FINAL REPORT – Executive Summary Only

CRDC ID: CMSE1802

Project Title: Precision Management for Improved Cotton Quality.

Confidential or for public release?

Part 1 – Contact Details & Submission Checklist

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Executive summary

The executive summary is presented as a summary of each research chapter or section as listed in the table of contents.

Predicting cotton fibre quality using UAV multispectral images.

The use of unmanned aerial vehicle (UAV) imagery of cotton crops to predict cotton fibre quality parameters from high volume instrumentation (HVI) data was attempted. Artificial neural network (ANN) approaches were used and incorporated multiple spectral vegetation indices (SVIs) derived from multispectral imagery, in combination with ground-truth measurements. The successful prediction of micronaire class was obtained using a composite image, containing two SVIs, the normalised difference vegetation index (NDVI) and the modified chlorophyll absorption in reflectance index (MCARI), performing at 71% accuracy. This model was improved to 80% accuracy by incorporating stem weight measurements at eighty-eight days after sowing. This time-point for greatest accuracy in micronaire class prediction corresponds to flowering and boll development. Micronaire grade predictions made here could inform grower decisions around defoliation application and harvest management.

None of the other fibre quality parameters could be successfully modelled with any practical level of accuracy.

Monitoring cotton defoliation efficacy using UAV colour imaging.
After an initial application of defoliation chemicals to cotton crops, often there requires further defoliation treatments before harvest can commence. Defoliation effectiveness is usually determined through visual inspection of the crop which is time consuming and makes complete field coverage difficult. This research presents an airborne remote sensing approach for monitoring defoliation effectiveness using UAV RGB camera images of cotton crops. Traditional machine vision techniques were used to inform a framework for the separation of bolls, vegetation and soil background information. A novel algorithm was proposed which was used together with integer thresholds to successfully sort images of defoliated cotton crops into three classes of defoliation effectiveness. The defoliation scoring model returned a 76.0% accuracy result for the 2018–2019 dataset, and a 97.8% accuracy result when evaluated on the 2019–2020 dataset. The results of this study indicate that the approach is robust in its ability to operate on standard RGB and narrow bandpass RGB camera variations.

Assessing in-field optical reference standards.
The construction and testing of large neutral grey reference standards, and the testing of commercially available Labsphere Spectralon™ reflectance panels, was undertaken in the capacity of providing in-field reference standards for UAV captured images of cotton crops using both RGB colour and narrow band camera systems. Four large (circa >1m in length) panels were created, and a paint formular was devised to represent approx. neutral light, mid and dark grey. The panels were spectrally characterised with a handheld spectrophotometer. Images of the panels in conjunction with images of cotton crops were used to optimise colour camera exposure settings. Narrow band Spectralon panel images were used to optimise exposure settings for the Parrot Sequoia multispectral camera system.

In-field cameras for measuring plant components.
Growers and agronomists measure various cotton plant components during the crop life cycle. The aim of this work was to engineer simple cost-effective visible cameras that could be semi-permanently set up in cotton crops and be used to remotely capture images of growing cotton plants. The cameras were weather proof and survived a full growing season, had their own power supply, were able to automatically capture images of plants which were sent to a server for remote assessment. Some cotton crop vegetative and fruiting components were able to be measured by the cameras.

Can near infrared technology replace the boll cutting technique?
The boll cutting technique allows cotton producers to gauge the maturity of cotton bolls to help in their decisions in the final stages of management of their crop leading up to harvest. The aim of this work was to assess the feasibility of using portable near infrared technology as a non-destructive rapid replacement for the manual boll cutting technique. Near infrared spectra (702-1100 nm) were collected from bolls using a Felix F-750 Produce Quality Meter. Spectra were successfully calibrated with two levels of boll maturity (immature and mature) using a partial least squares model for a population of 201 bolls. Using separate boll populations, the model predicted boll maturity correctly with an average accuracy of 96 %. Calibrations that used spectra collected from bolls under field conditions performed similarly to calibrations that used spectra collected from the same bolls under controlled laboratory conditions. There was no preferred spectral sampling location on the bolls that resulted in better calibration performance. Calibration performance did not improve when spectral mathematical pre-treatments were used.

Blending relationships for fibre quality.

The aim of this work was to determine the degree of the linearity of resulting fibre quality parameters following the blending of seed cotton at different proportions. If round modules were to be blended at the gin, being able to accurately predict the quality of ginned lint would be invaluable for ginners. Batches of immature and mature seed cotton were blended together in 10 % increments and then ginned. Actual fibre quality data and calculated fibre quality data assuming a proportional linear blending relationship, were regressed and response statistics reported. For the fibre maturity related quality attributes micronaire, maturity ratio and fineness, there was a strong linear blending relationship. The same was also evident for upper half mean length and short fibre content, but the relationship was poor for length uniformity. The blending relationship was linear and reasonably strong for strength and elongation and reflected the range in tensile properties between immature and mature cotton. While there was a good range in the nep content between mature and immature cotton, the degree of the linearity of the blending was poor for neps. The data that was used for this exercise was from previously conducted research, and it examined small quantities of blended cotton and used sample ginning equipment without post-stand lint cleaning. Because of this, cotton leaf and colour grade data were not available. Future work would look to more comprehensive blending experiments to capture the effects of blending on cotton leaf and colour grade.

<u>Segregating round modules based on seed cotton moisture level: The development of a phone application as a demonstration tool.</u>

A phone software application was developed to locate harvested round modules in the field. The software enabled modules to be sorted on date and on seed cotton moisture level, with a feature that could segregate modules that were above or below the critical seed cotton moisture level of 12%. Harvested round modules with high moisture could be grouped and transported separately to the gin, potentially allowing improved ginning and fibre quality outcomes. The technology may also help producers to more accurately stage and transport modules in sequence, which is also associated with better fibre quality outcomes. This exercise was a practical demonstration applicable to other round module fibre quality attributes that are likely to be available in the future.

<u>Alternative defoliation practices.</u>

Research was conducted over three cotton growing seasons (2017/18, 2018/19 and 2019/20) to test if early applications of defoliant chemical, Thidiazuron, used at varied times and rates (as low as 25ml/ha) could effectively prepare a cotton crop for machine harvest. The key aim was to find out if this strategy could maintain optimal cotton lint yield and quality whilst reducing the amount of defoliant used. The warm conditions during the defoliation period in the first season resulted in an effective defoliation with only a small total amount of Thidiazuron active used (50 g/L). The second season involved two on-farm demonstration trials. Estimates of cotton lint yield for both trials resulted in no significant differences across treatments. However lint quality measurements from one of these trials showed significantly lower micronaire in the control. The crop however carried a late fruit load in the upper canopy and the early defoliation strategies may have removed some of this fruit that has typically lower micronaire. A much cooler defoliation period was encountered in the third season, reducing the efficacy of Thidiazuron applied. Cotton lint yield and quality measurements from the 2017/18 and 2019/20 seasons across treatments resulted in no significant differences at $P<0.1$ confidence level. These results have shown that an early, low rate defoliant strategy can maintain optimal yield and quality. In seasons where conditions a conducive to good defoliation efficacy, this strategy can be used to minimise the amount of chemical required to prepare the crop for harvest.

<u>Onboard cotton harvester camera for measuring seed cotton quality.</u>

The aim in this research was to develop a camera/sensor system to be fitted onboard a cotton harvester, to measure and class seed cotton before it reaches the gin. More comprehensive fibre quality data about round modules could be used by growers and ginners to stage modules entering the gin and improve the efficiency and minimize fibre damage during ginning. A prototype camera and lighting test system was built to measure the percent trash in seed cotton. It was successfully tested on seed cotton in round modules at the gin. Further research will look to engineer the camera so that it can be mounted onboard a cotton harvester, and automatically capture and store seed cotton quality information within the module RFID tag system.

Acknowledgments

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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:	Precision Management for Improved Cotton Quality.	
Project details:	CRDC project ID:	CMSE1802
	CRDC goal:	*1. Increase productivity and profitability on cotton farms*
	CRDC key focus area:	*1.1 Optimised farming systems*
	Principal researcher:	*Dr Robert Long, Senior Research Scientist.*
	Organisation:	*CSIRO*
	Start date:	*1st July 2017*
	End date:	*31st December 2020*
Objectives	• *To identify where existing or new sensor technologies coupled with knowledge of fibre development and environmental influences, can be used to better manage cotton crops and the interface between the end of crop production and post-harvest handling/ processing, to improve cotton fibre quality.*	
Background	• *CSIRO has experience in researching the realm of end of season cotton production and the interface between management decisions at this stage and the methods by which cotton is harvested and ginned. The interactions between these production and processing factors impact the quality and value of cotton fibre.*	
Research activities	• *Field experiments were conducted at the Australian Cotton Research Institute (ACRI), and on private cotton farms. Fibre samples were tested for quality at both commercial classing houses and at the fibre testing laboratories at the CSIRO.* • *Unmanned arial vehicles (UAVs or drones) colour and narrow band images of cotton crops were captured, and near infrared spectra were collected of cotton bolls.* • *Seed cotton blending data was analysed to determine the degree of the proportionality of blending prior to ginning on ginned fibre quality attributes.* • *A geolocation application was developed to sort round modules in the field that had high (>12 %) moisture content.* • *A protype camera and lighting system was developed to measure the trash content of seed cotton. The intention was to incorporate this technology on-board a cotton harvester to allow round modules to be graded for leaf trash prior to ginning.*	

Outputs	• *UAV (drone) imagery of cotton crops prior to defoliation was calibrated with ginned bale fibre micronaire to within a 70 to 80% accuracy.* • *UAV images were successfully calibrated to three levels of defoliation effectiveness, therefore demonstrating the feasibility of using drone technology to assist growers in measuring the success of defoliation applications.* • *The project demonstrated that near infrared technology can non-destructively measure the maturity of un-opened cotton bolls.* • *The degree of the linearity of blending seed cotton of known different fibre qualities was determined.* • *A phone software application successfully geolocated round modules in the field that had moisture levels above the critical threshold of 12%.* • *Alternative defoliation practices were explored.* • *A protype camera and lighting system intended to be incorporated into a cotton harvester, could measure the trash content of seed cotton.*
Impacts	• *Being able to predict crop micronaire and defoliation efficacy in real time using UAV technology will enable growers and agronomists to make more accurate defoliation timing decisions.* • *A non-destructive alternative for the potentially hazardous boll-cutting technique, will allow agronomists to more quickly and safely measure boll maturity.* • *Knowing the degree of the linearity of blending seed cotton and being able to identify modules in the field that are high in moisture, enables ginners to make practical decisions about how they decide to blend modules at ginning.* • *An onboard cotton harvester camera system that can grade modules on trash level, will assist ginners in staging and ginning cotton for more consistent better quality.*
Key publications	*Long, RL. and Bange, MP. (2020) Measuring the maturity of unopened cotton bolls with near infrared spectroscopy. Journal of Near Infrared Spectroscopy 28: 204-213.* *Long, R., McCarthy, C., Bange, M. (2019) Measuring the maturity of unopened cotton bolls. The Australian Cotton Grower 40 (no. 2): 16-18.* *Long, R. (2019) Using a portable diffuse reflectance near infrared spectrometer to measure the maturity of unopened cotton bolls. Proceedings 19th International Council for NIR Spectroscopy Meeting 'NIR2019', 15-20 September 2019, Gold Coast, Australia. Peer reviewed conference proceedings. Accepted.*