



# FINAL REPORT TEMPLATE

CRDC ID: ANU1704

Project Title: Building climate resilience in cotton through translational physiology

Confidential or for public release? **For Public Release**

## Part 1 – Contact Details & Submission Checklist

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### Submission checklist.

*Please ensure all documentation has been completed and included with this final report:*

- Final report template (this document)
- Final Technical Report (see Part 3)
- Final Schedule 2: IP register
- Final financial report
- PDF of all journal articles (for CRDC's records)

**Signature of Research Provider Representative:** 

Interim Director, Research School of Biology

**Date submitted:** 22.02.2021

## Part 2 - Monitoring & Evaluation

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**Public Release**

This data forms part of CRDC's M&E data collection. Please complete all fields and add additional rows into each table if required.

**Achievement against milestones in the Full Research Proposal**

<b>Milestone</b>	<b>Achieved/ Partially Achieved/ Not Achieved</b>	<b>Explanation</b>
<i>Literature Review</i>	<i>Achieved</i>	<i>Completed and included in thesis.</i>
<i>Additional milestone: Domestic cotton species</i>	<i>Achieved</i>	<i>An analysis comparing the four major domestic cotton species was conducted to assess the level of photosynthetic diversity closer to breeding material.</i>
<i>Heatwave Experiment</i>	<i>Achieved</i>	<i>A total of 14 Gossypium (cotton) species were examined.</i>
<i>Temperature Response</i>	<i>Achieved</i>	<i>A total of 7 Gossypium species were examined. A smaller selection was examined in high detail (e.g. mesophyll conductance temp. resp.) due to time constraints</i>
<i>Additional milestone: Plantecowrap</i>	<i>Achieved</i>	<i>An R package 'plantecowrap' was developed for the refined analysis of photosynthetic CO<sub>2</sub> responses of cotton. Its accuracy was tested across two cotton species.</i>
<i>DCaPST (Diurnal Canopy Photosynthesis and Stomatal Conductance) simulations</i>	<i>Achieved</i>	<i>Simulations compared the effect of photosynthetic elements (e.g. Rubisco, Rubisco activase) from G. hirsutum and G. australe on cotton RUE</i>
<i>Thesis</i>	<i>Achieved</i>	<i>Completed and submitted October 9<sup>th</sup> 2020</i>

**Outputs produced** (Please refer to examples document to assist in completing this section).

<b>Output</b>	<b>Description</b>
<i>Literature Review</i>	<i>Literature review of the evolutionary history of Gossypium (cotton), climate change impacts on crops including cotton and the impact of heat stress on photosynthesis and crop yield. The review concluded with a brief review of crop modelling and predicting climate impacts.</i>
<i>Plantecowrap</i>	<i>An R package 'plantecowrap' was developed to improve the species-specificity and temperature sensitivity of photosynthetic CO<sub>2</sub> response analysis. This package has been publicly released on Cran and Github.</i>
<i>Thesis</i>	<i>A thesis compiling the literature review, developing plantecowrap, domestic cotton species, heatwave experiments, temperature response experiments and</i>

## Public Release

	<i>DCaPST simulations was produced and submitted for examination on October 9<sup>th</sup> 2020.</i>

**Outcomes from project outputs** (Refer to examples document).

<b>Outcome</b>	<b>Description</b>
<i>Literature Review</i>	<i>Outlined key issues and deficiencies within the cotton industry to address experimentally in the thesis.</i>
<i>Plantecowrap</i>	<i>Improved accuracy of measuring key photosynthetic parameters in cotton.</i>

### **Part 3 – Technical Report**

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Projects may require different approaches to the structure of the Technical report. A detailed technical report should normally include the following items:

- *Table of contents (if necessary – depends on the length and complexity of your report);*
- *Executive summary*
- *Introduction*
- *Materials and methods*
- *Results*
- *Discussion*
- *Conclusions*
- *Key word index and*
- *A full list of industry and scientific publications, presentations, extension activities and other outputs.*

Please contact your R&D manager if you would like to adopt a different approach.

**Part 4 – Summary for public release**

*This summary will be published on Inside Cotton, CRDC's digital repository, along with the full final report (if suitable for public release). It is designed to provide a short overview of the project for all interested parties. Please complete all fields, ensuring that this exceeds no more than two pages.*

<b>Project title:</b>	<b>Type Title here</b>	
<b>Project details:</b>	CRDC project ID:	ANU1704
	CRDC goal:	<i>3. Build adaptive capacity of the cotton industry</i>
	CRDC key focus area:	<i>3.2 Futures thinking</i>
	Principal researcher:	Demi Sargent
	Organisation:	Australian National University/CSIRO
	Start date:	27/02/2017
	End date:	09/10/2020
<b>Objectives</b>	<ul style="list-style-type: none"> <li>• <i>Elucidate the level of physiological and biochemical diversity within the Gossypium genus;</i></li> <li>• <i>Interrogate the response of a range of Gossypium species to elevated temperatures;</i></li> <li>• <i>Determine the species-specificity of photosynthetic thermal optima at the leaf-level and biochemical-level, and;</i></li> <li>• <i>Use the simulation model DCaPST to determine the level of photosynthetic enhancement required to improve radiation use efficiency and biomass growth of cotton.</i></li> </ul>	
<b>Background</b>	<p><i>Climate change is predicted to increasingly challenge agricultural productivity through the increasing incidence and severity of climatic extremes such as heatwaves and droughts. Improving the abiotic stress resilience of cotton is critical to maintain and increase yields in increasingly challenging abiotic conditions. Improving the thermal optima and efficiency of photosynthesis is a promising approach that is yet to be investigated in cotton. Targeted improvements in photosynthetic properties of the photosynthetic enzyme Rubisco may lead to improved heat stress resilience and increased yield potential.</i></p> <p><i>The first objective of this research was to determine the level of diversity of photosynthetic performance and temperature sensitivity within the Gossypium genus. Secondly, the temperature dependency of cotton photosynthesis was determined for multiple Gossypium species, building an understanding of the thermal optima of a range of physiological and biochemical processes. Thirdly, the effects of photosynthetic modification were simulated using DCaPST, thus quantifying the level of photosynthetic enhancement required to improve cotton yield under a variety of environmental temperatures.</i></p>	
<b>Research activities</b>	<p><i>A literature review was produced, covering the evolutionary history of cotton, climate change impacts on crops including cotton and the impact of heat stress on photosynthesis and crop yield. The review concluded with a brief review of crop modelling and predicting climate impacts.</i></p>	

*A new package in the software program R called 'plantecowrap' was developed for the refined analysis of leaf-level photosynthetic gas exchange. This package was designed to enable more specific parameterisation, thereby enhancing species-specificity and temperature-sensitivity of photosynthetic measurements. The enhanced accuracy of this package was tested through analysing photosynthetic measurements across two Gossypium species – G. hirsutum and G. australe – across multiple temperatures and comparing this to results obtained through adopting previous parameterisation approaches such as using inputs derived from tobacco.*

*A preliminary screen assessing the photosynthetic diversity between the four domesticated Gossypium species was conducted. Photosynthetic parameters at the leaf level and biochemical level were analysed and compared.*

*The photosynthetic response of 14 diverse Gossypium species to a heatwave event was analysed. This experiment demonstrated the high level of leaf-level photosynthetic diversity between the wild cotton relatives, and the vastly different responses of these species to heatwaves. This experiment highlighted the ability of some species to withstand the immediate and/or permanent effects of extreme heat events, while other species were susceptible to severe effects.*

*The temperature response of multiple processes, from leaf-level to biochemical-level, was analysed in 7 diverse Gossypium species. These species varied in their optimum temperature for various photosynthetic processes including photosynthetic carbon assimilation rate, maximum rate of carboxylation by Rubisco, maximal rate of electron transport and Rubisco kinetic properties. G. hirsutum and G. australe were also analysed further for variation in the temperature response of mesophyll conductance and specificity of Rubisco for CO<sub>2</sub>. The variation in Rubisco kinetic properties of these species was assessed further through analysing the variation in the Rubisco large subunit amino acid sequence. This analysis identified substantial sequence variation between G. hirsutum and G. australe, indicating differences in the Rubisco large subunit likely contributed to the variation in photosynthetic performance between these two species.*

*The impact of 3 different photosynthetic manipulation scenarios on the radiation use efficiency (RUE) and biomass growth of cotton was simulated using DCaPST. These scenarios included increasing the thermotolerance of Rubisco's 'helper' protein Rubisco activase, introducing Rubisco from G. australe and incorporating multiple photosynthetic elements from G. australe.*

## Public Release

<p><b>Outputs</b></p>	<p><i>This project unveiled multiple novel findings in the fields of cotton physiology and biochemistry. The most notable findings include:</i></p> <ul style="list-style-type: none"> <li>- <i>The domestic cotton species are unlikely courses of novel traits to enhance the photosynthetic performance of cotton cultivars.</i></li> <li>- <i>Gossypium species vary in their response to temperature, including extreme heat events. This has been linked to variation in their thermal optima, which is likely to be associated with adaptations to their climate of evolutionary origin.</i></li> <li>- <i>The greatest thermal optima and resilience to high temperatures at both the leaf-level and biochemical (Rubisco) level was observed in the Australian Gossypium species such as G. australe. This species also possessed the most 'productive' and efficient Rubisco, particularly at high temperatures.</i></li> <li>- <i>Photosynthetic variation is strongly linked to sequence variation in the Rubisco subunits</i></li> <li>- <i>RUE and therefore biomass growth of cotton could be increased by up to 4 – 5.5 % at temperatures above 33 °C through photosynthetic enhancements including introducing photosynthetic elements such as Rubisco from G. australe into cotton.</i></li> </ul> <p><i>This project also facilitated the production of a new package in R – plantecowrap. This package improves the accuracy of photosynthetic analysis in plants through incorporating species-specific and temperature-sensitive model parameterisation. This package has been publicly released in Cran and Github. The improved accuracy of this package and inaccuracy of analysing cotton photosynthesis using previous approaches was demonstrated in the thesis.</i></p>
<p><b>Impacts</b></p>	<p><i>The novel findings from this research are informing further research into the potential to fortify photosynthetic processes that underpin yield against the negative effects of elevated temperatures that are a common and increasing concern for the cotton industry. These findings have highlighted the potential to improve cotton heat stress resilience and productivity through photosynthetic traits that could be obtained from wild cotton species.</i></p> <p><i>This project has also resulted in the production of 'plantecowrap', an R package that has been demonstrated to improve the accuracy of photosynthetic gas exchange analysis in cotton. Therefore, analyses conducted using 'plantecowrap' is likely to improve the reliability of photosynthetic analysis conducted in cotton, as well as other crops photosynthetically dissimilar to tobacco.</i></p> <p><i>This research has also facilitated multiple valuable collaborations and connections within and outside of CRDC, CSIRO and ANU. These connections have enabled an array of skills and knowledge to be developed in the research team, hence broadening the research capabilities available to the cotton community.</i></p>

Public Release

<b>Key publications</b>	<i>No major publications directly related to this work have been published to date.</i>
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