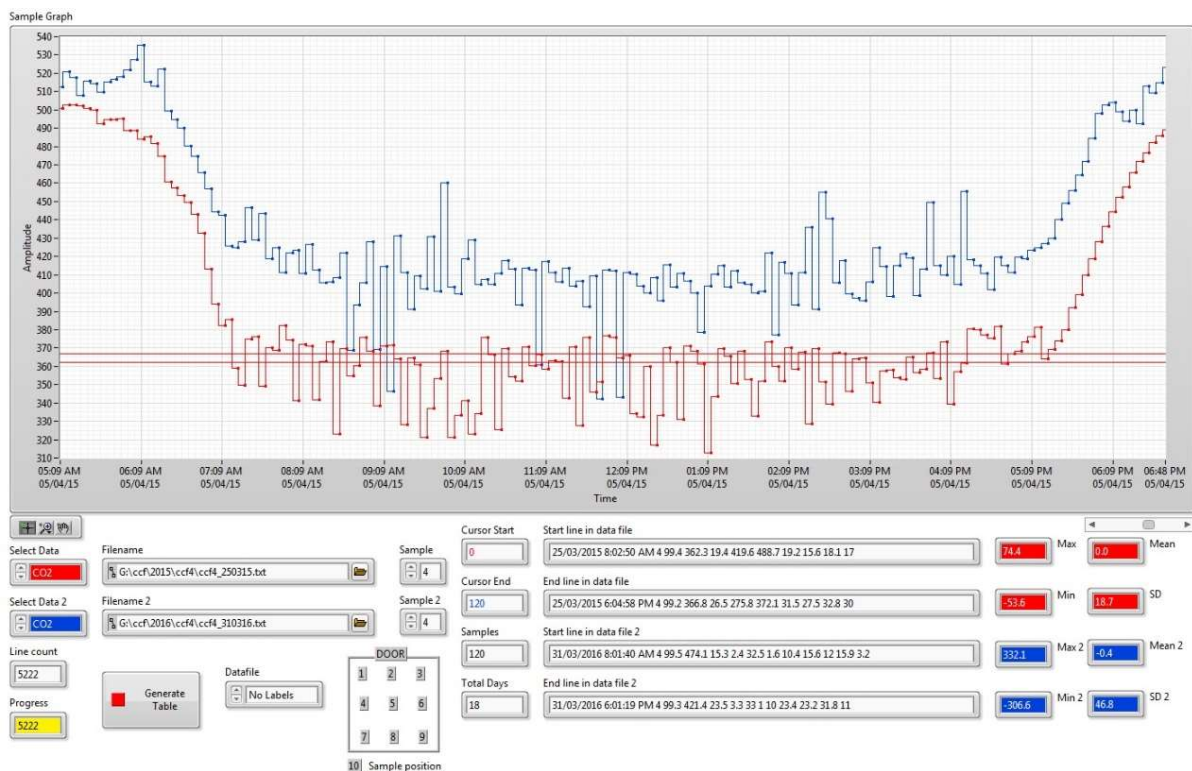


Figure 5: Comparison of atmospheric CO₂ control inside an ambient [CO₂] chamber for the 2014-15 cotton season (red) and the 2015/16 cotton season (blue).

Outcomes

5. Describe how the project's outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

It was identified in the project application that developing a National Facility for Cotton Climate Change Research will create a focused initiative to provide definitive information on climate change impacts on cotton production. The successful operation of the National Facility for Cotton Climate Change Research over three consecutive cotton seasons has enabled the collection of valuable data, providing information on physiology, growth and water use of cotton in future environments, as well as a better understanding of the effects of projected climate change on soil microbial communities. This Facility has also enabled collaborative research across a number of organisations (CSIRO, WSU, USDA, ANU). Thereby, through these collaborative projects, this project has, and will continue to contribute to the farming system program by:

- Improving knowledge of cotton growth and agronomy by quantifying the effects of extreme weather and future climate conditions on crop productivity and capacity to recover from these events,
- Improving management guidelines that enable growers to produce high-quality cotton lint, while simultaneously avoiding strategies that are mal-adaptive and reducing the environmental footprint under future climatic conditions; and
- Providing provisions for a robust adaptation framework to recover from extreme weather events under current and future climate conditions.

6. Please describe any:-

- a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);
- b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
- c) required changes to the Intellectual Property register.

Conclusion

7. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

The National Facility for Climate Change Research project (CSP1402) has enabled the construction and operation of four field chambers, that have been an important component for field based research investigating the interactive effects of projected climate change on cotton production in Australian systems. This is a world-first facility of this type. The chambers have successfully been used in field based climate research on cotton over three consecutive cotton seasons (2014-15 until 2016-17) at the Australian Cotton Research Institute at Narrabri. They have enabled the control of atmospheric CO₂ concentration and air temperature in the field, which can be particularly challenging in a hot environment. In conjunction with collaborative projects (i.e. CSP1501- Cotton production in a future climate), we are developing a better understanding of the response of cotton physiology, growth, water use and cotton production systems to the multiple environmental variables that are projected to alter with Climate Change.

Extension Opportunities

8. Detail a plan for the activities or other steps that may be taken:

- (a) to further develop or to exploit the project technology.**
- (b) for the future presentation and dissemination of the project outcomes.**
- (c) for future research.**

These chambers could continue to be used in field-based climate change research to develop a better understanding of the management strategies for cotton grown in projected climates. Given observed plant responses to elevated CO₂ and warmer temperature environments, we intend to use these chambers to investigate strategies to manage excessive vegetative growth, and improve plant water use efficiency of cotton in projected climates.

9. A. List the publications arising from the research project and/or a publication plan. (NB: Where possible, please provide a copy of any publication/s)

CRDC Spotlight magazine: Autumn 2016 “Leading the world in cotton future climate studies” (<http://www.crdc.com.au/publications/spotlight-magazine-autumn-2016>)

B. Have you developed any online resources and what is the website address?

No.

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

Rising atmospheric CO₂, higher air temperatures, lower humidity (high Vapour Pressure Deficit (VPD)) and reduced water availability as a consequence of climate change is likely to affect cotton production. However, there had previously been little research to assess the real-world interaction of rising CO₂, temperature, VPD and reduced water availability. To enhance the current understanding of cotton system adaptation to climate variability and plan for projected climate change, as a part of the National Facility for Climate Change Research project four chambers were constructed at the Australian Cotton Research Institute (ACRI) in Narrabri, NSW. These chambers have enabled higher atmospheric CO₂ and warmer air temperatures for field-grown cotton, throughout an entire season. The chambers have successfully been used over three consecutive cotton seasons (2014-15 to 2016-17) in field-

based research to further current understanding of the interactive effects of rising CO₂ and warmer temperatures on the physiology, growth, water use and soil microbial communities of cotton production systems in Australia. Therefore, the development of the National Facility for Cotton Climate Change Research has been, and will continue to be, a crucial aspect of investigating the response of field-grown cotton in Australian production systems to projected climate change.