INTERNATIONAL COTTON RESEARCHERS ASSOCIATION

VOLUME 1, ISSUE 5
JULY 2021

WWW.ICRACOTTON.ORG

Content

The Cotton Innovations Newsletter is published twelve times annually. Contributed articles, pictures, cartoons, and feedback are welcome at any time. Please send contributions to the General Editors (see below). The editors reserve the right to edit. The deadline for contributions is one month before the publication date.

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Published by ICRA Secretariat, Pakistan Central Cotton Committee, Multan-Pakistan
http://icracotton.org
The newsletter is also available at URL: http://www.icracotton.org/page/cotton-innovations

ISSN 2788-6611

News

TECHNICAL COOPERATION PROGRAM FOR OIC COUNTRIES

Dr. Fiaz Ahmad

The Islamic Development Bank has launched a reverse linkage/technical cooperation program for OIC countries. This is an excellent opportunity for the research organizations to establish cooperation in various sectors of mutual interest. The reverse linkage /technical cooperation benefits collaborating partners in way that an organization-A having strength in a particular field helps the collaborating partner-B in that field. In return partner -B extends support in areas of its strength to partner-A.

CCRI, Multan is willing to establish cooperation in following areas:

i) Agricultural machinery

ii) Exchange of germplasm

iii) Strengthening of research programs

iv) Exchange of researchers

v) Training programs

VI) New technologies

VII) Any other

It is a wonderful opportunity to be implemented under the administration of Islamic Development Bank. Hopefully, every institution would like to avail this opportunity.

Please Contact Dr. Fiaz Ahmad, by highlighting the area of your interest to establish the collaboration with CCRI, Multan.

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Climate Change and Extreme Weather Events on Australian Cotton Production

Katie Broughton, Michael Bange, David Tissue, Yui Osanai, Linh Nguyen, Qunying Luo, Brajesh Sign, Paxton Payton
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Worldwide cotton production is broadly adapted to growing in temperate, subtropical and tropical environments, but growth and production systems may be challenged by projected climate change. Changes in climate such as warmer air temperatures, rising atmospheric carbon dioxide (CO_2) concentration and extreme fluctuations in precipitation may significantly affect cotton growth and crop productivity. Therefore, it is important to understand the interactive effects of climate change for cotton systems.

In recent years, several research initiatives led by CSIRO and Western Sydney University, and supported by the Cotton Research and Development Corporation, have been underway to better understand how projected climate change may affect Australian cotton production. Research has incorporated a multi-faceted approach using simulation modelling, glasshouse- and field-based studies to better understand cotton system and plant-soil responses to projected environmental conditions for Australian cotton regions.

The effects of warmer temperatures and elevated CO2 on Australian cotton systems

The integrated effects of warmer temperatures and elevated CO2 on cotton growth, physiology and soil microbiology have been studied in several glasshouse and field studies (Table 1). In both field and glasshouse studies, elevated CO2 increased vegetative biomass and photosynthetic rates of cotton compared with plants grown at current CO2 levels. In glasshouse studies, elevated CO2 improved leaf- and plant-level water use efficiency (WUE), which was associated with improved photosynthesis and biomass production, rather than decreases in water use. However, these studies also showed that improved water use efficiencies were negated by warmer air temperatures, as more water was required to grow the plants.

Field studies showed similar outcomes, but other crop level issues emerged. Increased vegetative biomass and reduced WUE became evident as water consumption also increased. Crops had excessive vegetative growth with large leaf areas significantly increasing transpiration. Further reductions of water use efficiency were then associated with high temperatures, as well as the excessive shading caused by the leaves, leading to shedding of fruit throughout the season. In turn, this continued to exacerbate the vegetative growth and loss of fruit because there was little fruit load to restrict vegetative growth.

Studies have also indicated that projected climate change may affect nutrient availability and soil and microbial communities (Table 1). Soil microbes play a key role in nutrient cycling and availability in cotton systems.

Table 1: Summary of measured outcomes of climate change on plant and soil responses from glasshouse and field studies. Adapted from Osanai et al., Nguyen et al., and Broughton et al.

	Variable	Elevated CO_2		Warmer temperature	
		Glasshouse	Field	Glasshouse	Field
Plant	Photosynthesis	⇧	⇧	⇧	⇧
	Vegetative growth	⇧	⇧	⇧	⇧
	Seed cotton yield	⇧	⇧	⇧	⇩
	Water use	⇧	⇧	⇧	⇔
	Plant-level water use efficiency	⇧	⇩	⇩	⇩
Soil	Soil pH	⇔	⇔	⇩**	⇔
	Soil nitrate concentrations	⇩	⇩	⇧***	⇔
Microbes	Nitrifier abundance	⇔ AOB ⇧ AOA	⇧ AOB ⇧ AOA	⇔ AOB ⇧ AOA	⇔ AOB ⇧ AOA
	Nitrifier community composition	↻ AOB* -	↻ AOB* ↻ AOA*	↻ AOB* -	⇔ AOB ↻ AOA*
	Potential nitrification rate	⇩	⇧	⇔	⇔
	Microbial abundance	⇩ Fungal-to-Bacterial ratio	-	⇔	-
	Microbial community composition	↻ Bacterial community*	-	↻ Bacterial community*	-
	Microbial activity (respiration)	⇧*	-	⇧*	-

⇧ indicates increase, ⇩ indicates decrease, ⇔ indicates no significant difference and ↻ indicates change
AOA indicates ammonia oxidising archaea, AOB indicates ammonia oxidising bacteria
* Dependent on growth stage of crop
** Dependent on soil type
*** Based on plant N uptake

For further information:

Further details of the recent research into effects of climate change and extreme weather events on Australian cotton systems are summarised in a review on the CRDC website (see below). A global assessment of the impact of climate change and adaptation in modern cotton farming systems has been published by the International Cotton Advisory Committee (ICAC).

https://www.cottoninfo.com.au/sites/default/files/documents/Effects%20of%20climate%20change%20and%20extreme%20weather%20on%20cotton.pdf

Re-evaluating Prediction Models for Cotton Development

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Key management recommendations rely on accurate estimates of crop development using a 'day degree' approach. Currently, the day degree approach used in Australia is not entirely robust to accommodate sometime extremes of climate (heat/cold) and has not been validated for use with current cotton cultivars. The aim of this research was to refine an approach for cotton development for temperature extremes and ensure it can be used confidently in new cotton regions in Australia. Crop development data was collected from observations (a total of 29 field locations) by CSIRO in Australia, USDA in USA, and from the Australian Cotton Seed Distributors Ambassador program from 2002 until 2017. Using this data we developed and validated new algorithms to predict first square and first flower including: i) the existing Australian industry day degree function (base temperature 12°C with no upper threshold); ii) the existing industry function with modifications for cold shock; iii) new day degree models with base temperatures ranging from 12°C to 7°C combined with an upper threshold temperature ranging from 30°C to 36°C; and iv) and a function that represented the biological rate response to temperature generated from controlled environment studies undertaken in the Phytotron in Canberra.

Approximately half the data was used to build algorithms and the other half was used for validation. The results showed that there were significant improvements in the RMSD (root mean square deviation representing the variation of observed versus predicted outcomes) of algorithms over the existing Australian industry function that: i) had a base temperature of 15.6°C, combined with an upper threshold of 32 to 36°C; and ii) used a function that represented a biological rate response. The rate response function also helped consolidate the use of 15.6°C as an appropriate base temperature. The base temperature of 15.6°C is the same base temperature used in the USA crop development function (60°F). Another key component of these functions was no need for adjustments for cold shock like that used in the current Australian day degree function. These new functions could be applied universally across nations to capture cotton's (Gossypium hirsutum L.) developmental responses to temperature.

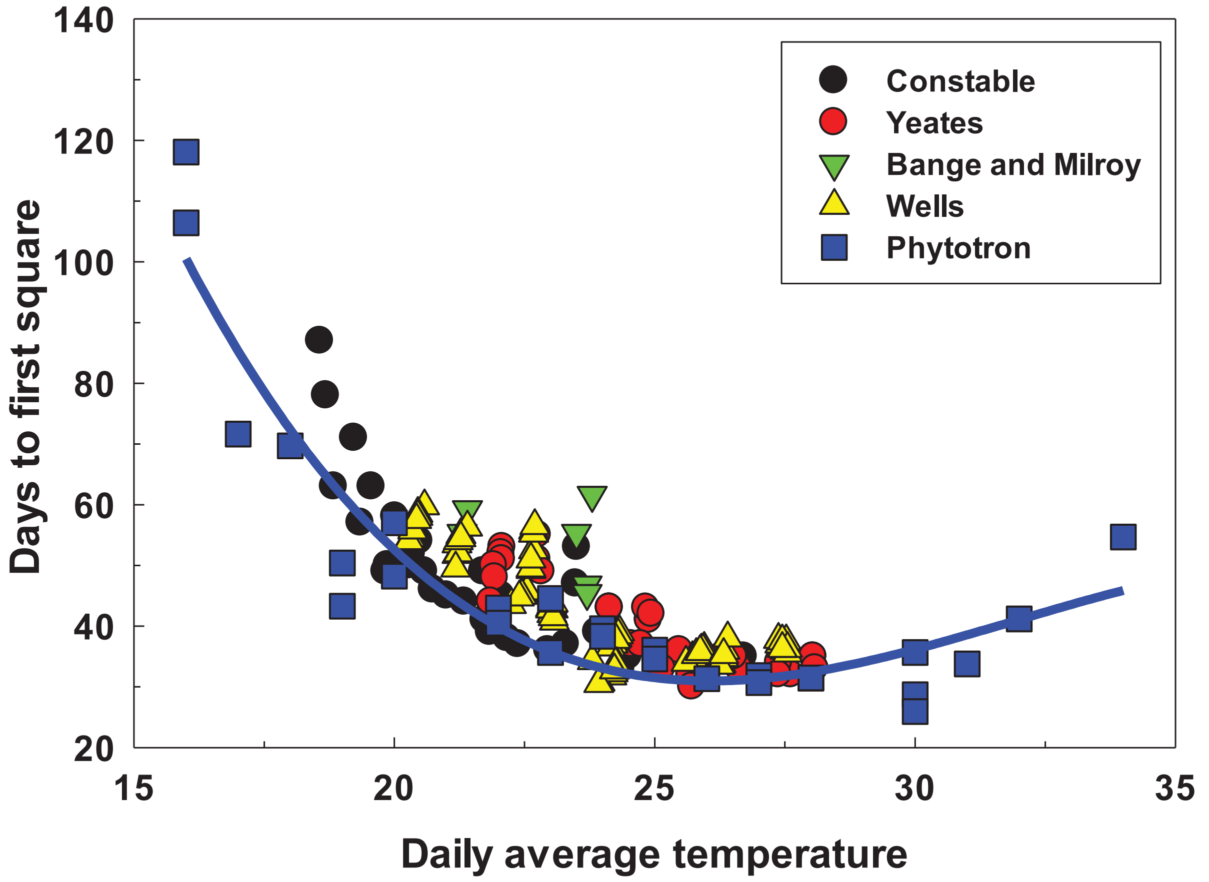

Figure: A combination of controlled environment studies and field measurements of phenology were used to validate alternative functions to predict cotton development. Here is the response of the timing of first square (after planting) in response to average temperature between planting and first square.

The *Gossypium* genus – an untapped pool of novel photosynthetic traits for cotton?

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Increasing annual temperatures and more frequent and extreme heatwaves as a result of climate change are predicted to reduce cotton yield potential. 'Future-proofing' cotton cultivars (*Gossypium hirsutum*) to withstand elevating temperatures is required to maintain and further improve cotton yields under increasingly challenging future climates. Improving the resilience, performance and efficiency of photosynthesis is a potential target to improve crop yields under suboptimal conditions[1]. Exploiting the natural diversity of photosynthesis in crop varieties and wild relatives is a promising approach[2].

Our research investigates the potential to utilise photosynthetic traits from within the Gossypium genus in the development of climate-adapted cotton cultivars. This requires screening for diversity in photosynthetic performance and thermotolerance. The Gossypium genus is a large and diverse genus comprised of over 50 species. These species are categorised into eight diploid genomes (A, B, C, D, E, F, G and K) and one tetraploid genome (AD) to which cultivated cotton (G. hirsutum and G. barbadense) belong.

These different genomes, and even the species within each genome, vary enormously in their origin and therefore the climates in which they've evolved. This has resulted in remarkable differences in their morphology, and likely physiology. These evolutionary differences have spotlighted these species as potential sources of novel traits to abiotic stresses such as heat and drought.

Our research at the Hawkesbury Institute for the Environment (Western Sydney University) and CSIRO, supported by the Cotton Research and Development Corporation (CRDC) investigates interspecies variation in photosynthetic traits.

The Diurnal Canopy Photosynthesis and Stomatal Conductance (DCaPST)[3] simulation platform is used to test the effect of exploiting various photosynthetic traits of diverse Gossypium species on cotton radiation use efficiency (RUE) and therefore biomass accumulation. This platform is used to test photosynthetic modification scenarios and the value of these traits to the Australian cotton industry.

[1]*Sharwood (2017) Engineering chloroplasts to improve Rubisco catalysis: prospects for translating improvements into food and fiber crops. New Phytologist*
[2]*Sharwood et al. (2016) Temperature responses of Rubisco from Paniceae grasses provide opportunities for improving* C_3 *photosynthesis. Nature Plants*
[3]*Wu et al. (2018) Simulating daily field canopy photosynthesis: an integrated software package. Functional Plant Biology*

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Breeding low leaf sodium concentration to enhance sodicity tolerance in cotton

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Sodic soils are common in where cotton is grown and produced globally. Alkaline and excessive Na salts undermine soil physical and chemical properties, and they reduce availability and uptake of important nutrients, e.g. potassium (K) and phosphorus (P) for cotton (Rochester, 2010). Cotton can suffer many physiological stresses including nutrient imbalance, deficiency and Na toxicity, which subsequently constrain plant growth and reduce yield and fibre quality. Exploiting novel genetics that regulates Na uptake, transport and sequestration has long been regarded as the most effective approach to enhance cotton tolerance to soil sodicity.

Over last few years, we evaluated low leaf Na concentration trait existing in *G. barbadense* to understand its inheritance and role of mitigating the impact of soil sodicity on cotton. In leaf samples taken at early flowering, Na concentrations exhibited 5 to 10-fold difference between lines from *G. barbadense*, e.g. VH8-4601 (HV8) and Sipima 280 and from *G. hirsutum.* e.g. Sicot 75 and Guazuncho 2 (GUA) (Fig. 1). The measurement was proved to be reliable to quantify the difference of test lines, as little distorted by the interaction between test line and season (Fig. 1 and also referring to Liu *et al.* (2020)). In an interspecific derived RIL population, a large segregation was observed for the trait (Fig.1), nevertheless, 30% more of its variation could be explained by two QTLs mapped in chromosome A1 and D1 (Liu *et al.*, 2015).

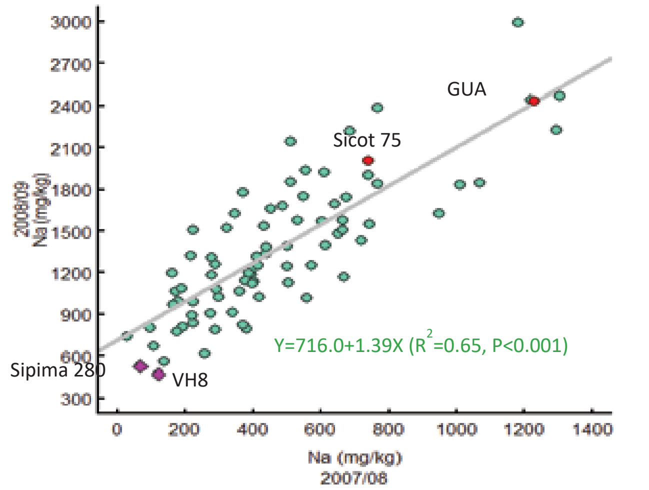

Fig. 1. Seasonal variations and interrelation of leaf Na concentration in a RIL population derived from an interspecific cross of Guazuncho 2/VH8-4602. Red and purple squares represent the concentrations of two parents and two local controls.

High hertiable nature of leaf Na concentration trait was further confirmed by backcrossing breeding to reduce leaf Na in cotton. In that instance, a RIL with low leaf Na concentration was chosen as a donor, and a then commercial *G. hirsutum* cultivar, Sicot 71BRF as a recurrent parent (RP). Fig. 2 illustrates leaf Na concentration and lint yield of BC derived lines tested in farm fields with sodic subsoils. Among 11 lines with reduced Na concentration when compared to RP ($P \leq 0.05$), six had lint yield competitive to RP and three exceeded by 4 to 5%. However, two with very low Na concentrations exhibited poor yields. All high yielders had fibre quality combinations comparable to RP. Therefore, at some extent, further reducing leaf Na concentration would not compromise agronomic performance in cotton.

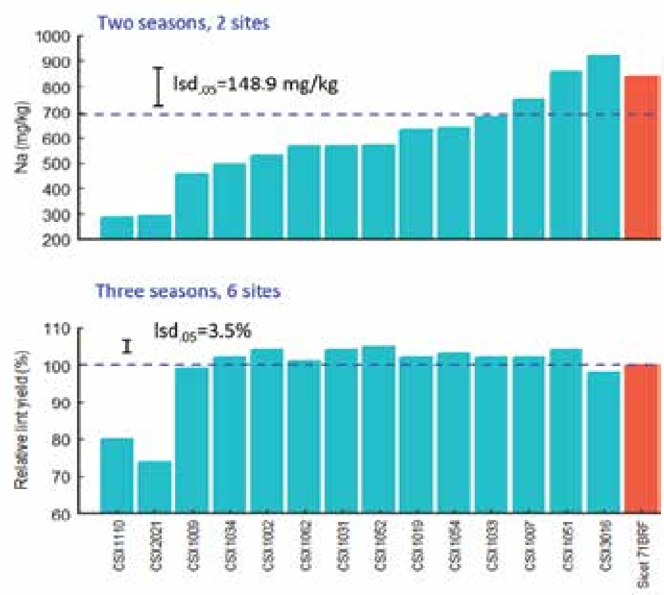

Fig. 2. Leaf Na concentration and relative lint yield of 14 BC derived line and recurrent parent (RP) during multiple season tests. Blue dash line represents Na concentration of one l.s.d less than RP (upper panel) and relative yield against RP (2604 kg/ha, lower panel).

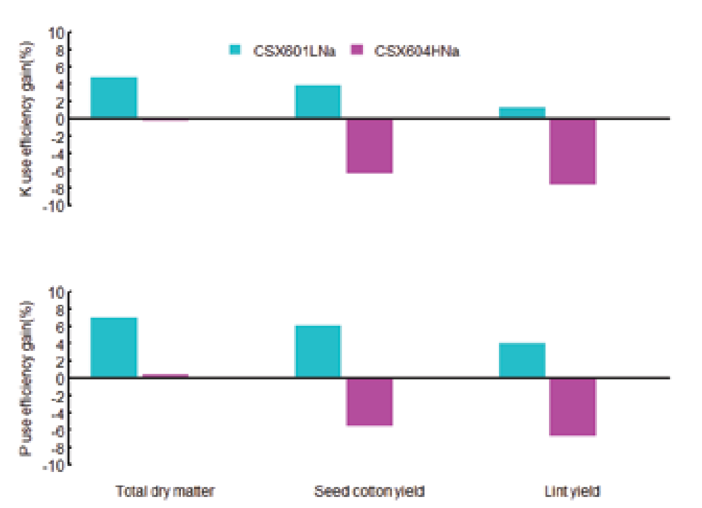

Fig. 3. Gain (green) and loss (red) of K and P use efficiency for low and high Na lines when compared to Sicot 71BRF, which had use effficency of 59.8, 36.3 and 14. 6 mg/mg for K and of 448.0, 273.0, and 109.0 mg/mg for P estimated from three preductivity traits, respectively. CSX601LNa and CSX604HNa represent low Na and high Na line, respectively.

We also examined how low and high leaf Na trait affected Na uptake, distribution and nutrient use efficiency of P and K in plant. Based on nutrient analysis of whole plant biomass collected at cut-out stage, low Na line maintained low Na concentration in leaf canopy, but higher Na concentration in stems and roots; however, that was opposite to the high Na sister line and RP (Liu *et al.*, 2020). Overall, low Na line took up and accumulated more Na in plant, but interestingly, that was accompanied with improved K and P use efficiency in low Na line when compared with its sister line and RP (Fig. 3).

In summary, our research demonstrated low Na trait in cotton was heritable and had value to reduce Na concentration in leaf canopy without compromising agronomic performance. The trait did not only increase Na uptake and accumulation, but also altered its transport, distribution and storage. Most importantly, it appers to make cotton more efficient in use of P and K. Our ongoing reseasrch is now being undertaken to unveil genes, gene regulation network and physiologic mechansim behind the triat.

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Progressing Cotton Systems Downunder in a Climate of Change

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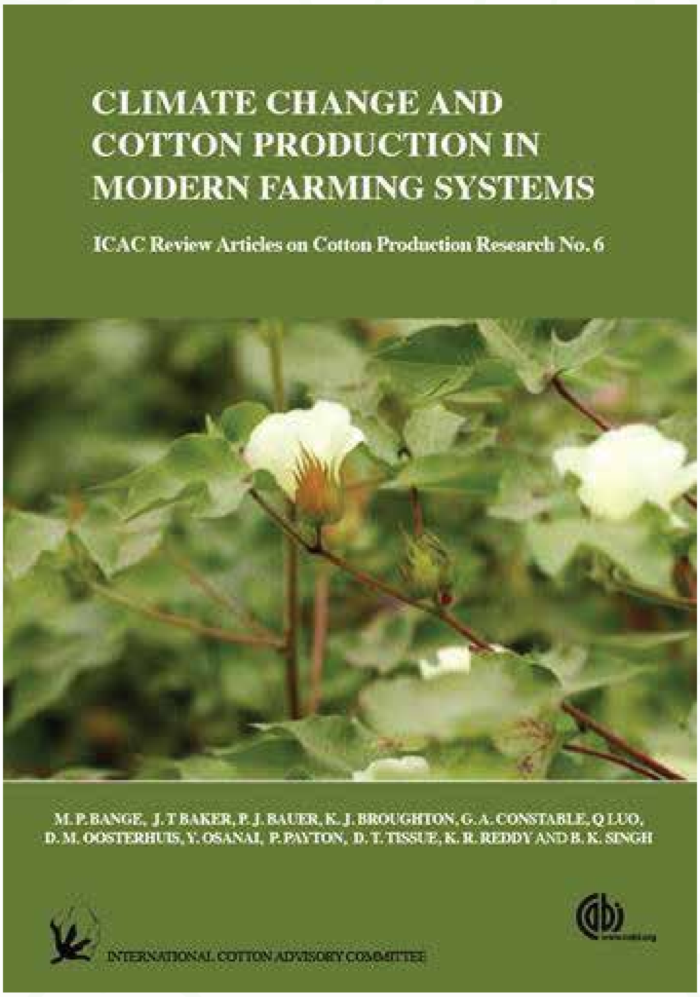
The Australian cotton industry has evolved from low yielding rainfed systems to be Australia's fourth biggest exporter, achieving some of the highest yielding crops worldwide (typical Australian yields are 2200 kg/ha irrigated and 500 kg/ha dryland. Brazil has yields about 1700 kg/ha, USA 1000 kg/ha, with global average of 800 kg/ha). Australian cotton systems are characterised as high input/high yielding systems. Success of the industry has resulted from significant investment in integrated cotton management addressing all aspects of the production across the whole value chain.

Strategies to improve Australian cotton production and sustainability will continue to require integrated systems research over a wide range of environments (including future climates) and stresses, to assess impacts and adaptation options for yield and quality improvements. One of the most significant challenge for irrigated cotton is climate change as it is multifaceted and complex, and it will affect the sustainability of farms, ecosystems and the wider community. Because elevated CO_2 can mitigate many of the negative impacts of environmental stresses on plants, one promising course of action would be to breed cotton cultivars that are highly responsive to elevated CO_2. Broughton et al. (2017) suggested that breeding efforts have not yet exploited that variation. Future climate however, may also present challenges associated with increasing canopy photosynthesis, especially for high input crops in elevated CO_2 with warmer temperatures. It may encourage excessive vegetative growth causing fruit shedding and increasing transpiration therefore lowering WUE, despite the improvements in leaf photosynthesis.

Furthermore, molecular biology should target photosynthetic capacity to increase canopy radiation use efficiency especially in stressed situations. Conaty and Constable (2020) recently documented that lint yield improvement over the past few decades in Australia was associated with increases in harvest index and biomass; however, there was some evidence that yield was negatively associated with canopy radiation interception adding to the complication in improving yield improvement. Frameworks that scale from leaf to canopy photosynthesis are needed to address this complexity and considerations on how to resolve these issues are necessary for breeding and management combined (Bange et al. 2016).

For Australian cotton breeders, delivering high yielding cultivars to cotton growers is still essential to maintain economic viability. Along with traditional approaches to breeding, future breeding efforts will need to rely on both high-throughput genotyping and phenotyping approaches for trait selection. Specific tolerances for heat and water stress in rain-fed environments have been recorded despite no specific selection pressure on these stresses. Recently, genetic variability of transpiration rates to vapour pressure deficits (VPD) and sodicity tolerance have been identified.

Access to water through reductions in sources of irrigation, less rainfall or increases in evapotranspiration remains a significant challenge. Increased yields so far have been largely obtained by more rapid fruit setting. Well-managed, insect resistant crops have near optimal retention and fruit set, so further increases in yield will require a longer crop duration but maintaining a functioning canopy for longer would require more water.


CLIMATE CHANGE AND COTTON PRODUCTION IN MODERN FARMING SYSTEMS
ICAC Review Articles on Cotton Production Research No. 6
M. P. BANGE, J. T BAKER, P. J. BAUER, K. J. BROUGHTON, G. A. CONSTABLE, Q LUO, D. M. OOSTERHUIS, Y. OSANAI, P. PAYTON, D. T. TISSUE, K. R. REDDY AND B. K. SINGH
INTERNATIONAL COTTON ADVISORY COMMITTEE

Considerable research has been undertaken in well-watered conditions, and less research has considered the implications of cotton growth, yield and fibre quality with less water availability. Australian systems will require closer examination of the response to various water deficits and drought recovery cycles.

Constable and Bange (2015) identified nutrition as a major limitation for yield improvement going forward. There is a wide diversity of nutritional management approaches used in cotton systems, a large diversity in soil types and regions, and proven diversity between cultivars in nutrient use efficiency (Rochester and Constable 2015). Consequently, we believe that improving yield through enhanced nutritional management, and better matching genotypes to different cropping environments, represent a key opportunity in Genetic by Environment by Management (GxExM) research. A greater understanding of nutrient uptake and its timing, distribution, and redistribution in relation to cotton fruiting dynamics is required to develop strategies which would result in consistently high yields.

Given the importance of high fibre quality to Australian industry's share in international markets it is also imperative that it retains focus on further improving fibre quality. The task for the industry is to optimise fibre quality in all steps from strategic farm plans, cultivar choice, crop management, harvesting and ginning. Bange et al. (2018) have termed this 'Integrated Fibre Management' to emphasise the importance of a balanced approach across the whole value chain.

Here we present to the members of ICRA a snapshot of cotton research being conducted in Australia. In keeping with the spirit of encouraging collaboration within the ICRA I encourage you to contact the researchers presented here if their topic sparks your interest.

This commentary is an excerpt from an article written by Bange, Constable and Liu for the Australian Agronomy Conference (2021).

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Optimizing irrigation scheduling in cotton using canopy temperature monitoring – A new addition to farmer toolbox

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Water is the most limiting factor in Australian cotton production systems. Optimized irrigation scheduling is central to achieving high water productivity as both overwatering and water stress reduces yield. Cotton growers in Australia predominantly use soil water sensors to schedule irrigations. To provide growers with more information on their crop's water status, this research aimed to develop a more direct approach by monitoring the canopy temperature of cotton plants using wireless infrared sensors (Fig. 1). Plants grow optimally in a narrow range of species-specific canopy temperatures known as the "thermal kinetic window (TKW)" which for cotton is around 28 to 32°C. Plants maintain canopy temperature closer to the TKW by releasing their heat load through evaporation which requires energy. Conversely, when water availability becomes limited, plants respond by closing the stomata which results in reduced transpiration and elevated canopy temperature because of plants' reduced capacity to dissipate energy.

Figure 1: A wireless infra-red sensor monitoring canopy temperature in a cotton field.

As such the canopy temperature of a water-stressed crop is generally higher than the temperature of a wall-watered crop (Fig. 2), resulting in a strong relationship between yield and canopy temperature (Fig. 3). We used this understanding to develop an irrigation scheduling method based on continuous monitoring of canopy temperature and underpinning physiology. Continuous monitoring of crops reflects crop conditions approaching the need for irrigation – avoiding plant stress. This decision-making tool will enable growers to make an irrigation decision based on crop's response to current soil water status rather than relying on a fixed soil water deficit. Being a plant-based approach, canopy temperature offers different but complementing information to soil and weather-based approaches. Canopy temperature infrared sensors are affordable, easy to use and maintain, and will hopefully be a valuable addition to the suite of tools available to growers for making important irrigation decisions.

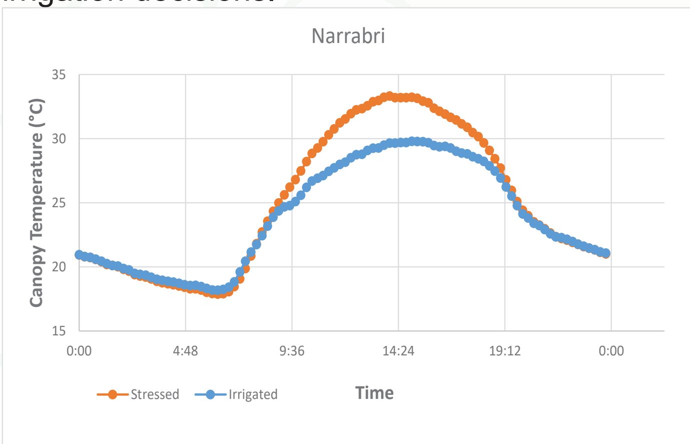

Figure 2: The difference in canopy temperature of a well-watered (blue) and a water-stressed (orange) crop at CSIRO trials in Narrabri during a 24-hour period.

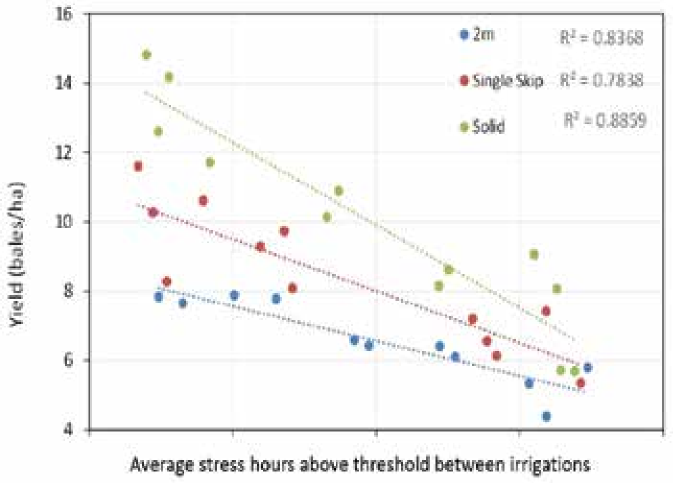

Figure 3: The relationship between yield and stress time between irrigations measured using canopy temperature (1 bale = 227 kg lint) in three row configurations commonly used in Australia

Commercial availability of the technology

The canopy temperature technology including the algorithms to convert data into an irrigation decision is being delivered to growers by Goanna Ag (www.goannaag.com.au) through a commercial agreement with CSIRO (research agency) and CRDC (funding agency). Goanna have integrated the canopy temperature data into their existing platform to show both soil water and crop stress derived from canopy temperature (Fig. 4). An irrigation is recommended when cop stress reaches the threshold displayed as 100% in bottom panel of figure 4. Green and red colours indicate whether a crop is stressed or well-watered, respectively, at that point in time (Fig. 4).

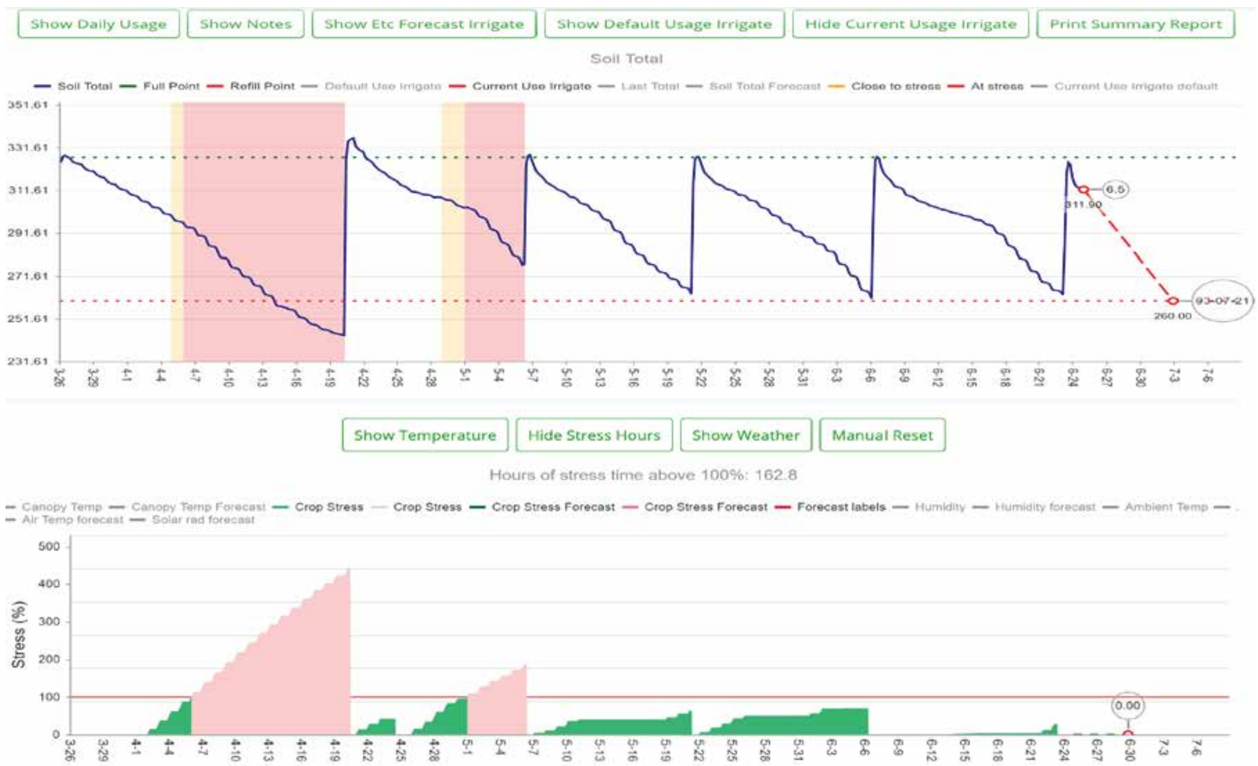

Figure 4: Goanna Ag platform displaying soil water data (top panel) and crop stress derived from continuous measurements of canopy temperature; the red horizontal line in bottom panel shows the stress threshold at which an irrigation is recommended.

Our recent research has demonstrated that soil constraints such as compaction caused by farm machinery alters the soil-plant-water dynamics. Compaction hinders root penetration in soil profile and reduces both crop water use and soil water recharge following irrigation and rainfall, thus affecting root zone and plant available water. Integrating canopy temperature and soil water data in real time helps understand the presence of water in soil profile and its availability to crop thus helping growers a more informed decision.

Acknowledgements

This research is funded by Cotton Research and Development Corporation (CRDC) and the Department of Agriculture and Water Resources. We acknowledge the support of many farmers and consultants who collaborated with CSIRO during development of this technology over last several years.

Phosphorus movement within irrigation network of Australian cotton farm

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Tracing the nutrients in cropping field is a complex process which is often influenced by a range of factors such as current management, soil characteristics, seasonal variability and management history of the farm. Vertisols around the world are vital resources that serve as the lifeline of agriculture because of their high productivity. Efforts to improve the productivity and long-term sustainability of these resources for current and future generations are an ongoing process. The modern agricultural practice (e.g. fertiliser application) to improve production has resulted in nutrient stratification with enrichment of topsoil and depletion of subsoil. This effect is more pronounced for nutrients such as phosphorus (P) that are less mobile in Vertisols, thereby increasing the potential risk of dissolved reactive P (DRP) movement in surface runoff water to adjacent water bodies. There is a paucity of empirical studies on the links between crop management practices and dissolved P movement from cotton fields to on-farm storage dams within Australian cotton farms. We synthesised the results from two field investigations over six years that were focussed on studying the impact of nitrogen (N) management practices, crop rotation and tillage on irrigation induced dissolved P movement in intensive cotton production systems.

A three-year field investigation (2014-2017) was overlaid on a long-term experiment near Narrabri, New South Wales, Australia to evaluate the effect of tillage practices and in input irrigation and runoff waters. The six cropping systems investigated included: (1) maximum tillage cotton monoculture (MXT-CC), (2) maximum tillage cotton maize (MXT-CM), (3) minimum tillage cotton monoculture (MNT-CC), (4) minimum tillage cotton maize (MNT-CM), (5) minimum tillage cotton-wheat (MNW-C) and (6) minimum tillage cotton-wheat-maize (MNW-CM) rotations. In addition, phosphorus movement and balance were also monitored in the trials investigating irrigation frequency, N and P interactions over three years (2017-2020). Irrigation volume, runoff, total and dissolved P balance during irrigation were monitored during cotton seasons. The closed irrigation network of cotton farms recycles runoff water during irrigation and rainfall (Figure 1). In this study, the term runoff suggests the tail drain water that is recycled back to on-farm dams within cotton fields.

The dissolved reactive P balance in surface hydrological pathways within the irrigation network of the cotton farm showed that the maximum tillage treatment had a positive P balance within the fields (negative net dissolved reactive P losses) (Figure 2A). The net addition of reactive P to the field in irrigation water ranged upto 583 g/ha/year over the three years. The maize rotation within the minimum tillage system resulted in higher reactive P losses in runoff water which was related to both reactive P concentrations (Figure 2A and 2B) in runoff water and higher runoff volume under minimum tillage,

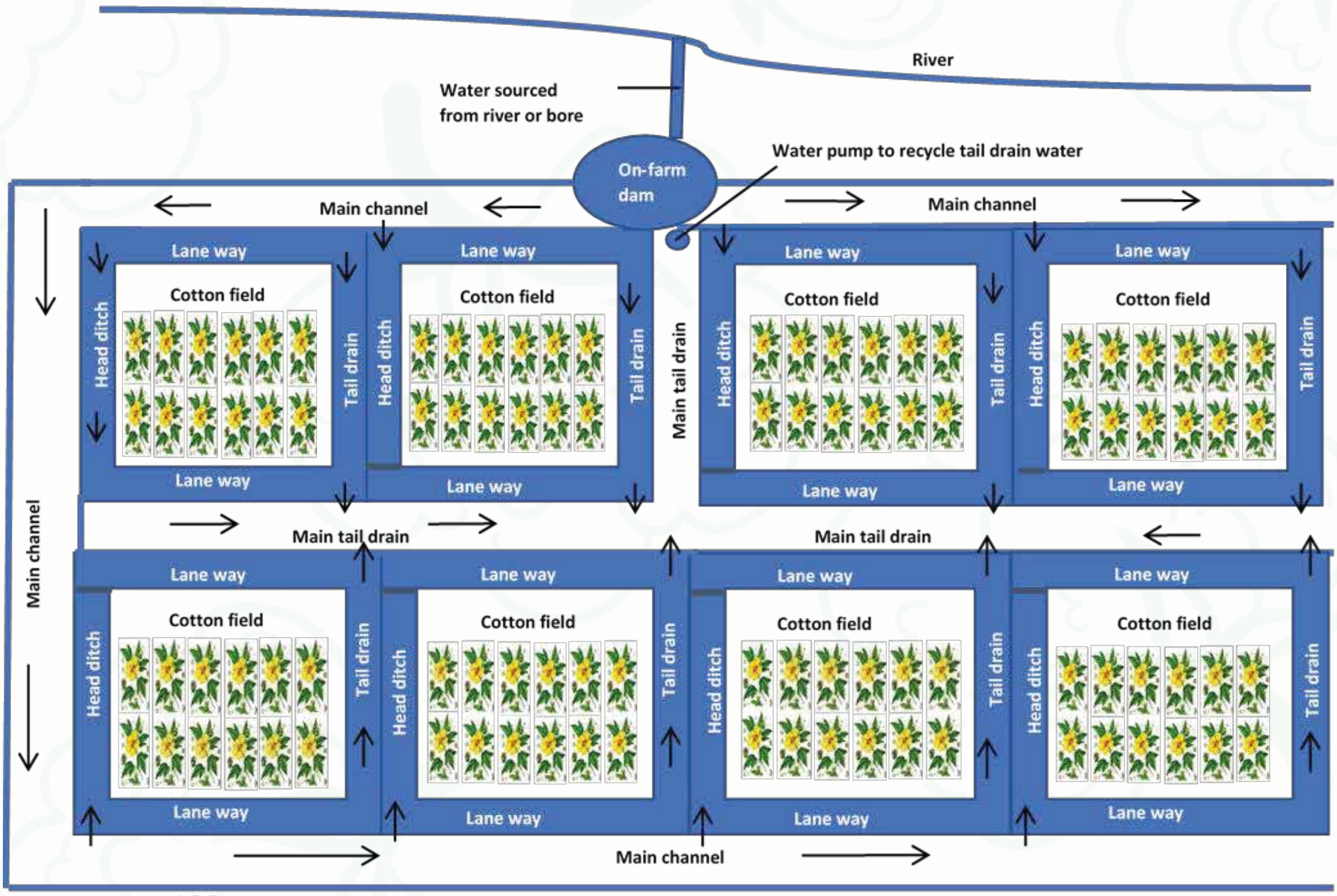

Figure 1. Closed irrigation network layout of cotton farms in Australia

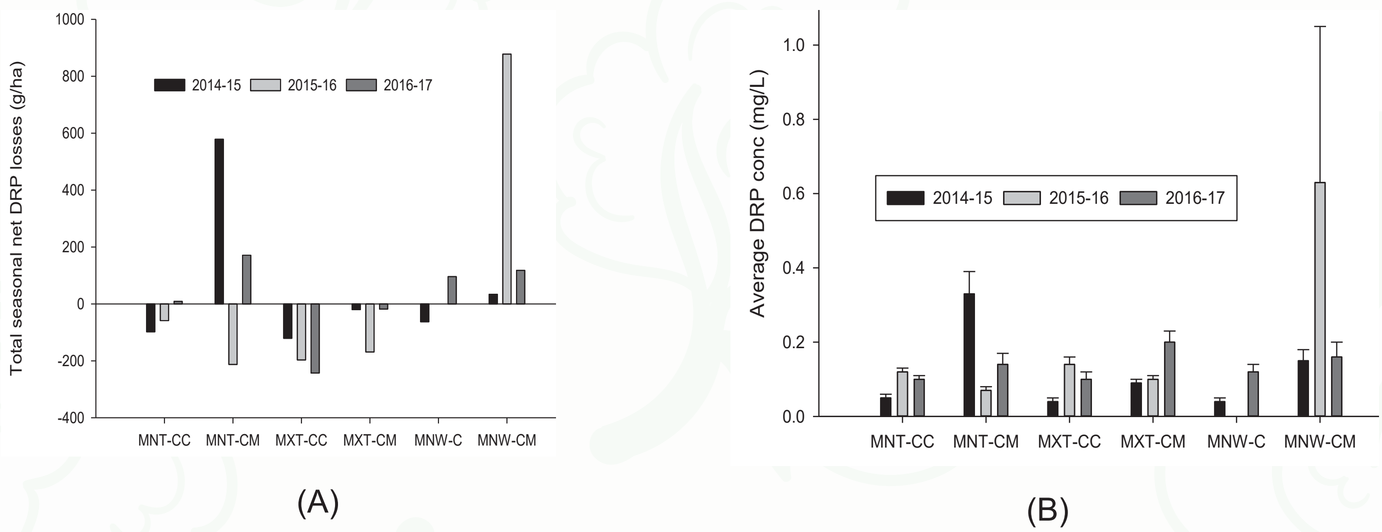

Figure 2. Dissolved Reactive P (DRP) balance in cotton farming systems- A) Average DRP concentrations (mg/L), B) Total seasonal net DRP losses (negative values indicate gains to cotton fields) (maximum tillage cotton monoculture-MXT-CC), maximum tillage cotton maize- MXT-CM, minimum tillage cotton monoculture-MNT-CC, minimum tillage cotton maize-MNT-CM, minimum tillage cotton-wheat- MNW-C and minimum tillage cotton-wheat-maize-MNW-CM)

compared to maximum tillage. The DRP results suggest that, except for maize rotation systems under minimum tillage, all other cropping systems resulted in a positive P balance (Figure 2A). The DRP accounted for greater than 90% of total dissolved P in irrigation and runoff water. Though this investigation on long term trial has not undertaken the measurement of particulate P movement in sediments which might contribute to net P losses from the field, the total suspended solids measurements (TSS) in this study over three years suggest net addition of sediments to the field, so net sediment P losses are unlikely.

The second investigation studying the interaction of nitrogen, phosphorus and irrigation frequency suggested nitrogen application minimised the phosphorus movement in runoff water. While mechanistic studies are warranted to further understand the effect of N on minimising P movement in the runoff, the potential causes for this interaction could be the N priming effect on microbes resulting in P immobilisation and higher plant P uptake with N applied plots as a result of higher biomass production contributing towards minimum fertiliser P losses in runoff water. While the 2017-18 season resulted in a negative P balance as a result of higher runoff volume, the 2018-19 and 2019-20 seasons resulted in a positive P balance (data not presented). The total P analysis of 2019-20 season water samples indicated that sediment P accounted for ~40% of total P in runoff and another year of positive P balance. The phosphorus loads in irrigation water and runoff may not be agronomically significant, the net addition to the cotton field during irrigation minimise risk to on-farm dams and improves farm sustainability. These results demonstrate that the cotton-growing cracking clay with moderate P sorption capacity has the potential to minimise the P movement in irrigation water and improve the overall on-farm sustainability of cotton farms.

Acknowledgement

This research was undertaken as a sub-project of the More Profit from Nitrogen Program, supported by funding from the Australian Government Department of Agriculture, Water and Environment as a part of its Rural R&D for Profit program, Cotton Research and Development Corporation and NSW Department of Primary Industries is gratefully acknowledged. Assistance from various technical and ACRI farm staff are gratefully acknowledged

Machine vision technology for in-season cotton management

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Introduction

Automated cotton growth assessments can reduce labour for in-crop inspections and generate maps that can be interpreted by data analytics frameworks to inform in-season management. This can be achieved by linking machine vision sensors with biophysical crop models (e.g. He & Mostovoy 2019) and machine learning models (e.g. Dayal et al. 2019). Three main platforms for crop sensing are satellite imagery, on-the-go (e.g. UAV) and fixed infield sensors which have differing spatial and temporal resolutions, cost and labour requirements (Table 1). Cotton physiological features commonly detected using machine vision are canopy cover, flowering and boll opening. Traditional colour and shape-based machine vision algorithms have been implemented to detect canopy cover and open bolls from infield and UAV cameras with $R^2=0.91$ for flowers and $R^2=0.80$ for open bolls (Jia et al. 2014, Thorp & Dierig 2011, Yeom et al. 2018). Deep learning has also been used to detect changes in growth stages from appearance of plants (e.g. presence of bolls, flowers, Wang et al. 2020) and has potential to be trained to detect canopy and count fruit flowers and fruit. From satellite imagery, vegetation indices NDVI or NDRE are common indicators of leaf area index (Pasqualotto et al. 2019 with $R^2=0.73$). Open bolls can also be detected from satellite imagery by calculating a 'boll opening index' using reflectance in the red edge, blue and red channels (Ren et al. 2020 with $R^2=0.71$ at 66 cm row spacing). There is potential to use

Table 1. Comparison of sensor platforms used for spatial crop sensing

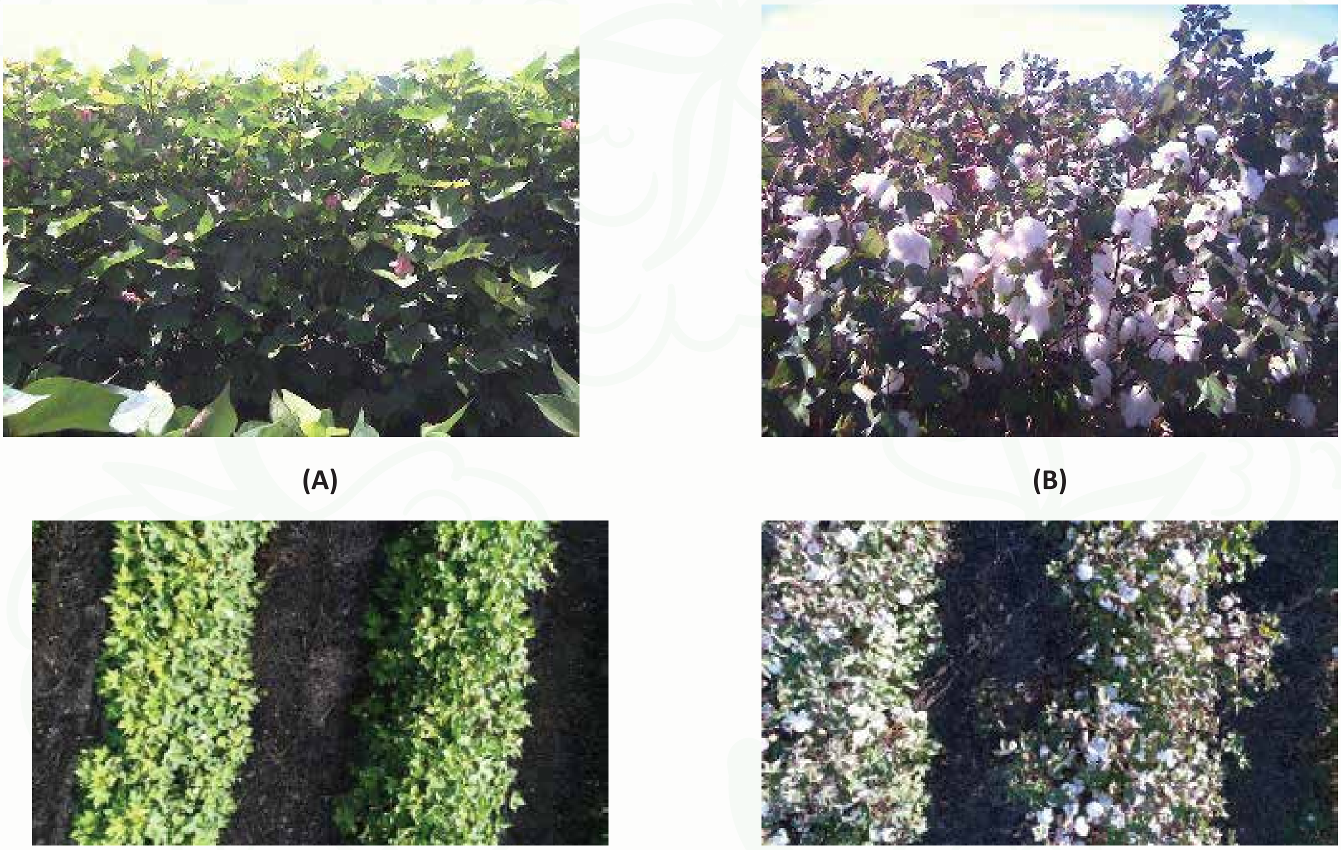
Sensor platform	Orientation	Field of view	Temporal frequency	Labour requirements	Cost $AUD
Satellite imagery	Top view	10-100 m²	Weekly-monthly depending on cloud cover	None	Varying – free options available
On-the-go (e.g. UAV)	Top or oblique view	Up to 1 m²	As labour permits	UAV mission development and supervision	~$2000 for UAV + labour
Infield fixed	Top, oblique or side view	~10 plants	Continuously	None	~$200 per location

Materials and method

Data was collected on three centre pivot irrigated cotton fields on the Darling Downs, Queensland, Australia (Table 2) to establish the accuracy of UAV, infield and satellite imagery systems for canopy cover, flowering and boll opening assessment using traditional and deep learning machine vision algorithms. Crops were planted at 1 m row spacing in the first season and at 1.5 m row spacing in the other seasons. Image and ground truthing datasets were collected weekly at 4 to 24 sampling locations in each season. Field measurements collected were canopy width, flower counts/m², boll counts/m².

Table 2. Images captured over three seasons of field data collection

Season	Satellite images	UAV images	Infield camera images
2017/18	28	105	3436
2018/19	24	311	2833
2019/20	20	503	2932



(A) (B) (C) (D)

Figure 1. Sample images captured from infield cameras for measuring: (a) canopy cover and flowering and (b) boll opening; and from UAV for measuring: (c) canopy cover and flowering; and (d) boll opening.

Top view colour UAV images were captured using a DJI Phantom 4 at each sampling location. Side view colour images were captured at 4 to 5 sampling locations from solar powered smartphones each season. Sample images captured are shown in Figure 1. Traditional machine vision algorithms were implemented on images captured from the infield and UAV cameras. Canopy cover was determined by applying excess green thresholding on images (Woebbecke et al. 1995), whilst flower and open boll area were determined by applying white colour segmentation on the images (Thorp & Dierig 2011) and assuming an average flower and boll area. Convolutional neural network deep learning machine vision algorithms were trained with a random 50/50 test/train data split.

Two types of deep learning models were developed for each crop feature (canopy cover, flower counts and boll counts). One model was trained with one season of data and tested on the other two seasons of data, whilst the other model was trained with two seasons of data and tested on the other single season of data. Each model was replicated three times for the three possible combinations of seasons used for training.

Satellite imagery was acquired from Sentinel-2 using Google Earth Engine for each sampling location. NDVI, NDRE and the boll opening index were calculated for each site. The boll opening index was also implemented to calculate a flowering index.

The machine vision and satellite imagery algorithm results were compared with ground truthing datasets collected on the day of sampling for the infield and UAV imagery and the closest available date for the satellite imagery. The results are reported as percentage RMSE and coefficient of determination (R^2). For the deep learning algorithms, RMSE and R^2 were averaged across the replicates.

Results and discussion

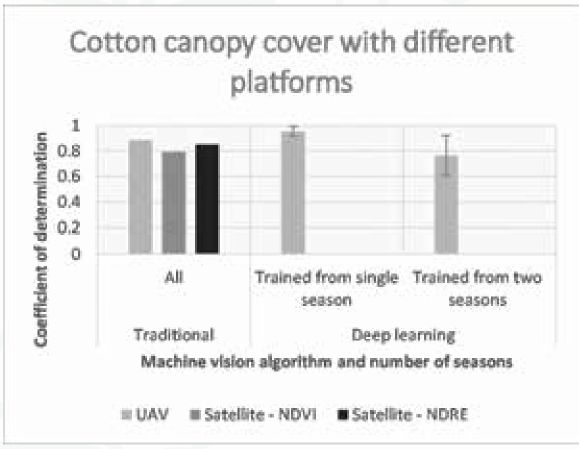
Figure 2 compares the performance of the machine vision algorithms. Canopy cover was most accurately assessed using either traditional or dep learning machine vision algorithms from either UAV or satellite imagery (R^2=0.89, RMSE=13.8%). Cotton flowering was most accurately determined using deep learning algorithms trained from two seasons of data (R^2=0.93, RMSE=34.9%). Boll opening was most accurately determined using traditional algorithms on infield or UAV imagery rather than satellite imagery (R^2=0.91, RMSE=19.0%). Flowering and boll opening algorithms were more accurate than existing reported methods. The accuracy of deep learning algorithms generally improved with training from two seasons instead of one season. Traditional algorithms could be used until larger datasets are available for training.

Conclusions

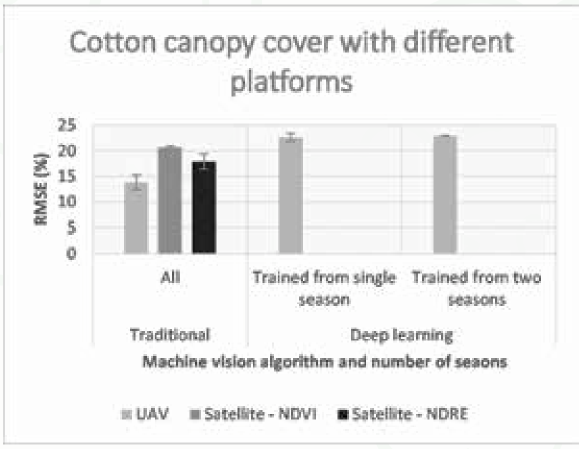
Traditional and deep learning machine vision algorithms were evaluated on infield, UAV and satellite imagery for detecting cotton canopy cover, flowering and boll opening. There was very little difference between the traditional and deep learning algorithms for detecting canopy cover; flowering was only accurately detected using deep learning and two seasons of data; and boll opening was most accurately detected using traditional algorithms. It is expected that with further training data, the deep learning algorithms would have the same or better performance than the traditional algorithms for detecting boll opening. Further work is to identify the number of seasons and sites of data required for sufficient deep learning model training.

Acknowledgements

This project is supported by the Australian Government Department of Agriculture, Water and Environment as part of its Rural R&D for Profit program and the Cotton Research and Development Corporation. The authors are grateful to grower Neil Nass (Leahaven) for providing the field trial site.



(A)



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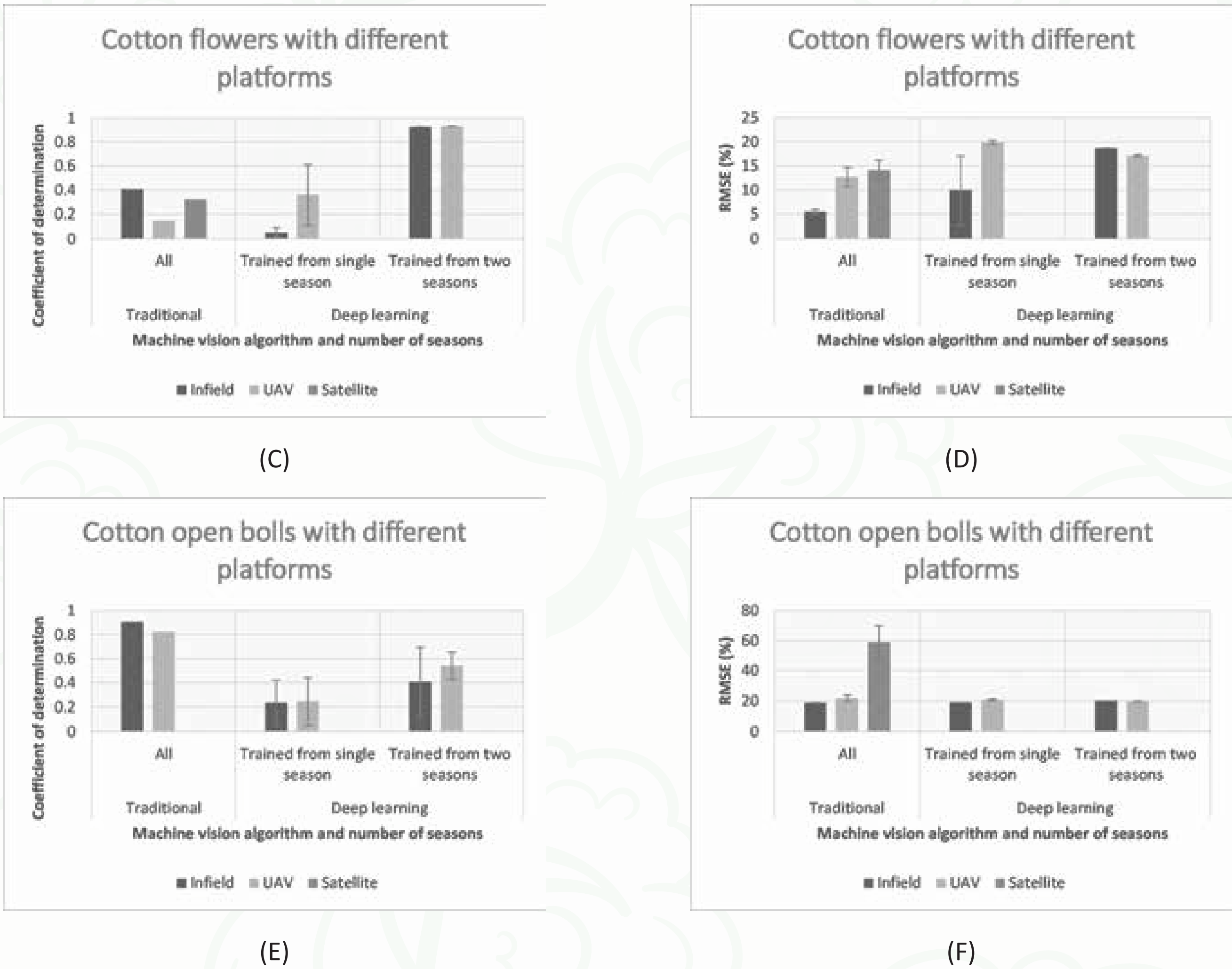

Figure 2. Coefficients of determination and RMSE of traditional and deep learning machine vision algorithms for determining: (a)-(b) canopy cover, (c)-(d) flower counts and (e)-(f) open bolls.

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Soiled undies, soil health and mycorrhizal myths

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In 2018 a Nuffield scholar returning from Canada brought the idea of soiling a pair of cotton undies to investigate soil health to the attention of Oliver. This soil health engagement tool seemed like a brilliant idea and so Oliver with the assistance of his colleagues in CottonInfo organised for a few dozen pants to go out to some cotton growers. The plan was the growers would soil them (i.e. burying them in the soil) and bring them in to the Australian Cotton Conference to start a conversation around soil health. The discussion the returned pants generated and the competition for the most degraded pair of pants between growers led to an extension of the project, which over the next few years grew beyond our cotton farms, into their communities and eventually across every state and territory in Australia in a citizen science challenge. The result of this simple engagement tool, which involves burying a pair of cotton pants five cm deep for eight weeks and then looking at the level of degradation, has got thousands of Australians thinking about their soil health and ways to either maintain or improve it (Figure 1).

There have been other spin offs to the soil your undies initiative. Australia may have a little way to go to catch up with some of the Cotton Incorporated work that Mary Ankeny wrote about in issue 2, but we're rapidly making in solutions to textile waste. The University of New England (UNE) team has been fortunate enough to become involved in some waste reduction projects. The biggest one of these, the Coreo led 'Transition to Action', which has now progressed to field trials at Alcheringa, a cotton farm operated by Goondiwindi Cotton owner Sam Coulton, on the back of risk assessments work undertake at UNE.

Central to a lot of our cotton work are the learnings we make about how our science will impact on our systems and its long-term sustainability. This is where our systems work and collaborations with several industry partners has allowed us to pursue our interest not just in crop production, but also into how our soil systems are behaving throughout the depth of the cotton root zone. To this end we've made advancement in our knowledge about the level and activity of the microbial communities we find associated with our cotton roots as well as the implications that this has on the fate of carbon and the potential for sequestration within our cotton production systems in Australia (Osanai et al., 2020a, b; Polain et al., 2020).

Of course we recognise that our soil's health is not all about carbon and whether we can or cannot manipulate it, but has to include the soil biology that plays a role in determining our crops performance. However, given there is such a diversity of life in these soils our more recent research has focused on the arbuscular mycorrhizae (AM) and their role in crop development.

The findings from reviewing over thirty years of industry funded activity in this space bring up several questions as to the actual benefit of these soil fungi to cotton (Eskandari et al., 2018).

Figure 1: Oliver with the first of the cotton undies that cotton growers had soiled and brought into the Australian Cotton Conference to discuss their soil health (Photo Credit; Mel Jenson).

Our recent research has questioned the widespread belief in the importance of AM to cotton, asks whether we need to manipulate what is there rather than adding inoculants and suggests their reported demise due to long periods of fallow is entirely hearsay, when it comes to cotton production. Being scientists though, it would be remiss of us not to offer an alternative. We have proposed, through articles in the Australian industry literature, that the ability of the ubiquitous soil biology to bounce back and scavenge nutrients after a period of lack is just far greater than that of a newly planted seed and emerging plant. For anyone looking for a metaphor to compare this to we'd simply ask, how many mice did you see during the last drought and what's it like now? In both situations, mice or mycorrhizal, we have to hold on to the belief that things will return to normal, possibly regardless of any interventions we might make.

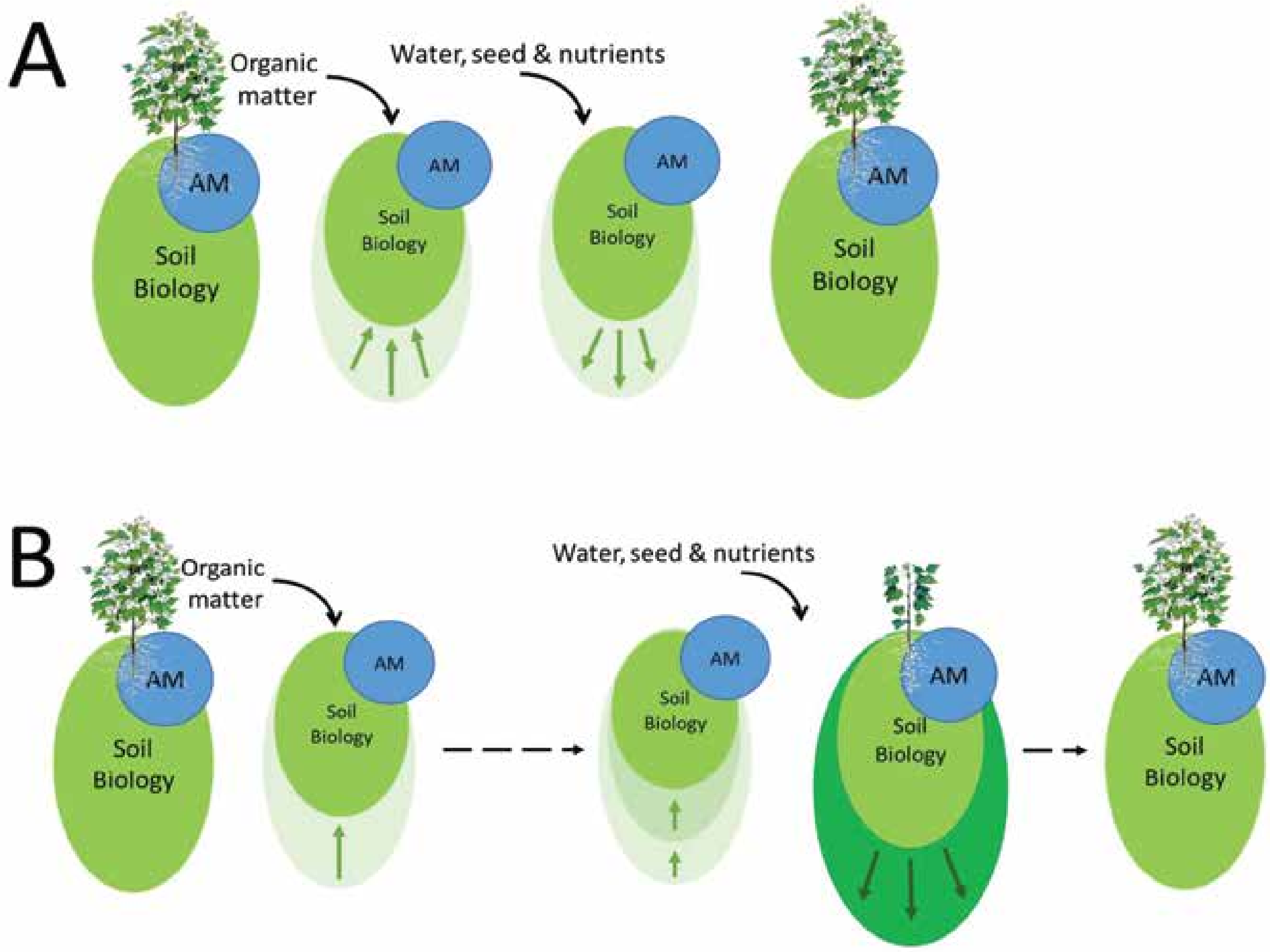

Figure 2. A schematic comparison of how after a fallow the soil biology responds more rapidly to favourable conditions (B), resulting in less nutrient availability to the developing plant until such time as the population returns to 'normal' levels (A).

If you are interested in any of the work we are now pursuing on AM and cotton, creating circular cotton systems, and engaging with growers about soil health then please reach out to us, read our blogs at the Cotton Hub UNE or follow us on twitter, @CottonHubUNE.

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Measuring the variation in cross-sectional properties along the length of cotton fibres

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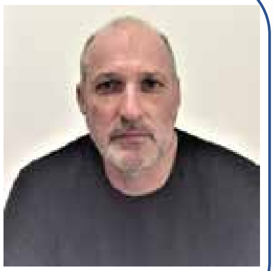

In a recent (small) study sponsored by Cotton Incorporated, CSIRO A&F's Natural Fibres Team investigated the ability of the Cottonscope instrument to measure the cross-sectional variation along cotton fibre lengths.

From a structural perspective the cotton fibre is a singularly discrete, elongated plant cell with no junctions or inter-cellular boundaries. Its form in nature is essentially unadulterated from the field to the spinning mill where its cross-section properties, as for any textile fibre, are central in determining the properties of the yarn and fabric made from it.

Figure 1: Cross-sections of cotton fibres embedded in methyl-butyl methacrylate resin showing variation in fibre cell wall and lumen (Margaret Pate, CSIRO)

However, because a cotton fibre is a plant cell the geometry of its cross-section includes a cell wall and a hollow cavity, formerly the cell protoplasm, called the lumen. The dimensions of these features are continuously distributed according to normal under which the cell develops. Thus, a cotton fibre's cross-sectional shape, which is hollow, irregular and highly variable between individual fibres, brings challenges in measurement (see Figure 1). In contrast, the equivalent properties of man-made fibres that compete with cotton, e.g. polyester, are easier to describe because of their more uniform symmetry.

A fibre's growth from the cotton seed epidermis is initiated at pollination and its extension in length starts within one day of flowering or anthesis – the period is often referred to in days post-anthesis (DPA). Figure 2 shows seed epidermis cells beginning their extension into fibres at one DPA. The width of the cells at this point is thought to be pre-determined by genetics because the average perimeter tends to reflect a 'known' fineness value for a given cultivar. However, a more recent hypothesis is that the perimeter could vary under different environmental conditions during fibre wall development, and that the rate of response to these changes is determined by genetics.

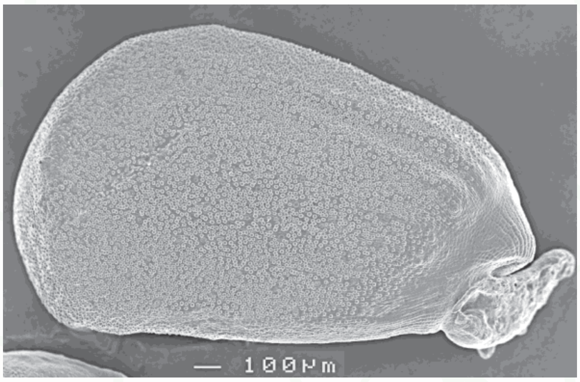

Figure 2: Fibre 'epidermis' cells beginning their elongation and development at one DPA (Rosemary White, CSIRO)

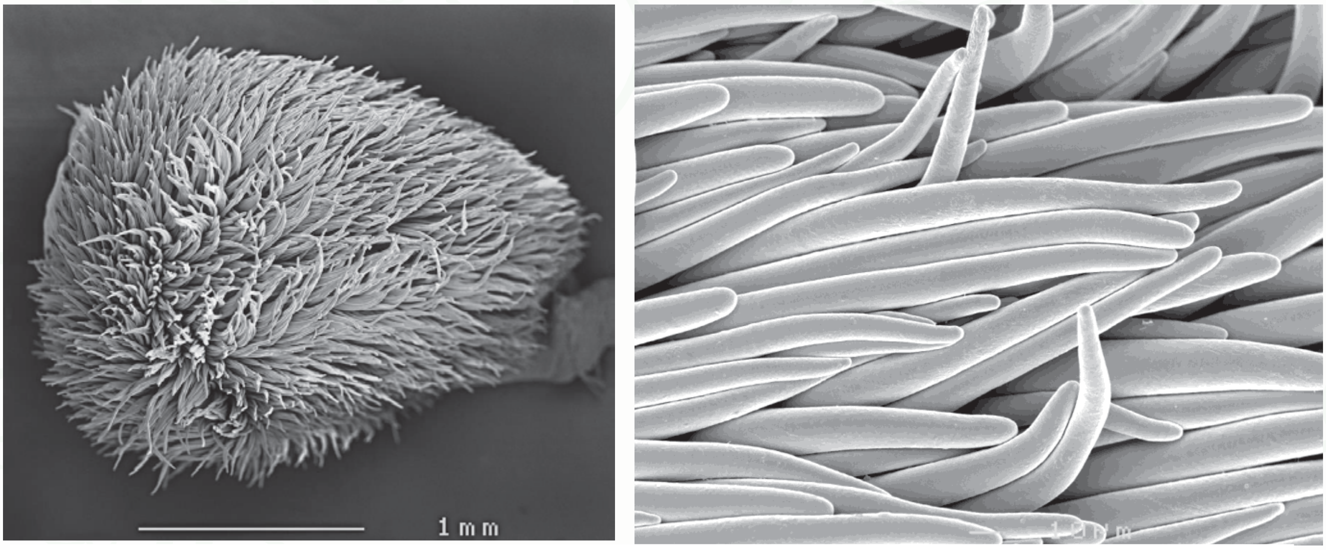

Figure 3: Fibre 'epidermis' cells at three DPA on seed and closeup (Rosemary White, CSIRO)

Over the next 50+ days the epidermal cell that becomes a cotton fibre undergoes; elongation (up to >2.5 cm in some cotton species) via primary wall synthesis, transitional wall thickening and then secondary wall thickening where the secondary cell wall of the fibre is laid down in a series of concentric growth rings or lamellae. The exact period of elongation and secondary thickening depends on factors such as the variety (genetics), growing temperature, light level and water turgor. However, the effects of genetics and environment are difficult to quarantine unless; (1) appropriate controls on the plant's physiological responses to, e.g. water, temperature, radiation and fertilization, are applied, and (2) there is a method to measure the geometric and material response in the fibre. In this short study, a set of opened boll samples from the same experimental crop (planted at CSIRO's Australian Cotton Research Institute (ACRI) for the 19/20 season) was investigated. The set samples came from the same crop year and variety (Sicot 74BRF), grown in adjacent rows under the same conditions but sown at three different times (ToS); early, standard and late (Sicot 74BRF), grown in adjacent rows under the same conditions but sown at three different times (ToS); early, standard and late.

Fibre snippets for Cottonscope measurement were prepared from quartile length sections while fibres were still attached to the seed (see Figure 4). The fibre still attached to the seed was 'combed' gently by hand and then 0.9 mm snippets cut progressively from tip (1) to the fibre base (4) at the seed epidermis, with snippets from each quartile length section segregated. The examination looked at fineness, fibre width and maturity along the quartile lengths of the fibre at the different times of sowing.

Cottonscope measurements were subject to a nested analysis of variance (ANOVA) wherein the quartile position and (three) replicate measurements were nested within the three times of sowing. Figures 5, 6 and 7 show Cottonscope measurements and the ANOVA effects for linear density measured in mtex or milligrams per km, width measured in microns and maturity measured as the maturity ratio.

Figure 4: Seed-cotton fibre locks (Sicot 74BRF ToS 2). Fibre specimens cut along combed sections (top and bottom quartiles shown) of the seed-cotton were isolated in their quartile measurements from tip to base.

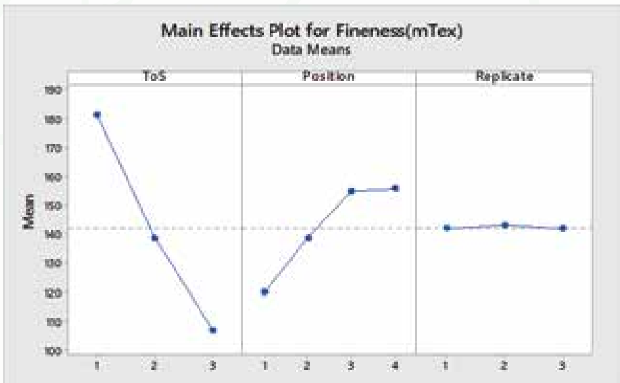

Figure 5: Linear density (mg/km) effects along the length of quartile sections of fibres. ToS 1 = early, 2 = standard and 3 = late. Position 1 = tip Q1, 2 = Q2, 3 = Q3 and 4 = base Q4. Replicates as numbered.

Evident from this preliminary analysis are large ToS effects on linear density, fibre width and maturity ratio with significant fibre wall tapering effects between the base to the tip; amounting to +30 mtex, +0.05 MR and +0.75 µm differences for this variety (and environment) between the base and the fibre tip. Interesting is that an early time of sowing resulted in a 'finer' but more mature (heavier) fibre. The decrease in MR at the base (quartile 4) is because immature linter fibres (short immature fibres) were included in the measurement. These linters do not extend more than 5 mm in length.

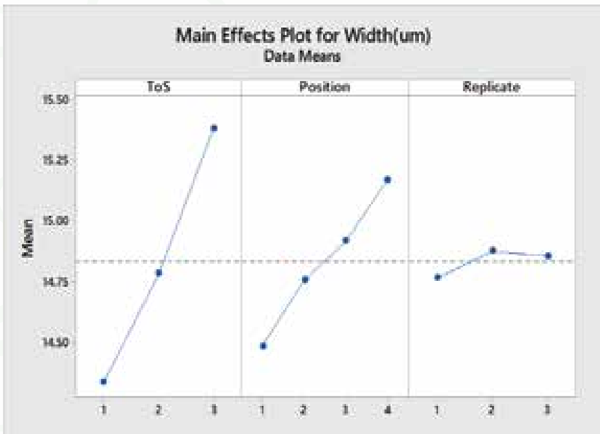

Figure 6: Fibre width (10-6 m) effects along the length of quartile sections of fibres. ToS 1 = early, 2 = standard and 3 = late. Position 1 = tip Q1, 2 = Q2, 3 = Q3 and 4 = base Q4. Replicates as numbered.

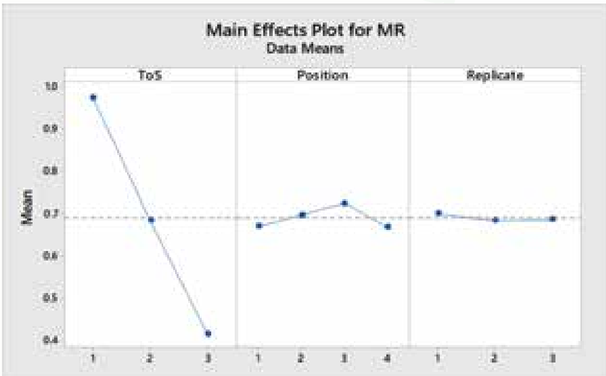

Figure 7: Fibre maturity ratio effects along the length of quartile sections of fibres. ToS 1 = early, 2 = standard and 3 = late. Position 1 = tip Q1, 2 = Q2, 3 = Q3 and 4 = base Q4. Replicates as numbered.

These measurements raise questions about the genetic and environmental influences on tapering along the fibre length and the consequences in processing (ginning and spinning). The variation along the length of cotton fibres has been noted by other researchers. But without a quick direct method for measurement, determining and understanding the genetic and environmental triggers and the extent of variation in fibre ripening (thickening) has been limited. The taper of the fibre ribbon width and the variation around the taper within fibre samples from the same crop, row, plant and even boll observed here suggests there is actually no distinct cell wall thickening phase applicable to the plant as a whole but rather each fibre develops, like the rest of the plant, in an indeterminant but progressive fashion that is affected by combinations of genetics, time, turgor pressure, sunlight and subsequently carbohydrate flow. Understanding the combination of factors at play in fibre ripening will be key in negating the issues associated with fibre immaturity, fibre breakage and other quality issues.

Provision of boll samples examined in this study by Sandra Williams and her team is gratefully acknowledged.

Cotton Harvesting - To Pick or Strip?

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Traditionally, seed cotton was harvested by hand, with mechanical harvesters developed and implemented in the early 1940s. Although only 30% of the cotton produced worldwide is harvested mechanically, some of the largest producers and exporters, such as the US, Australia and Brazil, harvest 100% of their seed cotton mechanically. The adoption of mechanical harvesters was mainly due to an increase in cotton acreage and yield, which resulted in dramatic increases in production, as well as due to the shortage, inefficiency, and cost of labour. Although the introduction of mechanical harvesting has led to trashier, more variable, and sometimes cotton with higher moisture content being delivered to the gin. Therefore, harvesting plays an important role in determining fibre and seed quality, as the quality of ginned cotton is directly related to the quality of seed cotton prior to ginning. There are basically two ways in which cotton can be mechanically harvested:

The Spindle Harvester - uses rotating tapered, barbed spindles (Figure 1), to pull seed cotton from opened bolls into the machine. Spindle harvesters require precise setup and adjustment and are generally more expensive to operate and maintain.

The Stripper Harvester - uses brushes and bats to strip seed cotton from bolls. These harvesters are predominately used to harvest seed cotton from rain-fed cotton crops which generally have shorter plant heights and lower yields. These harvesters are generally less expensive to operate and maintain, are more efficient with higher harvesting efficiencies. But, they remove not only the well opened bolls but also the cracked, immature, and unopened bolls, along with burrs, plant sticks, bark, and other foreign matter.

Currently the spindle harvester accounts for the bulk of all the cotton harvested in Australia, but as the industry looks at increased rain-fed and semi-irrigated cotton production, with the anticipated increase in stripper type harvesters several studies aimed to investigate the quality of fibre harvested using the two harvesting systems in terms of fibre quality are currently being conducted. Harvesting efficiency, yield and lint turn out were also evaluated with the results not shown in this short report

Materials and Methods

Paired comparisons of plots harvested with stripper and spindle harvesters were conducted at three locations in Australia. Following defoliation, the fields were harvested, with John Deere CP690 and CS690 round module spindle and brush strippers, respectively. The design was a randomized complete block design, with five replications of each of the two harvesting methods.

This allowed the gins to utilise the same cleaning and drying processes (i.e., two stages of seed cotton drying and cleaning, followed by the saw gin stand, and then by a flow through air lint cleaner and two stages of either the controlled-batt saw or batt-less saw lint cleaning) for both spindle and stripper harvested seed cotton.

Figure 2. Spindle type and Stripper type harvesters

Classing samples, from opposite sides, of each bale were collected at the gin after bale formation. These bale samples were subjected to objective measurement, using an HVI™ 1000 for colour in terms of yellowness (+b), reflectance (Rd), upper half mean length, length uniformity, short fibre index %, bundle strength, elongation and micronaire. Visual classing of the lint was assessed for colour (colour grade) and visible trash.

To test for statistical differences between treatment means, ANOVA was conducted on the experimental data with means for each parameter followed by the same letter not significantly different at $P \leq 0.05$.

Results and Discussion

Table 1 shows that, except for UI%, there were no significant differences between the two harvesting methods in HVI measured fibre quality in terms of UHML, SFI%, micronaire, strength and elongation. Although there was no significant difference in UI% from Farm A & B, there was however, a small but significant difference for Farm C with the spindle harvested cotton more uniform than the stripper harvested cotton.

Although there were significant differences in Rd and +b values this did not influence the colour grade which at 11-2 (Good Middling) was better than the Australian base grade of 31-3 (Middling) and resulted in a premium.

There were significant differences between the two harvesting methods in terms of trash, with fibre from the seed cotton harvested by the stripper on average containing significantly more trash particles which covered a larger percent area. However, these significant differences did not influence the manual visual trash grade which at 1 and 2 were better than the Australian base grade of 3 and hence did not result in a discount.

Conclusion

This study was conducted on commercial scale dryland Upland cotton, producing < 2.5 bales ha^{-1}, to determine the performance of John Deere CP690 and CS690 spindle and brush type stripper, harvesters in terms of 1) harvester performance, including harvesting efficiency, harvest loss, seed cotton yield and lint turn out and 2) fibre quality as measured by HVI™.

The stripper harvesters had higher productivity as they were able to harvest 5 ha h^{-1} more than the spindle harvester with almost 4-5 times lower harvest losses while harvesting 19% more seed cotton. The seed cotton harvested by the stripper contained plant material which resulted in 14% lower lint turn out.

As the fibre was mature, there were no significant differences in fibre quality between the two harvesting systems. Similarly, although there were significant differences in colour in terms of Rd and +b and trash as measured by HVI, this did not influence the visual colour and trash grades which was better than the Australian base grade and resulted in a premium.

This study has shown that stripper harvested cotton does not necessarily result in inferior fibre quality if the fibre is mature and if favourable conditions during defoliation and harvesting are experienced which allows the fibre to be ginned with minimal heat and cleaning. Further studies are being undertaken on crop grown in less than favourable conditions and higher yielding crops (4 to 5 bales ha^{-1}) to determine what the consequence will be in terms of harvesting efficiency, yield, lint turn out and fibre quality.

Acknowledgments

The support of the Australian Cotton Research and Development Corporation and the Dryland Cotton Growers Research Association is gratefully acknowledged.

Table 1. HVI measured fibre quality values.

Harvester	Mic	UHML inch	32nds	UI %	SFI %	Strength g tex^{-1}	El %	Trash			Colour		Visual	
								Count	% Area	Leaf	Rd	+ b	Colour	Leaf
Farm A														
Stripper	4.60	1.054	34	79	9.34	28.2	4.4	13.2a	0.11	1.9a	83.0a	9.6a	11	1
Spindle	4.65	1.059	34	79	9.32	28.3	4.4	9.5b	0.09	1.6b	82.3b	9.0b	11	1
Farm B														
Stripper	4.86	1.046	34	80.5	11.3	30.4	4.3	11.6a	0.11a	2.0a	82.2a	10.1a	11	2
Spindle	4.88	1.048	34	80.6	11.1	30.4	4.2	8.4b	0.09b	1.4b	81.1b	9.5b	11	2
Farm C														
Stripper	4.78	1.089	35	80.2a	9.7	30.5	4.8	16a	0.16a	1.9	83.4a	9.3a	11	2
Spindle	4.78	1.098	35	80.9b	9.6	30.6	4.8	10b	0.09b	2.1	83.2b	8.7b	11	2

An eco-friendly whitening process for cotton

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Raw cotton consists mainly of cellulose with non-cellulosic constituents located either on the outer layers (cuticle and primary cell wall) or inside the lumen (protoplasm) of the fibre (cell wall) [1]. Because of the hydrophobic nature of the outer cuticle or wax layer, which is comprised of an amalgam of wax alkanes, fatty acids, fatty alcohols, plant steroids and glycerides, its removal prior to any wet treatments applied to cotton yarn or fabric is extremely important. Removal is typically executed in pre-dyeing processes like scouring, bleaching or mercerisation. Hydrogen peroxide-based bleaching is widely used in the cotton industry to improve the whiteness and dyeing ability of cotton material. Like any strong oxidant, hydrogen peroxide must be handled with care. Moreover, it is also noted the burst strength (and toughness) of cotton material can be reduced with hydrogen peroxide bleaching [2]. The other chemical process used to improve the appearance of cotton is mercerisation [3]. Mercerisation is a finishing process that has been used to improve the mechanical properties, lustre and dye absorption of cotton yarn and fabric since the mid-1800s. Cotton is typically treated under tension in mercerisation using highly concentrated sodium hydroxide solution (>20% w/v), leading to swelling of the fibre and improvements in the treated yarn or fabric's dyeability, lustre and strength. While mercerisation has been used for a long period and produces a range of beneficial qualities in cotton yarn and fabric, the process is not routinely used because of its high costs and issues associated with caustic recovery. An alternative approach is cotton with similarly improved handle properties and appearance. However, plant costs and the recovery of ammonia hinders its use as a mercerizing agent. Moreover, in both caustic and ammonia mercerization, penetration of the solution into the fibres of the twisted yarns and tightly woven fabrics is sometimes compromised with the consequence that surface fibres are often over-treated relative to core fibres, resulting in uneven uptake of dye [4]. In view of these issues, a team led by Deakin University and CSIRO sponsored by the Australian Cotton Research and Development Corporation, developed a 'softer' amino acid (glycine) based mercerizing treatment for cotton [4].

Methodology

For the results presented here, treatments were applied to yarn packages (1.5 kg) using a pressurized yarn package dyeing system. Glycine treatments (using 20% weight of glycine in solution) were applied at 120°C for one-hour post scouring. Buffering the solution for different pH allows glycine's zwitterion properties to be managed so that more effective bonding of the glycine occurs at either pH 4 or 11.

Results

At these pH levels the glycine treatment increased the whiteness and lustre of the cotton (Figures 1 and 2), but also improved its handle properties (softness) over scoured equivalents, without any degradation in tensile properties.

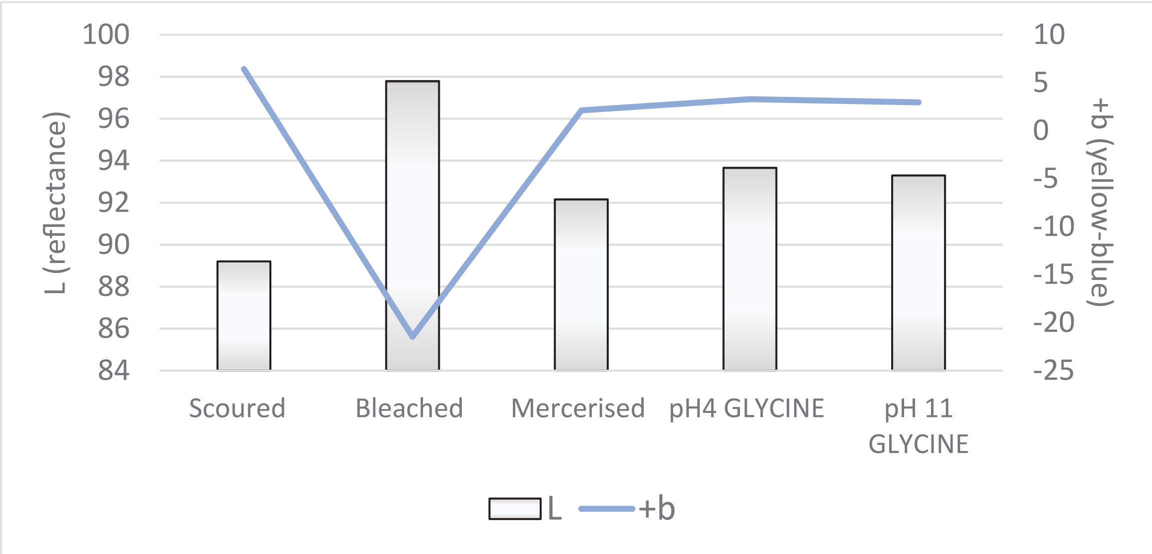

Figure 1: CIELab values for knit fabric scoured and then treated in 20% glycine solution for 1 hour at pH 4 and 11, compared with scoured, bleached and mercerized fabric.

Figure 2: From left to right; mercerized, glycine and scoured fabric appearance (under a standard TL84 Store Light)

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