# FINAL REPORT - PhD

**CRDC ID:** CSP 1604

**Project Title:** Utilising novel plant growth regulators to develop resilient future cotton systems.

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

## Part 1 – Contact Details & Submission Checklist

**Principal Researcher: Claire Welsh, Research Affiliate**

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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) – CRDC will accept the Thesis as the Technical Report

☒ Final Schedule 2: IP register

☒ Final Financial report - SER

☒ PDF of all journal articles (for CRDC's records)

**Signature of Research Provider Representative:** _____

**Date submitted:** _____

## Part 2 - Monitoring & Evaluation

*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**

| Milestone | Achieved/ Partially Achieved/ Not Achieved | Explanation |
|---|---|---|
| *1.0 Review of Literature* | *Achieved* | *Thesis, Ch. 2.* |
| *2.0 Developing novel approaches for agronomic management of Australian cotton crops utilising applications of PGRs / hormones* | *Achieved* | *Thesis, Ch. 4, 5 and 6.* |
| *3.0 Crop modelling of system response to PGR treatments.* | *Achieved* | *Thesis, Ch. 6 and 7.* |
| *4.0 Developing an improved understanding of the capacity of novel remote sensing technologies, to quantify crop physiological responses to PGR applications under varying field and abiotic stress conditions.* | *Achieved* | *Thesis, Ch. 4, 5 and 6.* |
| *5.0 Defining the application rates and timing of individual PGRs, under specific field and climatic conditions, to optimise crop efficiencies and yield / lint quality outcomes.* | *Partially Achieved* | *Thesis, Ch. 6, 7 and 8. Ongoing validation of application methodologies, with view to label registration of early vegetative growth applications of Trinexapac-ethyl for delaying peak crop resource demand, is occurring in CRDC CSP2001.* |
| *6.0 Thesis preparation and submission.* | *Achieved* | *Thesis document, response to examiner's comments, letter of recommendation (USyd), letter of completion (USyd), course result history / transcript (USyd).* |

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

| Output | Description |
|---|---|
| *Presentations* | As part of a CRDC funded travel bursary, in August 2017 project briefings were presented to;<br>• Valent Biosciences LLC, Long Grove IL, USA (Dr Steve McArtney, (Product Development Manager; Plant Growth Regulators), Dr Peter Petracek, (Manager Plant Sciences), Dr Marci Surpin (Manager Crop Enhancement Research) and cohort).<br>• Texas Tech University (Assoc. Prof. Glenn Ritchie and cohort) and the USDA ARS Cropping Systems Lab, Lubbock TX, USA (Drs' James Mahan and Paxton Payton).<br>• Texas A&M AgriLife Research and Extension, Corpus Christie TX, USA (Prof. Juan Landivar Bowles (Center Director, Research), Assoc. Prof. Jinha Jung and Dr Murilo Maeda).<br><br>Project updates were presented to three DCRA AGM meetings in 2017, 2018 and 2019; usual attendance being ~20+ growers and industry personnel.<br><br>Invited presentation within the dryland cotton session, 20th Australian Cotton Conference, (7-9 August 2018, Gold Coast QLD); presenting early project findings to 150+ growers and industry personnel.<br><br>Presentation of project scope, importance and preliminary / intended outcomes, 29th August 2018, as part of CSIRO A&F external review process; panellists included Prof. Marilyn Anderson (Molecular Sciences, LaTrobe University), Dr Marianne Banziger (Deputy Director General, Research and Partnerships, CIMMYT Brazil), Dr Colin Dennis (Chair, Board of Trustees of IFIS Ltd. and British Nutrition Foundation, UK) and Prof. Achim Dobermann (Director and CE, Rothamsted Research, UK).<br><br>Presentation of preliminary findings to the CRDC board meeting and grower information session, St George QLD, 7th November 2018.<br><br>DCRA field walk through Terry Hie Hie Gibberellin Biosynthesis Inhibitors (delay) trial, 25th February 2019; demonstrating and discussing results with 40+ growers and industry personnel in attendance.<br><br>USyd / DCRA industry update, 28th March 2019; presentation of (PGR manipulated) crop simulation modelling outcomes demonstrating systems fit of technology, to 30+ growers and industry personnel.<br><br>Presentation of PhD final research outcomes, University of Sydney, Faculty of Science, SOLES HDR student showcase, 12th November 2019. |

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| *Publications – Conference and Poster* | • Welsh, C.J. (2018). Gaming the system: using PGRs to develop resilient future cotton systems. In Proceedings of the 2018 Australian Cotton Conference "Pushing Boundaries", Gold Coast, Australia: Cotton Australia and the Australian Cotton Shippers Association. Retrieved from http://australiancottonconference.com.au/program/presentation-papers/<br>• Welsh, C.J., Bange, M., and Tan, D.K.Y. (2017). Utilising plant growth regulators to develop resilient future cotton systems. In Proceedings of the 2017 Australian Cotton Research Conference "SciCott2017: Cotton Science Delivering Impact", Canberra, Australia: Association of Australian Cotton Scientists. Retrieved from http://cottonresearch.org<br>• Dodge, W., Young, A., Welsh, C., Bange, M., Mahan, J., and Payton, P. (2018). Blue Pill / Red Pill: Yield Phenotyping in a Rain Grown Matrix. In Proceedings of the 2018 Beltwide Cotton Conferences, San Antonio, United States of America: National Cotton Council of America. Retrieved from http://www.cotton.org/beltwide/proceedings/2005-2018/index/htm |
| *Scholarships, travel and learning programs* | • Utilised CRDC funded travel bursary (CSP1801: Attend Plant Growth Regulator Society, America Annual Conference, 6 – 19 August 2017) to attend the Plant Growth Regulator Society of America annual conference, meet with research personnel and scope facilities, with view to collaboration opportunities; Valent Biosciences LLC (Libertyville, IL), USDA ARS Cropping Systems Research Lab (Lubbock, TX), Texas A&M AgriLife Research and Extension Centre (Corpus Christie, TX). |
| *Extension Resources and services* | • Annual update of Precision Ag chapter in Australian Cotton Production Manual, 2017, 2018 and 2019. |

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

| Outcome | Description |
|---|---|
| *Increased Scientific Knowledge* | This project developed new understandings around both the capacity of adaptive management strategies to promote agroecosystem resilience in rain grown cotton production systems, as well as the impact of specific applications of plant growth regulators (PGRs) on cotton crop physiology and biochemistry.<br><br>Unique Australian rain grown cotton production system-level adaptive management opportunities were identified. Moreover, the utility of specific PGRs to accomplish such adaptive changes, through the strategic and reliable manipulation of cotton plant growth and development, is quantified. Specifically;<br>• Increased understandings of cotton plant phenological response to specific 6-Benzylaminopurine treatment scenarios, under resource-constrained rain grown production setting.<br>• Increased understandings of cotton plant phenological response to specific Gibberellin $A_3$ and Gibberellin $A_{4,7}$ treatment scenarios, under resource-constrained rain grown production setting.<br>• Increased understandings of cotton plant phenological response to specific Gibberellin Biosynthesis Inhibiting PGR treatment scenarios, under resource-constrained rain grown production setting.<br>• Increased understandings of the systems-value (economic) of PGR driven adaptive management strategies.<br><br>The resulting data contributes to the understanding of cotton plant phenological responses to specific exogenous PGR treatment scenarios, under resource-constrained rain grown production settings and where applicable provides insight to the systems-value of such PGR-driven adaptive management strategies. |
| *Industry Capacity Building* | This project provided the opportunity for the PhD candidate to learn valid scientific research methods, develop skills in crop / plant physiology, biochemistry, crop simulation / modelling methods and cotton systems management.<br><br>Additionally, capacities were also developed in modern crop sensing techniques and the aggregation, management and analysis of geospatial meta-data (“big data”); including applications of both towards research and production contexts.<br><br>The project maintained crucial independent research capacity in applied cotton systems research for the Australian industry. The project produced an applied scientist specialising in systems agronomy and plant / crop physiology; trained with the ability to package and apply technology for improving productivity on farm.<br><br>These skillsets will be applied in an ongoing manner for the benefit of Australian agriculture and the wider cotton industry. |

## Part 3 – Technical Report

The published thesis document can be accessed via the University of Sydney library:
https://hdl.handle.net/2123/23910

## 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.*

| **Project title:** | *Error! Reference source not found.* | |
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| **Project details:** | CRDC project ID: | *CRDC CSP1604* |
| | CRDC goal: | *1. Increase productivity and profitability on cotton farms* |
| | CRDC key focus area: | *1.1 Optimised farming systems* |
| | Principal researcher: | *Dr Claire Welsh, Cropping Systems Agronomist (Cotton)* |
| | Organisation: | *CSIRO Ag & Food* |
| | Start date: | *1/4/2016* |
| | End date: | *18/11/2020* |
| **Objectives** | • Undertake detailed physiology research to identify appropriate plant growth regulators (PGRs) for assisting agronomic manipulation of crop growth.<br>• Undertake detailed plant and crop physiology evaluations utilising a select range of applied PGRs in controlled environment and field conditions; utilise this knowledge generated in physiology studies, to inform appropriate application of PGRs to maximise their efficacy to improve cotton yield and quality.<br>• Concurrently, develop new understanding of the plant response to PGR applications under various levels of stress, by quantifying the degree of stress utilising novel remote sensing technologies (eg. ECa, canopy temperature, high resolution multispectral and thermal imagery).<br>• Utilise new knowledge to initiate the development of a predictive framework (decision support platform) for PGR application; considering the influencing climatic, topographic, farming methodologies and varietal data. | |
| **Background** | Rain grown cotton production is characterised by significant climate variability with water limitation a focal constraint. Ensuing system exposure to climate risk results in substantial variability in production area, lint yield, lint quality and profit outcomes. Current climate risk management involves manipulation of multiple agronomic management and genetic solutions simultaneously; moderating existing limitations to reach the system water-limited yield potential. Such strategies can deliver capacity to introduce management diversity to the farming system, but lack application agility, have increased costs associated with implementation and critically, the rainfed-nature of the system often precludes opportunities for implementation.<br><br>This project informs the discourse regarding novel adaptive management opportunities utilising PGRs, that enable in-season responsive management | |

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| | of limitations under changeable climatic conditions, to offset climate variability and improve system resilience. Resultant outcomes being increased farm gate profits, through the provision of improved crop resource use efficiencies and lint yield and quality outcomes, with less annualised variability. A scarcity of detailed information exists regarding cotton crop and plant responses to exogenous Gibberellin, Cytokinin and Gibberellin biosynthesis inhibiting PGR treatment scenarios, notably in early growth and under water-limited rain grown production contexts. Understanding these crop responses can enable future development of frameworks for strategic, predictive applications within rain grown cotton systems. |
| **Research activities** | This project investigated the utility of exogenously applied PGRs to promote system resilience by tactically modulating cotton growth and development under rain grown production contexts, to augment crop water availability.<br><br>Obtaining consistency of cotton plant response to PGR treatment scenarios is typically problematic and dependent upon a variety of temporal and spatial appraisals, to enable accurate characterisation. By drawing on preliminary glasshouse and comprehensive field experiments over three production seasons (2016-19) at three locations in New South Wales, a broad-scale indication of specific treatment efficacy was presented. Treatments were positioned around achieving vegetative stage growth responses, negating endogenous hormonal influences associated with reproductive growth. Moreover, to efficiently progress research, initial selection of specific PGR chemistry exploited published data from horticulture and tree crops, irrigated cotton and international rain grown production contexts.<br><br>Physiological mechanisms underpinning existing agronomic adaptation strategies were identified and resultantly, unique adaptive management opportunities utilising PGRs were proposed for Australian rain grown cotton systems. Utilising a top-down approach with a systems, crop and plant level focus; promotion of system resilience to climatic variability was examined via three identified response strategies, all aiming to increase crop water availability. Glasshouse and field experiments increased understanding around the capabilities; of synthetic Adenine-type Cytokinin PGRs to promote increased root biomass accumulation and plant root growth area, of naturally occurring bioactive Gibberellin PGRs to increase early plant structural and canopy biomass and, of Gibberellin biosynthesis inhibiting PGRs to slow early growth or induce physiological stasis, to delay crop-level reproductive phase change. Conclusively where applicable, the effectiveness of these approaches was evaluated to establish resource use efficiency benefits and / or economic values of the treatment propositions, to Australian rain grown production systems. |
| **Outputs & Impacts** | Primarily, this project developed new understandings around both the capacity of adaptive management strategies to promote agroecosystem resilience in rain grown cotton production systems, as well as the impact of specific applications of PGRs on cotton crop physiology and biochemistry. Unique Australian rain grown cotton production system-level adaptive management opportunities were identified and the utility of specific PGRs to accomplish such adaptive changes, through the strategic and reliable manipulation of cotton plant growth and development, was quantified. The resulting data contributes to the understanding of cotton plant phenological responses to specific exogenous PGR treatment scenarios, under resource-constrained rain grown production settings and where |

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| | applicable provides insight to the systems-value of such PGR-driven adaptive management strategies.<br><br>Secondly, this project provided the opportunity for the PhD candidate to learn valid scientific research methods, develop skills in crop / plant physiology, biochemistry, crop simulation / modelling methods and cotton systems management. Capacities were also developed in modern crop sensing techniques and the aggregation, management and analysis of geospatial meta-data ("big data"); including applications of both towards research and production contexts. The project maintained crucial independent research capacity in applied cotton systems research for the Australian industry. The project produced an applied scientist specialising in systems agronomy and plant / crop physiology; trained with the ability to package and apply technology for improving productivity on farm. These skillsets will be applied in an ongoing manner for the benefit of Australian agriculture and the wider cotton industry. |
| **Key publications** | • Welsh, C.J. (2020). Promoting resilience in rain grown cotton systems with plant growth regulators. (Doctoral dissertation, University of Sydney, Sydney, Australia). Retrieved from https://hdl.handle.net/2123/23910<br>• Welsh, C.J. (2018). Gaming the system: using PGRs to develop resilient future cotton systems. In Proceedings of the 2018 Australian Cotton Conference "Pushing Boundaries", Gold Coast, Australia: Cotton Australia and the Australian Cotton Shippers Association. Retrieved from http://australiancottonconference.com.au/program/presentation-papers/<br>• Welsh, C.J., Bange, M., and Tan, D.K.Y. (2017). Utilising plant growth regulators to develop resilient future cotton systems. In Proceedings of the 2017 Australian Cotton Research Conference "SciCott2017: Cotton Science Delivering Impact", Canberra, Australia: Association of Australian Cotton Scientists. Retrieved from http://cottonresearch.org<br>• Dodge, W., Young, A., Welsh, C., Bange, M., Mahan, J., and Payton, P. (2018). Blue Pill / Red Pill: Yield Phenotyping in a Rain Grown Matrix. In Proceedings of the 2018 Beltwide Cotton Conferences, San Antonio, United States of America: National Cotton Council of America. Retrieved from http://www.cotton.org/beltwide/proceedings/2005-2018/index/htm |