Australian Government
Cotton Research and Development Corporation

FINAL REPORT 2016

For Public Release

Part 1 - Summary Details

Please use your TAB key to complete Parts 1 & 2.

CRDC Project Number: CSP1308

Project Title: Agronomic Management for Better Fibre and Textile Quality

Project Commencement Date: 01/07/2012 **Project Completion Date:** 30/06/2016

CRDC Research Program: 1 Farmers

Part 2 – Contact Details

Administrator: Ms Jo Cain (Project Support Officer)
Organisation: CSIRO Agriculture
Postal Address: Locked Bag 59 Narrabri NSW 2390
Ph: 02 67991500 **Fax:** 02 67931186 **E-mail:** Jo.Cain@csiro.au

Principal Researchers: Dr Michael Bange/Dr Robert Long
Organisation: CSIRO Agriculture
Postal Address: Locked Bag 59 Narrabri NSW 2390
Ph: 02 67991500 **Fax:** 02 67931186 **E-mail:** Michael.Bange@csiro.au

Supervisor: Dr Mark Peoples/Dr Stuart Gordon
Organisation: CSIRO Agriculture/ CSIRO Manufacturing
Postal Address: CSIRO Black Mountain/ CSIRO Waurn Ponds
Ph: **Fax:** **E-mail:** Mark.peoples@csiro.au
Stuart.Gordon@csiro.au

Signature of Research Provider Representative: ______________________________

Date Submitted: __________________

Table of contents:

Project Background (from original project proposal)

"Australian cotton is purchased for a premium as it meets spinner's requirements on the basis of quality and consistency. Coarse (high micronaire) fibre, high nep counts and excessive short fibre content are aspects of Australian cotton that spinners would like to see improved. Through examination of quality from both field and textile perspectives the previous project 'Agronomic management to optimise textile performance' successfully quantified relative influences of boll load, temperature, and water stress on micronaire; developed methodologies for predicting temperature and defoliation timing effects on micronaire; validated monitoring techniques to better time defoliation; quantified machine picking effects on neps; developed a new understanding of the effects of fibre diameter and maturity on yarn strength; assessed benefits of in-field blending; investigated end of season management for improving quality consistency; and scoped novel studies of how single fibre strength influences the textile performance of Aust. cultivars. Knowledge generated in this project will be included in an updated FIBREpak, and will be used as a basis for management decisions in the systems experiments undertaken in this new project."

Project Aim (from original project proposal)

"The project aims to optimise cotton fibre quality and enhance the commercial value of Australian cotton through research into direct influences of on-farm agronomic management and climate on fibre development; and post-harvest research that investigates the degree of these influences on cotton ginning and textile performance in the mill. Specific industry objectives are to: (i) Embark on developing tools/ methods to enable growers and ginners to quantify the quality of harvested fibre (prior to ginning). (ii) Develop pre-emptive management strategies for improving micronaire (optimising fineness and maturity), reducing neps and reducing variability between different varieties, regions and climatic conditions. (iii) Provide a cost/benefit analysis of specific management strategies for optimising quality (from planting to textile processing) for base and premium fibre varieties. (iv) New knowledge of when and what bolls developing at the end of a cotton season are no longer contributing to yield and quality. (v) Provide information (growers, ginners, spinners) on the textile performance of newly released cotton varieties. (vi) Maintain a crucial research capacity in agronomic research into fibre quality."

For this final report, the main parts of the project are summarised by science/ experimental objectives (1 to 5), within each full details are presented with a comprehensive summary.

***Objective 1** – Establish the value of crop and post-harvest management focussed on producing better fibre quality (Seeds to Shirt).*

1.1 Management for better cotton fibre – capturing some interactions between cultivar, season, in-field production, and post processing variables

Summary

Two field experiments were undertaken during the 2011 and 2012 harvest seasons to assess a standard upland cotton (Sicot 74BRF) and a premium lower yielding upland cotton (Sicot 340BRF). These were grown under a standard management practice, and via an alternative practice designed not to impact yield but include a later defoliation, irrigation targeting flowering, and applying a pix growth regulator which represents what could be implemented to bring the crop to a timely end in the event of the requirement to avoid inclement weather. Cotton was ginned with either no lint cleaning or with two lint cleaner passages. The intention was to capture and assess genetic (cultivar) x environment (seasons) x management x processing (gin) interactions. Some outcomes included:

- Targeting irrigation at flowering increased the length of fibre on average by approx. one 32nd inch, and reduced short fibre content, and reduced neps in ginned lint to under the industry threshold of 250 count/g. Neither of these fibre attributes were linked to improved yarn performance. Although it was beneficial to capture practices that influence a growths reputation. More pronounced improvements of these attributes, and or in combination with improvements in other fibre quality attributes (e.g. fineness) would positively influence yarn performance.
- The premium cultivar had longer, finer and stronger fibre which translated into yarns that were stronger and more even.
- Lint cleaning at the gin improved the value of cotton due to less trash, and this tended to lower yield, although the yield of carded useable sliver per hectare was not affected. Lint cleaning was a detriment to yarn strength for Sicala 340BRF, but not Sicot74BRF. Yarns made from lint cleaned material had more yarn neps and were less even. So clearly, lint cleaning adds value to fibre, but can be detrimental to yarn performance.
- The 2011 season produced cotton that was lower in perimeter (lower mic and fineness), which demonstrated the environmental influence on fibre perimeter which is also strongly influenced by genetics (cultivar). The 2011 season also produced longer cotton. These seasonal quality differences translated into the 2011 season producing yarns that were 8.6% stronger and 2.8% more even.
- Trash content (leaf grade) was related to cotton colour and dominated other potential premium quality attributes.
- For gross margin analysis, cultivar and ginning treatments were the only influencing factors, with higher yield (cultivar driven) and lint cleaning having the biggest positive influences.

Introduction

Cotton fibre quality is affected by a large number of interacting factors: variety, climate, in-season management, harvesting and post-harvest ginning practices. While some of these factors cannot be controlled, there are many that can. Fortunately the majority of crop management factors which increase or optimise yield will also benefit fibre quality. Indeed with the advent of specific premium fibre varieties there may be a need to have tailored management regimes to ensure that these varieties produce premium quality cotton, although typically 'premium' cultivars come with a yield penalty which usually outweighs any price premiums gained due to specific (e.g. fibre length) improvements. Through better understanding of the nature of fibre and the factors that affect its quality, improved varieties, management for each region's climate, and processing to minimise damage to fibre are all opportunities to improve the quality of fibre delivered to mills.

Since the fibre is primarily cellulose, any influence on plant photosynthesis and production of carbohydrate will have a similar influence on fibre growth. Cell expansion during growth is strongly driven by turgor, so plant water relations (irrigation) will also affect fibre elongation in the period immediately following flowering. Early crop defoliation or leaf removal can cause substantial reductions in fibre Micronaire due to the cessation in carbohydrate supply for fibre thickening. Few agronomic or climatic conditions have been shown to consistently affect fibre strength. Any management which delays crop maturity can lead to reduced Micronaire and more neps (Bange et al., 2010), as well as lower grades from discolouration and increases in leaf material (Bednarz et al., 2002), all due to exposure of a greater proportion of a crop to un favorable conditions such as cooler or cloudy weather.

The post-harvest ginning process transforms the cotton into a marketable commodity by removing the lint from the seed and removing foreign material. Ginners are faced with often conflicting objectives: the need to maximize gin outturn to increase lint yield for growers; to minimize impact on fibre quality to meet the needs of the spinners; and optimizing gin throughput and operating efficiencies. As the ginning process will impact on fibre quality (Anthony, 1999), any operation in the gin should be bypassed in an attempt to preserve quality if the cotton does not need specific treatment, a particular process that is a focus of fibre preservation is the use of a different number of lint cleaners (Long et al., 2010).

This work presents yield, fibre quality, and ring spun yarn results of large scale farming systems experiments that attempted to capture statistical interactions between cultivars, modified agronomy (including changes in irrigation, crop cessation and defoliation management) and ginning. Improving the understanding of the links between production, harvest, ginning and textile processing, will enable the most appropriate questions to be asked regarding what needs to be done to maximise returns for growers while maximising the quality reputation of the fibre produced.

Materials and methods

Production and harvesting

Two field experiments assessing two different *Gossypium hirsutum* L. (upland) cultivars grown under two field management scenarios were conducted over two consecutive growing seasons (2010/ 2011 – Exp. 1 and 2011/ 2012 – Exp. 2) at the Australian Cotton Research Institute (ACRI) at Narrabri (30.3º S 149.8º E) in north-western New South Wales, Australia. The location is a semi-arid environment with grey vertosol soil (Isbell 2002).

Both experiments employed a split plot randomized block design with the cultivar treatment nested within the field management treatment, with four replications. Two commercially available upland cultivars bred by the CSIRO were used, Sicot 74BRF and Sicala 340BRF. Sicot 74BRF is a popular high yielding cultivar, while Sicala 340BRF is a lower yielding cultivar (by approx. 6 %) but which exhibits better fiber properties. Cotton Seed Distributors (CSD), the commercial retailer of these cultivars, reports four quality parameters for its cultivars, which for Sicot 74BRF are 1.20 inch length , 83.6 % length uniformity, 32 g/ tex strength and 4.5 micronaire; and for Sicala 340BRF 1.24 inch length, 84.1 % length uniformity, 33 g/tex strength and 4.3 micronaire.

Experiments were sown with a disc opening Kinze commercial row-crop planter. Seeds were sown at 5 cm depth, delivered at 15 seeds m^{-1} in rows spaced at 1 m. Exp. 1 was sown on 13 October 2010, while Exp. 2 was sown on 13 October 2011. Treatment plots were two 583 m long rows in Exp. 1 and 175 m by 4 rows in Exp. 2. Crops were established and grown with normal furrow irrigation, and using non-limiting nitrogen applied as anhydrous ammonia (injected below and to the side of the plant line before sowing) at a rate of 180 kg ha^{-1} in Exp. 1 and at a rate of 160 kg ha^{-1} in Exp. 2. Crops were controlled for pests when required (Hearn and Fitt 1992; Deutscher *et al*. 2004).

For the two in-field management treatments, one represented what can occur during standard management practice, while the other was an alternative approach intended to enhance fibre quality. The alternative treatment included:

1. Irrigation was applied during early flowering, which was slightly different to what would normally be acceptable under a standard deficit irrigation management approach. The intention was to assist in fibre elongation and to thus maximise the opportunity to produce longer fibre. To assist in irrigation management, soil moisture was monitored using neutron probes installed in the centre of each experimental unit.

2. The growth regulator mepiquat choride (pix) was applied at approximately the time of the estimated average last effective flower date to assist the crop in maturing at the appropriate time to avoid inclement weather at the end of the season. The last effective flower date also coincides with when there is approximately 4 to 5 nodes above white flower, and this is the time when the photoassimilate demand of the fruit dominates and out-strips supply from the leaves, and thus provides the best opportunity to maximise the uniformity of fruit maturity (CottonInfo, 2015).

3. Avoiding the early use of harvest aids at the end of the season that cause bolls to open prematurely. More open less mature bolls could lower micronaire and maturity, and producing fibre more prone to breakage, and to form entanglements (neps).

Dates for some key production stages are detailed in Table 1.

Table 1. Dates and corresponding number of days after sowing (DAS) for key crop production events for the two in-field management strategies for both experiments (Exp. 1 the 2011 harvest, and Exp. 2 the 2012 harvest).

	Exp. 1 (2011 harvest)				Exp. 2 (2012 harvest)			
	Standard		Alternative		Standard		Alternative	
	Date	DAS	Date	DAS	Date	DAS	Date	DAS
Sowing	13/Oct/2010	0	13/Oct/10	0	13/Oct/2011	0	13/Oct/2011	0
Irrigation	24/Jan/2011	103	21/Jan/2011	100				
	7/Feb/2011	117	3/Feb/2011	113				
Pix			22/Feb/2011	132			17/Feb/2012	127
Harvest aid	13/Apr/2011	182	29/Apr/2011	198	5/Apr/2012	175	13/Apr/2012	183
	29/Apr/2011	198	11/May/2011	210	21/Apr/2012	191	21/Apr/2012	191
					27/Apr/2012	197		
Harvesting	9/June/2011	239	9/June/2011	239	15/May/2012	215	16/May/2012	216
	10/June/2011	240	10/June/2011	240				
	11/June/2011	241	11/June/2011	241				

Central rows of each experimental unit were machine-harvested with a John Deere spindle cotton picker.

Ginning, turnout and yield

Harvested seed cotton was machine ginned to separate the fibre from the seeds using a modified Continental/Moss-Gordin (Prattville, Alabama, U.S.) gin stand consisting of 119 saws each 41 cm (16 inch) in diameter. The gin had been narrowed to reduce the original width of the stand to a central section of 41 saws. The gin was fed via a modified feed hopper and stationary condenser unit with seed cotton fed into the hopper using a Lummus Rembert material fan to which a suction hose was connected. The narrowed gin stand had the capacity to run at approximately two 227 kg bales per hour. This capacity, which had the gin saw shaft rotating at 600 rpm for a surface speed of approximately 750 meters per minute (mpm), was utilized in these trials. The gin system included two Continental/Moss-Gordin Lodestar fixed batt saw lint cleaners, which were set-up with adjustable ducting to allow lint cleaning passages to be bypassed as required. The saw cylinders for these cleaners are also 41 cm (16 inch) in diameter, and fitted with five grid bars. A saw speed of 970 rpm with an approx. surface delivery speed of 1219 mpm was used for these trials with combing ratios (feed roller surface speed to saw surface speed) of 1:29 for the first lint cleaner and 1:19 for the second lint cleaner. Seed cotton from each experimental batch was divided in two parts. One part was ginned without any lint cleaning, while the second part was ginned and passed through both lint cleaners. An average of 93 kg of ginned cotton fibre was produced per gin run for each experimental unit (a single bale). Fifteen x 200 g samples were collected continuously through each batch after the battery condenser prior to baling, and this material was used for fibre quality measurements.

Experimental bales of ginned fibre were then transferred to a spinning mill, and fiber from each bale was opened and cleaned via a Trützschler 'blowroom' (Trützschler, Mönchengladbach, Germany) which incorporated an inclined lattice bale feed and CVT3 opener and cleaner. The fibre was then carded via a Trützschler DK 903 card. All carded cotton was retained and weighed for each experimental bale, which was enabled by collecting all material during the initial card start-up and sliver formation, and also by purging from the carding machine carded cotton not in sliver form at the end of each carding run.

The amount of separated ginned cotton fibre relative to the total amount of pre-ginned seed cotton (% turnout), was calculated as the weight of ginned fibre per the weight of pre-ginned seed cotton multiplied by 100 %.

$$\%\text{ Turnout} = \frac{\text{Weight of ginned fiber}}{\text{Weight of seed cotton}} \times 100\% \qquad (1)$$

Yield was calculated as both kg of ginned fiber per hectare, and as kg of carded mill-useable fiber per hectare.

Fibre quality measurements

From the resulting sub-sample of ginned cotton (approx. 3 kg), further subsampling was conducted randomly across the sample to provide two batches of fiber, with each batch subjected to the following fibre testing:

One 200 g sample of ginned cotton was tested via a High Volume Instrument (HVI) model 1000 (Uster Technologies, Uster, Switzerland), to determine upper half mean length (mm) (UHML) which is the average length of the longer half of fibres by weight, length uniformity (%) which is the ratio of the mean length to the UHML, short fiber index (%) which is an estimate of the percentage of fibers that are shorter than 12.7 mm, micronaire which is an air flow simultaneous measure of fibre fineness and maturity (no units), bundle strength (grams force per tex), bundle elongation (%), colour (reflectance Rd, Yellowness +b), and trash (% area, trash count, and grade from 1 to 7 with a 1 designation indicating low trash and 7 indicating high trash) (Uster technologies AG, 2015). Rd and +b data were used in conjunction with USDA colour classification tables to designate each relevant average result a cotton colour grade (USDA, 2005; Cotton Incorporated, 2013).

An estimation of the non-fibre content of a ginned cotton sample was determined via the ASTM D2812-07 gravimetric method (ASTM International, 2015). Each thoroughly cleaned approx. 100 g sample recovered from the gravimetric test, was then subjected to HVI testing as previously described.

One approx. 20 g sample of ginned cotton was subjected to testing via the Advanced Fibre Information System Pro (AFIS PRO) instrument (Uster Technologies, Uster, Switzerland). The AFIS instrument consists of opening, and fibre and particle individualization technology, to measure the number of fibre entanglements (neps) (count g^{-1}), nep size (µm), seed coat nep count, and seed coat nep size. The number of fibre neps was calculated as the total nep count subtract the seed coat nep count. The AFIS PRO also measures a range of fibre length attributes, total trash count g^{-1}, trash count excluding dust, dust (particles less than 500 µm in size) count, average size of all trash (and dust) particles (µm), and % visible foreign matter by weight. AFIS PRO results were the average of five 0.5 g replicate sliver tests.

One 30 g sample of ginned cotton was cleaned via one passage of a Shirley Analyser (SDL, Stockport, England), following which approx. 50 mg of 0.7 mm snippets were prepared and tested for the degree of relative secondary wall thickening (maturity), and linear density (millitex or mg km^{-1}), Cottonscope results for each sample were the average of three replicate tests.

Except for gravimetric non-fibre determination which was undertaken in a cotton spinning mill, all other fibre quality testing was undertaken within standard textile testing laboratory conditions for natural fibres, which is 20 °C ± 2 °C and 65 % RH ± 2 %. Fibre quality results for each experimental bale was the average of the two results determined per sub-sampled batch.

Fibre quality corrections and calculations
While the experimental gin used in this work incorporated full-scale gin machines, including important mechanically intensive saw lint cleaners, it did not fully replicate a commercial operation from the standpoint of full cylinder and stick machine cleaning of the seed cotton prior to delivery to the gin stand. Earlier work (USDA, 1958) (Anthony, 1985), documented an approx. 1.5 % difference in non-fibre content of ginned fibre due to pre cleaning, which corresponded to approx. one leaf grade, and one colour grade (specifically between 31 Middling, 41 Strict low middling, and 51 Low middling). Therefore in addition to colour and leaf grade results for ginned fibre reported here-in, colour and leaf results were also reported with an adjusted reduction of one grade, to give an approx. indication of what the grade of the cotton would have been if it had been subjected to commercial pre-cleaning.

An estimate of the fibre cross section perimeter (P), and cross section wall area (A_w), were calculated via equations described previously (Montalvo, 2005) (Montalvo and Von Hoven, 2007) (equations 2 and 3), using relevant micronaire, fineness (H) and maturity ratio (M) results.

$$\mathrm{P} = 3.785 \times \sqrt{\frac{\mathrm{H}}{\mathrm{M}}} \qquad (2)$$

$$\mathrm{A_w} = \mathrm{P} \times \sqrt{\left\{\frac{(\mathrm{Micronaire}+2.352)^2}{8.58} - 0.2525\right\}} \qquad (3)$$

Yarn spinning
Cotton was spun into 12 tex carded knit twist ring spun yarns at the CSIRO ring spinning facility in Geelong.

Data analysis
Experimental data analysis was undertaken using the Restricted Maximum Likelihood (REML) linear mixed model facility in Genstat 16th ed. (Lawes Agricultural Trust, IACR, Rothamsted, UK). The fixed model designation for the relevant factors was Harvest year x Management x Cultivar x Ginning treatments, while the random model designation was Harvest year/ Block/ Management/ Cultivar. The General Analysis of Variance facility in Genstat was also used to determine representative average least significant difference (LSD, at 5 %) values used to assist in means separation.

Results and discussion

Production conditions, yield and turnout
Average temperature was higher for November 2011 in exp. 2 compared to exp. 1, with the first three months of exp. 2 recording higher average solar radiation. However, average temperatures for December 2010 to March 2011 (exp. 1) were consistently higher, as was solar radiation for January and February 2011 compared to those months for the following year (Fig. 1A). This was reflected in cumulative day degrees data, with exp. 1 tracking with lower day degrees up until 100 days after sowing, following which day degrees tracked higher for the

remainder of the season in comparison with exp. 2. Exp. 2 recorded higher average monthly rainfall across that respective growing season, except for March and April (Fig. 1 B).

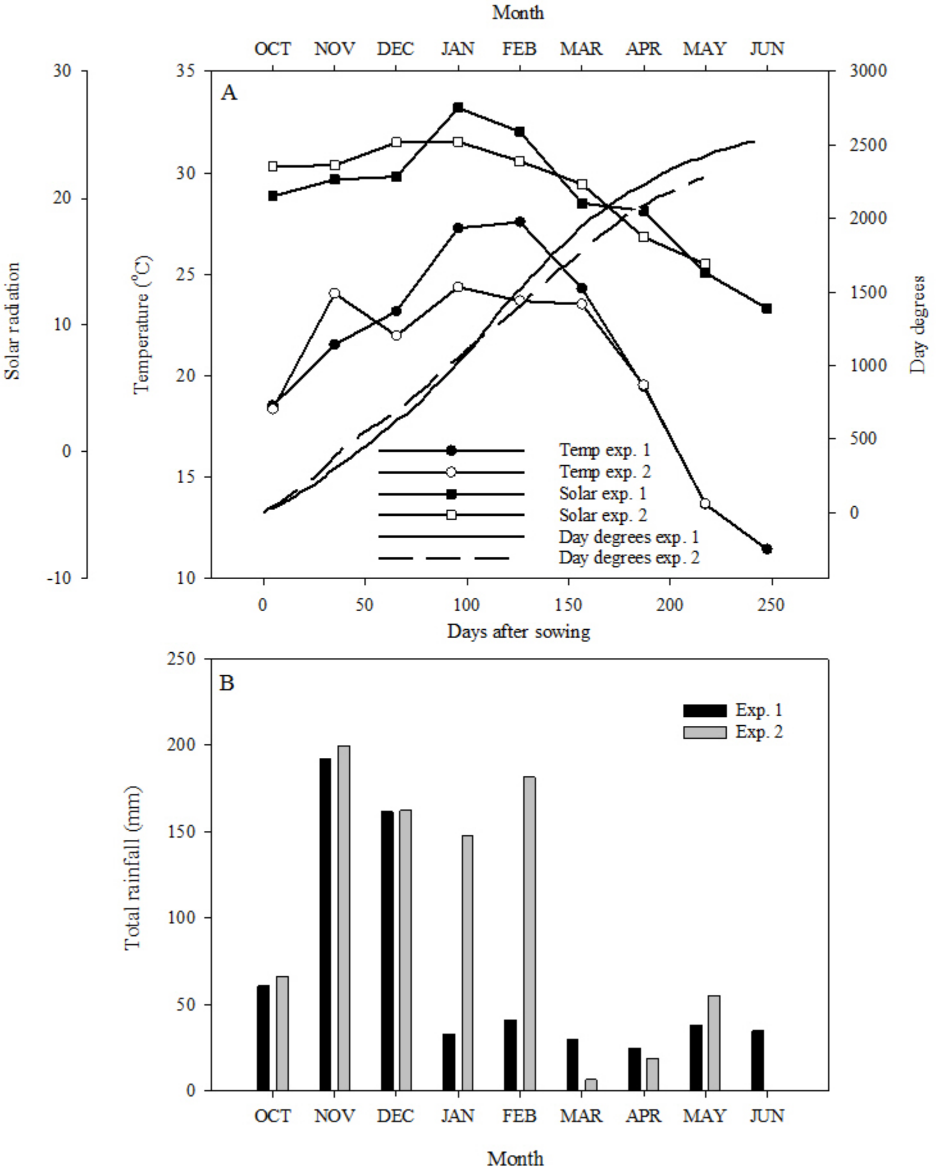


Figure 1. Average monthly temperature, solar radiation, accumulative day degrees (A) and total monthly rainfall (B), for experiment 1 (2011 harvest season) and experiment 2 (2012 harvest season).

For yield of ginned lint per hectare, there was no difference between experimental seasons, while a non-cross over interaction between management practice and ginning treatment showed that the lint cleaned treatment yielded less than the non-cleaned cotton for the alternative practice (Table 1). Yield in this case was related to interactions with the amount of trash in samples. As expected Sicot 74BRF yielded 6.5% more than the premium variety. Sicot 74BRF had higher turnout than Sicala 340BR, and turnout was greater for the 2012 season. For yield of carded useable sliver, which gives a direct indication of how much yarn can be produced, there was only clear significant main effects captured. There was no significant difference between the two in-field management practices for yield of carded sliver. Similarly, there was no difference in the yield of carded sliver between the two ginning treatments. This demonstrates that if the fibre is either cleaned more quickly, intensively, and therefore with more damage, at the cotton gin, or not, and thus allowing the delivery of much more trashier cotton to the mill, ultimately the carding process removes all unwanted impurities to a similar level. Although mills still need to deal with trash disposal. The variety difference in yield (of ginned lint) translated into a similar significant difference for carded sliver, i.e. Sicot 74BRF still yielded more useable carded sliver per hectare compared to Sicala 340BRF (Table 2).

The alternative management practice produced cotton that was longer (Table 3) which can be attributed to the earlier irrigation facilitating stress free turgor ensuring maximum elongation during this early phase of fibre development. This occurred for the first season only because rain events in the second (2012) harvest season negated the irrigation treatment. There was a strong environmental influence captured, with fibre form the 2011 season being significantly longer than that from the 2012 season. Saw lint cleaning produced fibre that was significantly shorter than ginned lint that was not cleaned, which is due to the more intense mechanical manipulation action of the gin lint cleaners. As predicted, the premium variety (Sicala 340BRF) was longer than Sicot 74BRF. For the uniformity of fibre length the alternative practice had better length uniformity in the 2012 season, and Sicala 340BRF had better length uniformity in the 2012 season. Short fibre content was lower for the alternative practice but only for the 2011 season, and the 2012 season was higher in short fibre content. Sicala 340BRF had lower short fibre content, and the 2 LC gin treatment had higher short fibre content.

Fibre was stronger for the 2011 season for Sicala 340BRF within each of the two gin treatments (Table 4), while the same was seasonal effect was captured for Sicot 74BRF but only for the 2LC gin treatment. Sicala 340BRF fibre was 6.5% stronger than Sicot 74BRF.

Sicala 340BRF had lower micronaire compared to Sicot 74BRF (Table 5), because the premium variety inherently has smaller perimeter fibres (Table 5). The 2012 season produced higher micronaire cotton in the non-premium G5-3 range mic (>4.50), because these fibres had a larger perimeter than 2011 cotton. This demonstrates the significant influence that growing environment has on influencing fibre perimeter which has traditionally seen to be dominated by genetic (variety) influences. This was reflected in gravimetric fineness (linear density) results (Table 5) with Sicala 340BRF having finer fibre than Sicot 74BRF within each respective season, but with Sicot 74BRF from the 2011 season having the same fineness as Sicala 340BRF from the 2012 season. For relative wall thickness or maturity, some non-cross over interaction trends were captured between season, management practice and gin treatment, with the 2012 season, but the clearest result showed that Sicot 74BRF had lower maturity for the 2012 season, while the maturity was the same across seasons for Sicala 340BRF.

For fibre entanglements or neps (Table 6), the alternative practice had less neps for the 2LC gin treatment. This demonstrates the mechanical effect of lint cleaning on nep formation for cotton with a greater propensity to entangle. This is attributed to the alternative treatment promoting less short fibre content which would otherwise be more prone to nep formation if present in higher quantities. In this case neps for the alternative management practice on average came in below the industry recognised threshold (i.e. <250 count per gram).

Table 2: Yield of ginned lint, % turnout, and yield of useable carded sliver.

Yield (Kg/ ha)	Year		Management x Gin * Lsd = 132			Cultivar **		
	2011	2012		Standard	Alternative	Sicot 74BRF	Sicala 340BRF	
	2146	2020	0LC	2083ab	2210b	2149	2017	
			2LC	1971a	2067a			
Turnout (%)	Year x Cultivar* Lsd = 0.9			Management		Gin ***		
		2011	2012	Standard	Alternative	0LC	2LC	
	Sicot 74BRF	41.9a	46.0c	42.4	42.5	43.8	41.1	
	Sicala 340BRF	39.4b	42.6a					
Yield carded sliver (Kg/ ha)	Year		Management		Cultivar **		Gin	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	1816	1707	1714	1809	1825	1698	1765	1758

Table 3: HVI fibre length attributes.

Upper half mean length (mm)	Year x Management** lsd = 0.36			Year x Cultivar** lsd=0.37			Gin ***	
		Standard	Alternative		Sicot 74BRF	Sicala 340BRF	0LC	2LC
	2011	31.73a	32.20b	2011	31.52a	32.41b	31.72	31.34
	2012	31.07c	31.13c	2012	30.42c	31.77a		
Length uniformity (%)	Year x Management x Cultivar** lsd =0.49				Gin **			
			Sicot 74BRF	Sicala 340BRF	0LC	2LC		
	2011	Standard	83.33abc	83.74b	83.87	83.21		
		Alternative	83.44ab	83.59b				
	2012	Standard	82.87c	83.74b				
		Alternative	83.04a	83.57b				
Short fibre content (%<12.7mm)	Year x Management * lsd =0.50			Cultivar ***		Gin***		
		Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC	
	2011	7.528a	6.841b	8.147	7.104	7.293	7.959	
	2012	8.089c	8.044c					

Table 4: HVI fibre tensile attributes.

Strength (g tex^{-1})	Year x Cultivar x Gin* Lsd= 0.73				Management			
			Sicot 74BRF	Sicala 340BRF	Standard	Alternative		
	2011	0LC	32.97b	35.27e	33.25	33.63		
		2LC	32.98b	34.68de				
	2012	0LC	32.55b	34.22cd				
		2LC	31.03a	33.82c				
Elongation (%)	Year x Cultivar x Gin** Lsd= 0.29				Management x Cultivar x Gin** Lsd= 0.25			
			Sicot 74BRF	Sicala 340BRF			Sicot 74BRF	Sicala 340BRF
	2011	0LC	6.05a	6.12ab	Standard	0LC	6.28a	6.57bc
		2LC	6.21abc	6.37bcd		2LC	6.65bc	6.45ab
	2012	0LC	6.49cd	6.91e	Alternative	0LC	6.26a	6.46ab
		2LC	6.90e	6.82e		2LC	6.46a	6.74c

Table 5: HVI determined fibre micronaire, and Cottonscope determined fibre fineness and maturity ratio.

HVI Micronaire	Year**		Management		Cultivar***		Gin***			
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC		
	4.37	4.61	4.50	4.48	4.62	4.36	4.53	4.45		
CS Fineness (mtex)	Year x Cultivar** Lsd= 7.4			Year x Gin* Lsd= 7.3			Management x Cultivar x Gin** Lsd= 8.0			
		Sicot 74BRF	Sicala 340BRF		0LC	2LC			Sicot 74BRF	Sicala 340BRF
	2011	189.2a	177.9b	2011	182.2a	184.8a	0LC	Standard	197.2b	185.5a
	2012	202.7c	190.5a	2012	199.3b	199.0b		Alternative	197.7b	182.6a
							2LC	Standard	201.1b	183.0a
								Alternative	197.7b	185.8a
CS Maturity Ratio	Year x Management x Gin* Lsd= 0.01				Year x Cultivar*** Lsd= 0.01					
			0LC	2LC		Sicot 74BRF	Sicala 340BRF			
	2011	Standard	0.90a	0.89ab	2011	0.89a	0.90a			
		Alternative	0.90a	0.90a	2012	0.87b	0.90a			
	2012	Standard	0.88b	0.88b						
		Alternative	0.88b	0.88b						

Table 6: Average values for AFIS nep count, nep size, seed coat nep count, seed coat nep size, and fibre nep count.

Neps (count/g)	Year		Management x Gin * Lsd =9.0			Cultivar***		
	2011	2012		Standard	Alternative	Sicot 74BRF	Sicala 340BRF	
	227.0	203.7	0LC	181.6a	179.9a	204.4	226.4	
			2LC	258.6c	241.5b			
Nep size (µm)	Year		Management		Cultivar		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	726.5	731.8	728.8	729.5	728.9	729.3	735.3	723.0
Seed coat neps (count/g)	Year		Management		Cultivar		Gin	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	39.66	40.12	39.91	39.88	38.61	41.17	38.73	41.05
Seed coat nep size (µm)	Year		Management		Cultivar		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	1092	1102	1100	1094	1102	1092	1073	1121

Table 7: Calculated fibre perimeter and wall area using previously described relationships (eqns. 2 and 3).

Perimeter MR (µm)	Year***		Management x Cultivar x Gin** Lsd = 0.46				
	2011	2012			0LC	2LC	
	54.17	56.87	Standard	Sicot 74BRF	56.71a	57.30c	
				Sicala 340BRF	54.31b	54.08b	
			Alternative	Sicot 74BRF	56.72a	56.73a	
				Sicala 340BRF	53.95b	54.36b	
Wall area Aw MR (square µm)	Year x Cultivar ** Lsd=3.7			Management		Gin*	
		2011	2012	Standard	Alternative	0LC	2LC
	Sicot 74BRF	125.8a	138.9c	127.1	126.5	127.3	126.2
	Sicala 340BRF	116.9b	125.5a				

The standard cultivar Sicot 74BRF had less neps than Sicala 340BRF, which as previously reported is related to the smaller perimeter and longer fiber being allowing a greater degree of entanglement to occur (Tables 6 and 7). As expected the 2LC gin treatment had more neps because of the intensive mechanical cleaning action of the cleaning action. Cleaning is undertaken to reduce the penalties that occur during the classing of cotton, which are heavily influenced by the colour and leaf trash present.

For colour, cotton was brighter (higher reflectance-Rd) and higher significantly in +b for the 2011 season which translated into one HVI color grade difference between seasons (41-1 for the 2011 season compared to a 41-2 for the 2012 seasons) (Table 8). Gin lint cleaning treatments effected colour grade, with 2LC treated cotton having higher reflectance (Rd = 75.74) and was more yellow (+b = 7.4) which equated to two HVI classing color grades (51-1 for 0LC cotton compared to 41-1 for 2LC).

Leaf grade was better (lower by 1 grade) for the 2012 season for Sicot 74BRF compared with Sicala 340BRF, and as expected, on average 2LC leaf was lower (leaf grade 4) than cotton with no lint cleaning (leaf grade 5) (Table 9).

Table 8: HVI colour results, reflectance (Rd), yellowness (+b), and corresponding colour grades.

Rd	Year **		Management		Cultivar		Gin ***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	74.78	72.85	73.75	73.88	74.03	73.60	71.89	75.74
+b	**						***	
	7.3	7.0	7.1	7.2	7.2	7.1	6.9	7.4
Color grade	41-1	41-2	41-2	41-2	41-2	41-2	51-1	41-1
Adjusted color grade	31-1	31-2	31-2	31-2	31-2	31-2	41-1	31-1

Table 9: HVI leaf grades

Leaf grade	Year x Cultivar**			Management		Gin***	
		Sicot 74BRF	Sicala 340BRF	Standard	Alternative	0LC	2LC
	2011	5	5	5	5	5	4
	2012	4	5				
Adjusted leaf grade		Sicot 74BRF	Sicala 340BRF	Management		Gin***	
	2011	4	4	Standard	Alternative	0LC	2LC
	2012	3	4	4	4	4	3

Table 10: HVI colour results, reflectance (Rd), yellowness (+b), and corresponding colour grades, and HVI leaf grades, for cotton samples subjected to full cleaning via 2 x passages of a Shirley lint cleaner as part of the standard gravimetric non-lint content determination method.

Rd	Year		Management		Cultivar x Gin * LSD = 0.62			
	2011	2012	Standard	Alternative		0LC	2LC	
	81.95	80.48	81.09	81.34	Sicot 74BRF	80.86ab	81.47bc	
					Sicala 340BRF	80.67a	81.87b	
+b	Year		Management		Cultivar x Gin			
	2011	2012	Standard	Alternative		0LC	2LC	
	8.7	8.6	8.5	8.8	Sicot 74BRF	8.7	8.6	
					Sicala 340BRF	8.6	8.8	
Color grade	Year		Management		Cultivar x Gin			
	2011	2012	Standard	Alternative		0LC	2LC	
	11-2	21-1	21-1	11-2	Sicot 74BRF	21-1	11-2	
					Sicala 340BRF	21-1	11-1	
Leaf grade	Year		Management		Cultivar		Gin	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	1	1	1	1	1	1	1	1

The little differences between cultivars in colour and leaf demonstrates the potential overarching masking effect that colour and leaf would have on any potential premiums available for the premium cultivar. Indeed for the HVI colour and leaf determined for the same cottons following ‘complete’ (2 x Shirley cleaned) through cleaning, rendering leaf grades across all cottons to 1, improved colour grade by up to 2 grades (up between 21-1 and 11-1) (Table 10). This demonstrates the large influence that leaf content has on the colour grade of cotton.

For the economic impact of the treatments, there was a significant influence of cultivar for the actual (un-adjusted) degree of price discounts, with Sicala 340BRF having higher discounts which is attributed to that treatment having more trash (Table 11). This was also evident when average premium and discount values were determined using the adjusted leaf and colour values, but in this case the combination of the alternative management practice and Sicala 340BRF had different (higher) discounts. This is also attributed to this combination having higher trash. Ginning treatment played a significant role in reducing discounts, with the 2LC treatment bestowing more value to fibre when considering the actual or adjusted premium/ discount analysis. These premium and discount values were also incorporated into a gross margin analysis which also took into account production cost differences for the agronomic treatments and yield of ginned lint (Table 12). Main effects for cultivar and gin were evident for this gross margin analysis. Sicot 74BRF had the best dollar return, which is attributed to the over-arching influence that the higher yield that this cultivar offers compared to the superior fibre quality offered by Sicala 340BRF. The 2LC treatment offered significantly higher gross margin return, which is attributed to the large reduction in discounts that occur when trash is reduced regardless of the potential damage and nep creation caused by lint cleaning.

Table 11: Premium and discount points (US cents/ pound x 10^2) determined from a commercial premium and discount sheet.

Actual	Year		Management		Cultivar*		Gin***		
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC	
	-1167	-1297	-1222	-1242	-1148	-1316	-1582	-881	
Adjusted	Management x Cultivar* Lsd=145.9			Year x Gin* Lsd=229			Cultivar x Gin* Lsd=130.9		
		Standard	Alternative		0LC	2LC		0LC	2LC
	Sicot 74BRF	-451.6a	-426.9a	2011	-789.1a	-92.5c	Sicot 74BRF	-791.4a	-87.0c
	Sicala 340BRF	-522.7a	-703.1b	2012	-1066.4b	-156.2c	Sicala 340BRF	-1064.1b	-161.7c

Table 12: Gross margin (AU$ per ha and (AU$ per ML)) for fully irrigated central and northern NSW (NSW-DPI analysis).

Actual	Year		Management		Cultivar***		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	1345(137)	995(102)	1094(112)	1246(127)	1356(139)	984(101)	1100(112)	1241(127)
Adjusted					***		***	
	1774(181)	1375(141)	1505(154)	1645(168)	1778(182)	1371(140)	1490(152)	1659(170)

The premium variety Sicala 350BRF spun more even and stronger yarns because of better length in combination with its smaller perimeter or finer fibre (Table 13). There was no influence of in-field management practice on spun yarn performance, reflecting the little difference seen in fibre parameters (i.e. only a small improvement in length, but no effect on strength or fineness). On the contrary the seasonal effect bestowed significant differences in yarn performance, with the first (2011) season's longer, stronger and finer fibre, producing yarns that were 8.6% stronger and 2.8% more even, compared to the second (2012 harvest) season. Ginning treatment also significantly affected yarn performance, with lint cleaned fibre spinning yarns that were less even, more hairy, and with more yarn neps. Lint cleaning detrimentally effected yarn strength for Sicala 340BRF, but not for Sicot 74BRF (Table 13).

Table 13: Yarn performance attributes for 12 tex carded knit twist ring spun yarns

CV%	Year		Management		Cultivar*		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	21.55	21.68	21.59	21.64	21.81	21.42	21.31	21.92
Hairiness	Year*		Management		Cultivar***		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	4.54	4.76	4.65	4.65	4.74	4.56	4.62	4.68
Neps	Year		Management		Cultivar**		Gin***	
	2011	2012	Standard	Alternative	Sicot 74BRF	Sicala 340BRF	0LC	2LC
	1986	1798	1872	1913	1796	1989	1738	2047
Tenacity (cN/tex)	Year x Gin* Lsd= 0.92			Management		Cultivar x Gin* Lsd= 0.35		
		0LC	2LC	Standard	Alternative		0LC	2LC
	2011	15.02a	14.96a	14.23	14.38	Sicot 74BRF	13.77a	13.70a
	2012	13.83b	13.40b			Sicala 340BRF	15.09b	14.67c

1.2 Management for better cotton fibre – Assessment of in-field management to influence fibre quality

This is a new objective included to cover off an opportunity to investigate the use of the growth regulator ethephon to change when the fruiting period occurs in crops as an attempt to improve fibre quality. Ethephon is a regulator used to promote the hormone ethylene associated with stress events in cotton crops often causing fruit and leaf abscission. Presently ethephon is used principally at defoliation to assist in the removal of leaves and assist boll opening.

The concept of using ethephon to shift the fruiting period in cotton has been investigated over a number of season by Glenn Rogan a St George cotton grower. The rates and recommendations on the use of ethephon in this study were provided by Glenn. Glenn considers this approach to assist management of crops when water can be limiting at certain times in the season. The intent is to shift the fruiting period into times of the season that are less stressful to the crops, thus improving fibre quality.

We established a large scale field experiment at the Australian Cotton Research Institute that attempted to quantify the impact of various management practices on fibre quality. Treatments included a normal and late planting time, an ethephon treatment applied at first flower to remove fruit, and the use of Mepiquat Chloride to optimise crop cutout for timely harvest, and use of end of season in-field. We also used end of season monitoring techniques described above (eg. micronaire predictor, boll cutting technique to optimise the timing of defoliation. The results reported below only include results for the planting time and ethephon treatments as there was no effect of: Mepiquat Chloride applied at cutout on yield or quality; and the optimal defoliation time was similar to the fixed defoliation time of 60% bolls open as the end of season was considerably cool. Note that this experiment was under fully irrigated conditions.

The results showed that like changes in planting time the use of ethephon to remove fruit could significantly affect both yield and fibre quality. Yield was reduced in both the ethephon and late planted treatments compared to the control (Table 14). The reduction in yield in the ethephon treatment was associated with a reduction in boll number (less retention) not from a reduction in boll size. For fibre quality the later planting time did not affect length and strength compared to the control however, it reduced micronaire. In the ethephon treatment length and strength were reduced compared to the control, however the micronaire was improved.

From this initial research a number of important outcomes can be derived, which include:

- Ethephon used at the correct rate at flowering can change the period when fruit development occurs in a crop influencing fibre quality at magnitudes similar or greater than changing planting times. Although yield was affected in this study, the concept of shifting the fruiting periods in stressed environments as proposed by Glenn Rogan to improve quality is potentially feasible. The use of crop simulation technologies may assist in assessing this management strategies in future research.
- The rate used by Glenn Rogan was used successful in this study and will form the basis of future research to manipulate crop growth using growth regulators.

Table 14: Results of a study that investigated the effect of shifting the crop fruiting period using planting time and fruit removal using Ethephon.

Variable Measured	Level of Significant difference	Treatment Means			Least Significant Difference (lsd)
		Ethephon fruit removal on Normal Planting	Late Planting (10/11/2014)	Normal Planting (23/10/2014)	
Yield (bales/ha)	**	8.46b	7.16a	10.28c	1.22
Boll Number (/m^2)	*	130ab	122a	149b	20
Boll Mass (g)	*	4.32b	3.83a	4.00a	0.26
HVI Length (inches)	**	1.27a	1.30b	1.30b	0.02
HVI Micronaire	**	3.93c	3.20a	3.47b	0.17
HVI Strength (g/tex)	**	30.69a	31.85c	30.95b	0.82
% fruit final fruit retention	***	35.7a	42.9b	48.2b	5.5

*Significance at the $P<0.05$ level; ** Significance at the $P<0.01$ level; ***Significance at the $P<0.001$ level.

Objective 2 – *Developed improved understanding of the relationship of fibre fineness and neps.*

2.1 Assessing some entanglements (neps) and standard fibre quality attributes for two cotton breeding lines, with emphasis on the 'top' and 'bottom' parts of the crops.

Summary

- Two field experiments conducted in seperate years assessed two un-released genotypes with different perimeter fibre, grown under two defoliation regimes and then subjected to gin lint cleaning.
- The work allowed entanglements (neps) propensity data to be quantified.
- When cotton micronaire was less than 4.0, neps increased two fold, and when fibre micronaire was less than 3.0 neps increased 4 fold.
- This work has allowed significant information to be collected that will be statistically analysed with historical defoliation - crop maturity x gin lint cleaning treatments, to better model adverse incidences of neps in cotton lint.
- It is intended that this research be developed into a peer reviewed publication and industry article.

An experiment was established at ACRI that was a factorial experiment with four replications involving two genotypes (Larger perimeter variety 981-117 and smaller perimeter variety = 981-41), two crop maturities (early defoliation (20 % open bolls) and late defoliation (100% open bolls = control). Experimental plots were hand harvested from either the top 6 nodes of plants ('top' cotton), and other 'bottom' fruit were harvested that were healthy full bolls excluding fruit form the bottom four nodes. Samples were ginned and tested for HVI fibre quality attributes. A sub-set of ginned lint was also subjected to an experimental lint cleaner and tested for neps via an AFISpro instrument.

For cotton fibre length, the position main effect was evident for the Year 1 harvest season (Table 15) with the top picked cotton being 4 32nds of an inch shorter than bottom picked cotton. For the 2012 season (Table 16), a genotype x position interaction showed that on average cotton from the top bolls for genotype 981-117 was shorter than the bottom, but no difference between the two position designations was evident for the other genotype.
The short fibre content for cotton from the 2011 harvest season showed two main effects, with the 981-117 genotype having more short fibre than 981-41, while bottom picked cotton had on average almost half the short fibre content as the top picked cotton (Table 15). For the second season, short fibre index was 12.23% for the top picked 981-117 cotton compared with a short fibre content of 9.84 for the bottom cotton, while the short fibre content was the same for both positions for genotype 981-41 (Table 16).

Table 15: Year 1 harvest season cotton fibre average quality attribute results for handpicked samples from either the top part or bottom of each plant, for two different un-released breeding lines (genotypes 981-117 [genotype A], and 981-41 [genotype B]). These were propagated under two defoliation (early or late) treatments. Quality attributes are HVI upper half mean length, short fibre index (SFI), strength, elongation, and micronaire (Mic) for the raw ginned lint. AFISpro measured entanglements (neps) are reported for cotton subjected to one passage of an experimental gin lint cleaner. Significant treatment effects are reported as <5%*, <1%**, and <0.1%***.

	Early defoliation				Late defoliation			
	Bottom		Top		Bottom		Top	
	Gen. A(17)	Gen. B	Gen. A	Gen. B	Gen. A	Gen. B	Gen. A	Gen. B
Length (inch)	1.23	1.26	1.09	1.12	1.23	1.23	1.13	1.14
	Position***							
SFI	10.68	7.68	18.00	14.33	9.25	6.63	14.40	13.90
	Genotype*; Position***							
Strength (g/tex)	30.53	29.63	24.85	24.33	32.40	30.40	27.35	27.03
	Genotype*; Defoliation***; Position***							
Elongation (%)	6.18	6.50	5.90	5.75	6.25	6.78	5.78	6.33
	Genotype x Defoliation* Lsd = 0.28 ; Position***							
Mic	4.13	3.86	2.45	2.23	4.18	3.87	2.97	2.74
	Genotype*; Defoliation x Position*** Lsd = 0.21							
Neps (cnt/g)	530a	472a	1294c	1642d	426a	491a	870b	1035b
	Genotype x Position x Defoliation* Lsd = 345							

For tensile properties, the strength of cotton from the first season was evident for the three main effects, with 981-117 genotype having the strongest fibre of the two, the early defoliation treatment having weaker cotton then the late treatment, and bottom picked cotton having much stronger fibres then top picked cotton (Table 15). The same variables influenced the elongation of cotton, albeit with genotype interacting with defoliation. Such that late defoliated 981-41 genotype cotton had higher elongation then either the early defoliated cotton for the same genotype which was the same as average fibre elongation as the early defoliated cotton for both genotypes.

For tensile properties for the second harvest season, genotype 981-117 had stronger bottom fibres than top fibres, while fibre strength was the same for both positions for genotype 981-41. Genotype 981-117 had lower fibre elongation than 981-41, which reflected its higher strength. Cotton from the more mature lower fruit had higher elongation than cotton from the top.

Average fibre micronaire for cotton from the Year 1 harvest season was significantly less for top cotton, and early defoliated top cotton had lower micronaire than late defoliated top cotton. Bottom cotton was higher in micronaire but bottom early and late defoliated cotton wasn't different. The genotype main effect was significant with 981-41 having lower micronaire than 981-117. For the Year 2 harvest season, genotype x position and defoliation x position interactions were captured, with the top harvested cotton from genotype 981-41 having lower micronaire (3.80) than top cotton from 981-117 although cotton from the bottom was similar for both varieties. Cotton from the top of the plant for the early defoliated treatments were on average lower than the rest, while bottom picked early and late defoliated cotton had the same micronaire, and late defoliated top and bottom cotton had similar miconraire (Table 16). Micronaire from the first season was on average lower (3.30) then the second harvest season (4.20).

For entanglements from the Year 1 harvest season, bottom harvested cotton had the same level of neps for both genotypes. Top picked cotton had more neps, but there was no difference between the amount of neps between genotypes for the late defoliated treatment, while top early defoliated cotton had the most neps within genotype 981-41 having more neps (Table 15). For the second harvest season, early defoliated cotton had on average 135 more neps than the late defoliation treatments, while on average the top position treatments had approx. 150 more neps than the bottom harvested samples (Table 16). Micronaire was linked to neps, with cotton having micronaire lower than 4.0 having approx. twice the nep count as cottons with micronaire values between 4.0 and 5.0. The cotton from the first season that had micronaire lower than 3.0 had approx. 3 times more neps than the other cotton.

Table 16: Year 2 harvest season cotton fibre average quality attribute results for handpicked samples from either the top part or bottom of each plant, for two different un-released breeding lines (genotypes 981-117 [genotype A], and 981-41 [genotype B]). These were propagated under two defoliation (early or late) treatments. Quality attributes are HVI length, short fibre index (SFI), strength, elongation, and micronaire (Mic) for the raw ginned lint. AFISpro measured entanglements (neps) are reported for cotton subjected to one passage of an experimental gin lint cleaner. Significant treatment effects are reported as <5%*, <1%**, and <0.1%***.

	Early defoliation				Late defoliation			
	Bottom		Top		Bottom		Top	
	Gen. A(17)	Gen. B	Gen. A	Gen. B	Gen. A	Gen. B	Gen. A	Gen. B
Length (inch)	1.221	1.214	1.168	1.196	1.215	1.230	1.172	1.213
	Genotype x Position* Lsd = 0.027							
SFI	9.90	9.95	12.88	10.65	9.78	8.53	11.58	9.05
	Genotype x Position* Lsd = 1.06; Defoliation*							
Strength (g/tex)	30.70	29.58	27.85	27.93	31.63	29.98	29.30	30.12
	Genotype x Position* Lsd = 1.11; Defoliation**							
Elongation (%)	7.22	7.33	6.65	6.88	7.08	7.45	6.65	6.85
	Genotype*; Position***							
Mic	4.36	4.34	3.64	3.37	4.59	4.31	4.71	4.24
	Genotype x Position* Lsd = 0.15; Defoliation x Position*** Lsd = 0.15							
Neps (cnt/g)	372	365	685	574	302	349	353	427
	Defoliation**; Position**							

***Objective 3** - Develop methodologies that assist in determining the value of end of season un-opened bolls.*

A number of new datasets were generated or compiled to assist this objective. The first activity was to collate and collect data that validates the boll cutting technique to highlight risks to fibre quality at defoliation. We will use this data to further promote this outcome. To date the recommendation of >29% immature bolls impacting yield and quality has been only based on the experiments we used to generate the recommendation. The validation on independent datasets will help to support the use of this recommendation. The second activity was to evaluate the CottASSIST last effective flower tool in its ability to reduce the amount of immature bolls at harvest time to raise quality. While the final was to collect data to understand the variation in boll development and fibre quality distribution within the canopy of a current commercial variety. If significant changes have occurred since previously published assessments by Greg Constable we would use this information to update recommendations for the date of last effective flower across regions.

3.1 Validation of Boll Cutting Technique to identify Neps Risk

In previous research published by Bange et al. (2010) we were able to demonstrate the relationship of increased neps associated with the proportion of immature bolls measured at defoliation time (see Figure 2). We collated additional data from additional two season where crops were defoliated at a range of times. In addition the crops had fruiting branches removed in an attempt to create variable canopies. In the first season the first five fruiting branches were removed, and in the second season fruiting branches 3 and 7 were removed early in flowering.

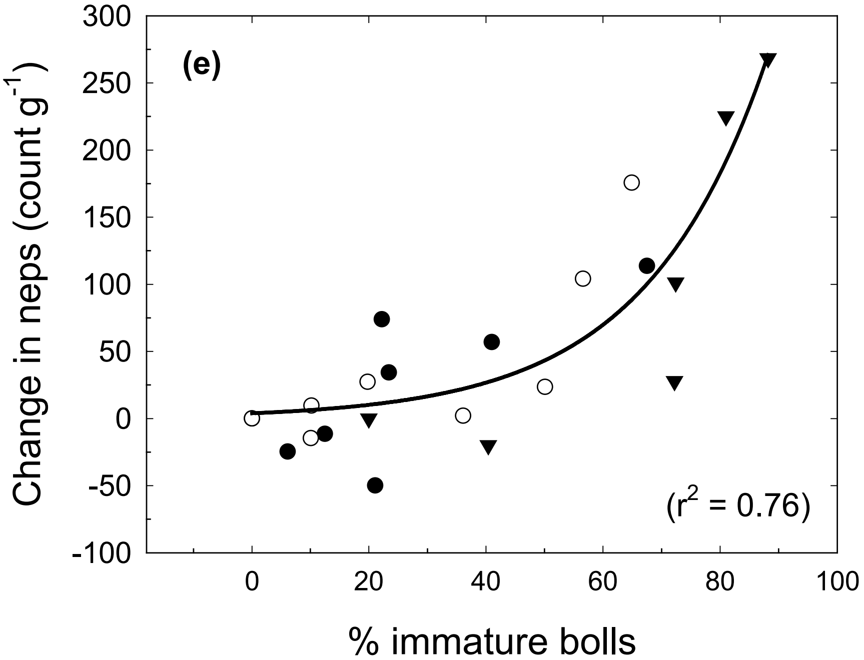


Figure 2: The change in total nep number in relation to the proportion of immature bolls at defoliation. Note that the increase in neps on average does not occur until 29% immature bolls is achieved. Published in Agronomy Journal Volume 102 Pages 781-789.

Total neps were measured using the AFIS located at CSIRO in Geelong. To validate if the original response and recommendation on where neps increased we added the new data the original data and compared the new response to the old (Figure 3). There was minimal change in the response as a result of the addition of the new data so we will remain promoting the original recommendation of >29% immature bolls increasing neps risk.

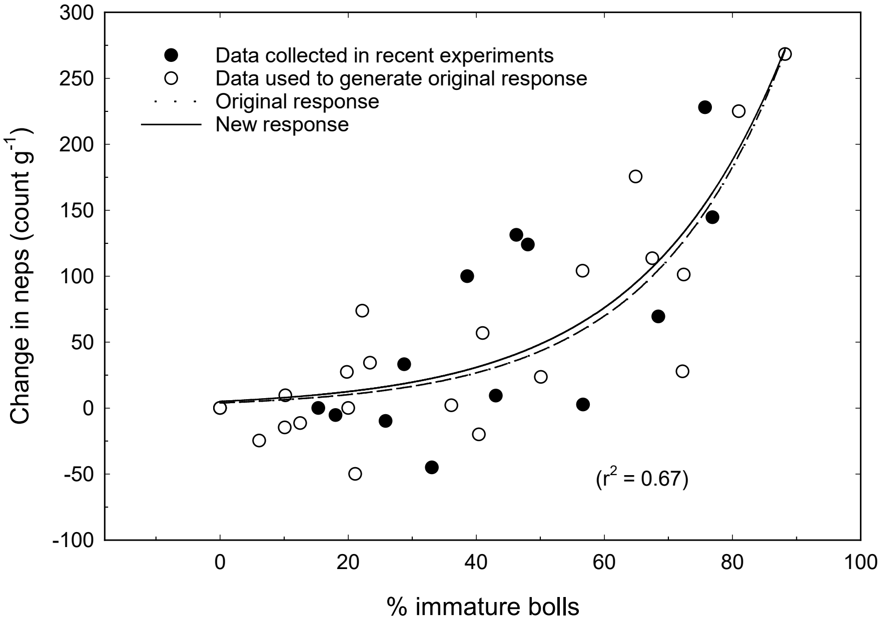


Figure 3: The change in total nep number in relation to the proportion of immature bolls at defoliation including independent data collated during this project. Note that the increase in neps on average does not occur until 29% immature bolls is achieved and has not change with the addition of extra data.

Following on from this assessment we also used the data to assess the responses that related the various measures of crop status (% open bolls, Nodes above cracked boll (NACB), % immature bolls, number of immature bolls) at defoliation. These responses were also published in Bange et al. (2010) (see Figure 4). To test these responses on the crops used in this study which included those that had fruiting branches removed we predicted the crop status using % open bolls and compared the estimates with the measured crop status (Figure 5). The most stable response was the % immature bolls, highlighting its utility in predicting crop maturity as well as utilising it as a foundation for predicting neps risk. Importantly it was stable in crops that had their fruiting branches removed generating different fruiting patterns.

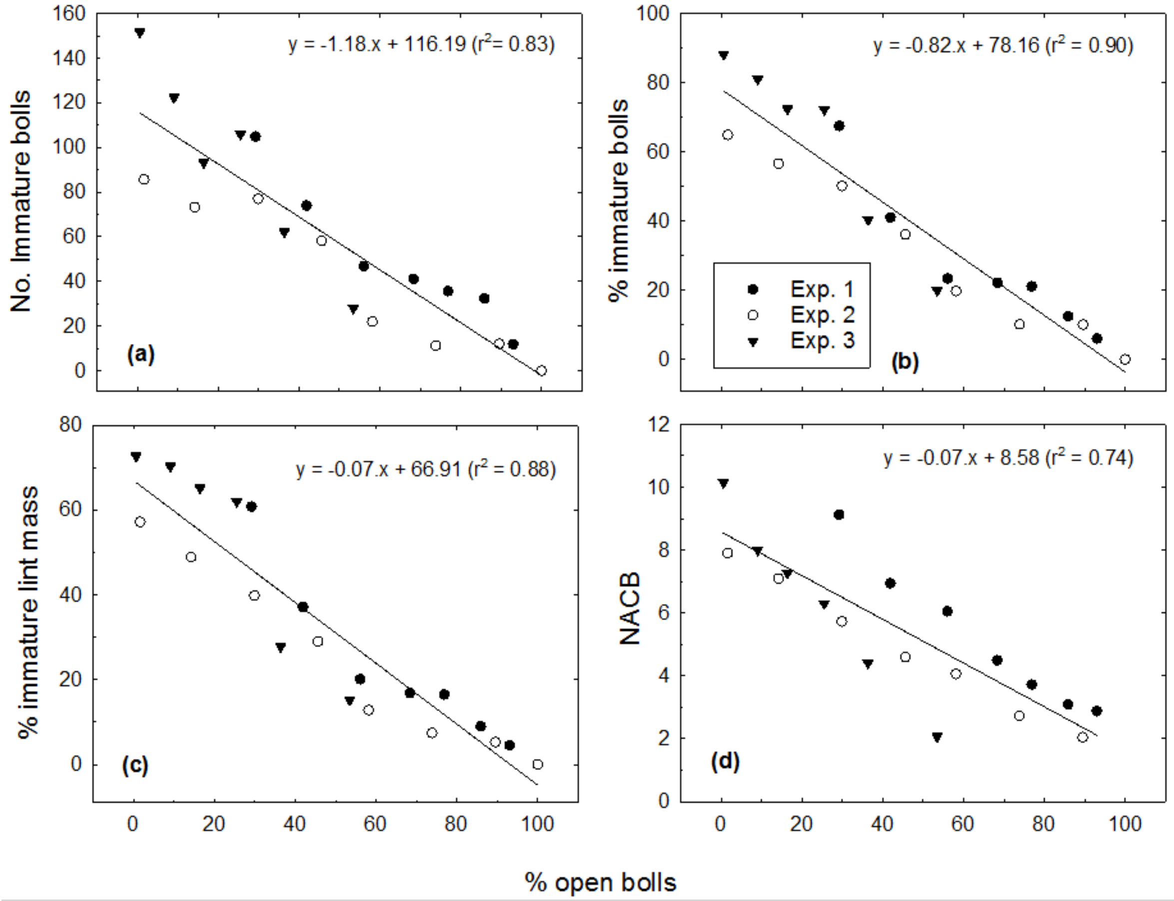


Figure 4: Relationships used to estimate the (a) number of immature bolls, (b) percent immature bolls, (c) percent immature lint mass, and (d) nodes above cracked boll (NACB) when crops were at 60% open bolls. Published in Agronomy Journal Volume 102 Pages 781-789.

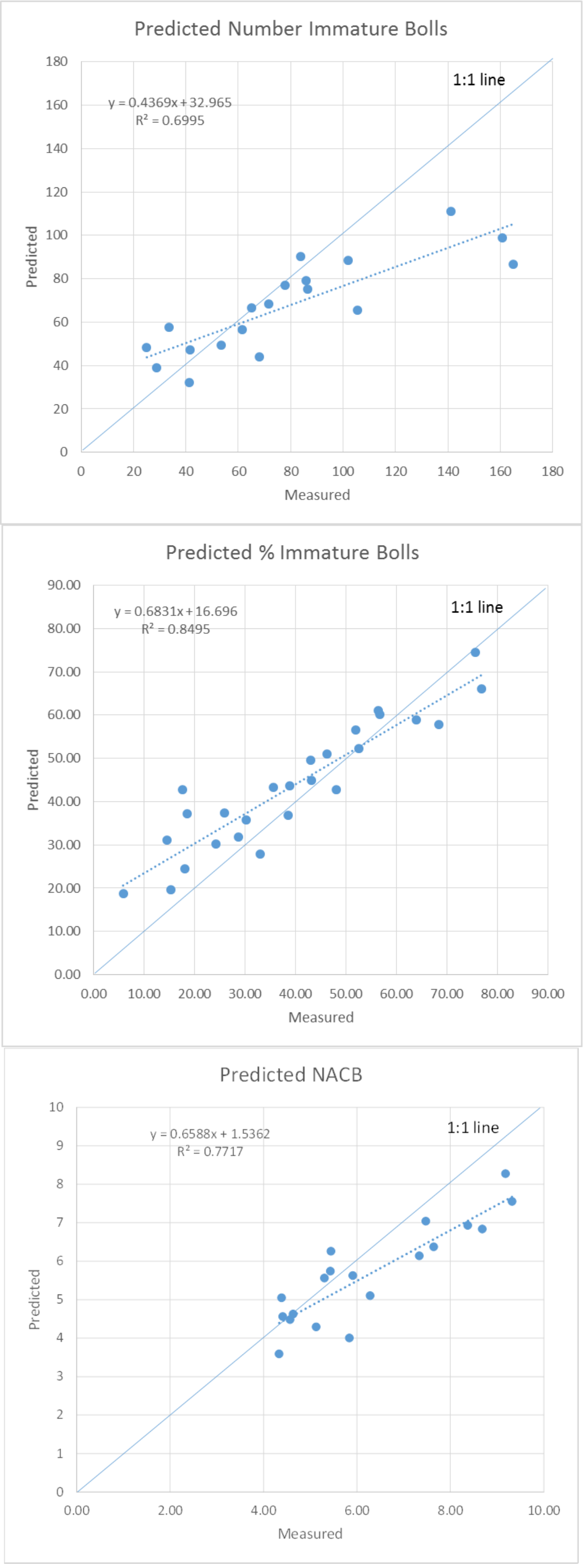


Figure 5. Relationships showing predicted crop status using relationship published in Bange et al. (2010) at defoliation compared to measure values collected in this study. The closer the points are to the 1:1 line the better the prediction.

3.2 In-Field Techniques to Reduce the Risk of Attaining Immature Bolls at Harvest – (An Assessment of the Last Effective Flower CottASSIST tool)

One of the most effective means of reducing neps and immature fibre is to avoid having immature bolls at harvest. To ensure this, all bolls on the plant need sufficient time to mature. The date of a crops last effective flower can be used to match the time when a manager may choose to cutout the crop based on Nodes Above White Flower (NAWF) to ensure that all bolls have on the plant have time to mature.

The Last Effective Flower Tool (LEFT) on the CottASSIST website uses temperature data and day degree targets for an average boll period (flower to open boll) to estimate the date of the last effective flower in a season that will contribute to a harvestable boll. The last harvestable boll can be defined by the date of the average first frost (minimum temperature less than or equal to 2 degrees Celsius), or can be defined differently as per the users choice.

In this project four sites were used to assess the LEFT tool generated last effective flower estimate. One site included a late sowing treatment at ACRI, while the other three sites (Boggabri, Breeza and Mullaley) were implemented in collaboration with Kirrily Blomfield from the CottonInfo team and AgVance. These were appropriate areas as they are cooler season areas within the industry and are often at risk of having immature bolls at harvest.

To assess the effectiveness of the last effective flower date estimated by the LEFT tool we tagged approximately 10 days earlier than the estimated date, tagged flowers on the estimated date, and flowers 10 days later than the estimated date. At each date we tagged 20 flowers in three replications. At defoliation we recorded if these fruit were shed, open or unopened and immature.

All assessments showed that growers can have confidence in using the LEFT tool to guide decisions on cutout timing to ensure that effective harvest aid decision and timeliness can be achieved. All assessments showed that flowers tagged on the optimum time of cutout based on the LEF tool were either abscised indicating cutout, or were mature at harvest. A summary of three sites coordinated by Kirrily is presented in the AgVance report attached. The results of the ACRI are presented in the Table 17 below. It showed in that year that even the later date did not present too much of a risk to increasing immature bolls.

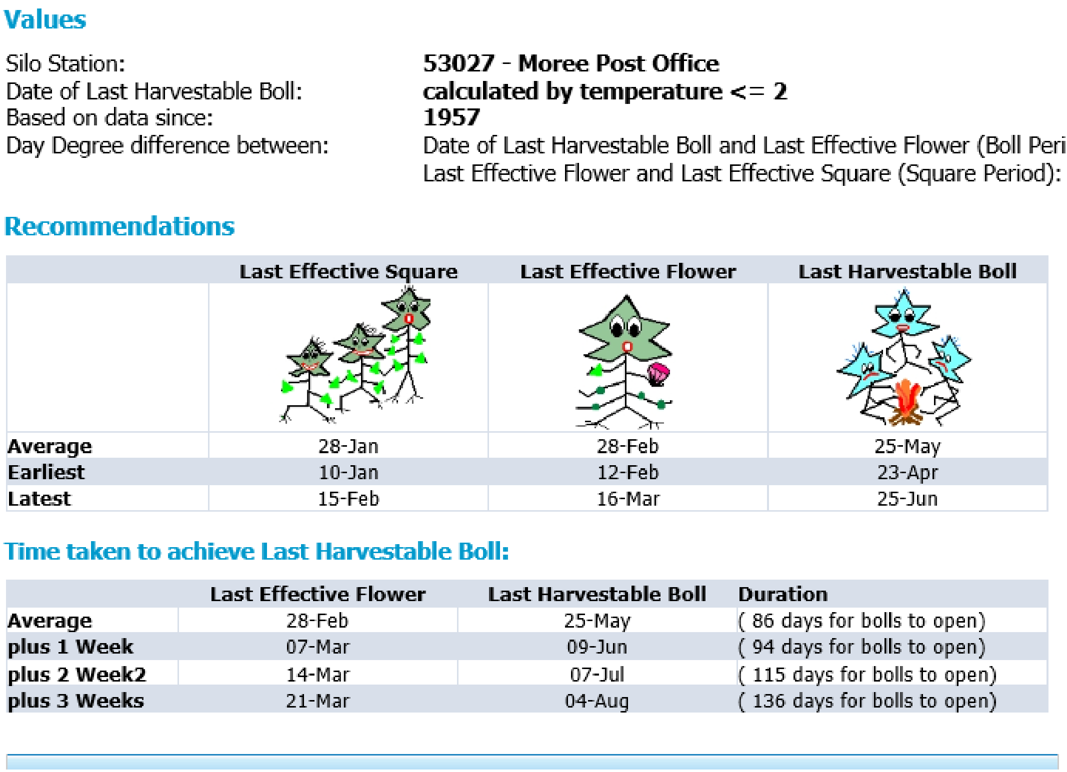
Table 17: Results of a field assessment of the estimated date of last effective flower (LEF) date using CottASSIST. A total of 20 flowers were tagged on the respective times.

Timing of Flower Tagging	Green/Immature Bolls	Shed Bolls at Defoliation	Open Bolls at Defoliation
Pre LEF	1.78	7.44	10.78
LEF	0.22	14.56	5.22
Post LEF	2.11	3.89	14.00
Significance	Not significant	**	**

** Significance at the P<0.01 level;

At the same time this study was being undertaken Michael Bange assisted in the redevelopment of the CottASSIST tool so that it could highlight the potential risk of delaying cutout past the last effective flower date. The modification of the tool showed the extended time needed to mature a boll at the end of the season associated with delaying cutout (Photo1). At the time this information was distributed widely as part of campaign to promote more effective end of season management.

It was decided that no further studies assessing this would be undertaken as there were more questions on the relevance of the boll period used to calculate the date of last effective flower for current varieties. The boll period used by CottASSIST was measured by Greg Constable in the 1980s. The focus of research effort was redirected in the following season to the effort described next in this report.



Values

Silo Station:	**53027 - Moree Post Office**
Date of Last Harvestable Boll:	**calculated by temperature <= 2**
Based on data since:	**1957**
Day Degree difference between:	Date of Last Harvestable Boll and Last Effective Flower (Boll Period): **750** Last Effective Flower and Last Effective Square (Square Period): **430**

Recommendations

	Last Effective Square	Last Effective Flower	Last Harvestable Boll
Average	28-Jan	28-Feb	25-May
Earliest	10-Jan	12-Feb	23-Apr
Latest	15-Feb	16-Mar	25-Jun

Time taken to achieve Last Harvestable Boll:

	Last Effective Flower	Last Harvestable Boll	Duration
Average	28-Feb	25-May	(86 days for bolls to open)
plus 1 Week	07-Mar	09-Jun	(94 days for bolls to open)
plus 2 Week2	14-Mar	07-Jul	(115 days for bolls to open)
plus 3 Weeks	21-Mar	04-Aug	(136 days for bolls to open)

Photo 1: A screen shot of the last effective flower tool (LEFT) with additional features highlighting the delaying the time of last effective flower on achieving the timing of last harvestable boll.

3.3 Assessment of Individual Boll Periods and Fibre Quality Distribution Patterns within Plants

Utilising a planting time experiment (three dates of planting) at ACRI detailed plant monitoring of boll periods (flower to open boll) on individual first position nodes of whole plants was undertaken. Once these bolls were open they were collected for fibre quality analysis using Cottonscope (over 800 samples collected and analysed). The intent is that more accurate assessments of last effective flower (and therefore estimates of the timing of last effective boll and its quality) can be made with knowing the position of the boll on the plant. Current recommendations are based on the work published in the 80's by Greg Constable.

In assessing the first position boll period at different nodes on the plant we plotted the periods at each node against average temperature and the thermal time calculated using the standard function (using a base temperature of 12 ºC) for each of the boll periods. We also compared this to estimates of boll periods for each node generated by functions created by Greg Constable (Figure 6).

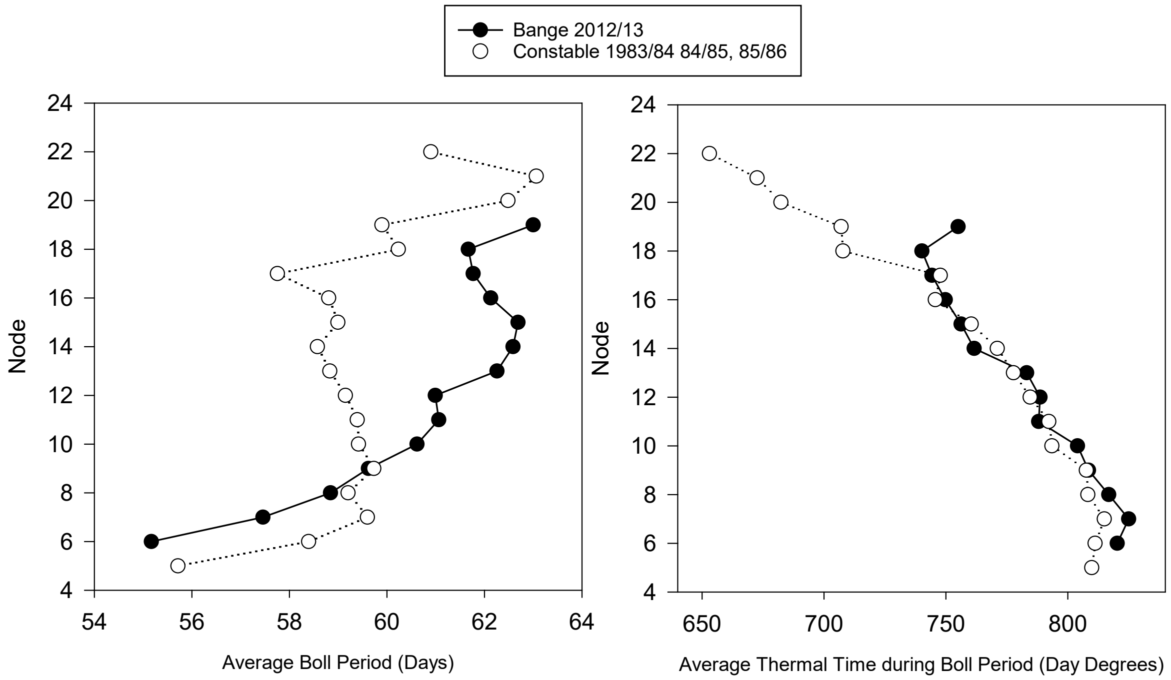


Figure 6: The first position boll periods (flower to boll open (as defined by two suture cracks)) for each node on plants in days and in thermal time for assessments made in this project. Graphs also include estimates from functions generated by Greg Constable in crops grown in the 80's.

There were significant changes in the boll period in days between nodes with generally longer periods as the node position increased. However, when the periods were calculated on a thermal time basis the opposite occurred, boll periods were less as nodes increased. While boll periods are shorter on a thermal time basis as nodes increase they are longer in real time because temperatures at this time of season are considerably cooler.

When comparing the data collected in this study with that generated by functions from Greg Constable it is notable that while the boll periods in his studies in real time were longer most likely reflecting cooler conditions of growth during his experiments. However, when all data is corrected on a thermal time basis there is little difference in boll periods across node positions. It is also interesting to note that Greg in all his studies had more fruiting nodes, most likely resulting from the fruit loss associated with non-Bollgard cultivars used at that time.

Therefore given that there was no substantial deviation in the responses across studies in thermal time for boll periods there is no urgent need to update the boll period response used to estimate last effective boll from last effective flower. An opportunity exists to update the response used in CottASSIST to account for the node number where last effective flower is present on the crop. Given the similarities in outcomes of this analysis we will look to combine data collected by Greg Constable with that collected in this study to update the response of boll period to thermal time accumulation.

In terms of fibre quality distribution there was no substantial or consistent changes in quality detected in this study (Figure 7). In general it is assumed that higher quality is generated on the nodes in the middle canopy. There was some evidence that micronaie was higher on the middle nodes, but there were also high values in the top of the canopy. It could be that this is a pattern of quality that is generated by Bollgard II crops with its more consistent fruiting pattern. We will continue to analyse this data to see if more robust patterns of quality can be generated. The overall intent is to see if we can generate a rating of quality of bolls that may develop post last effective flower and establish their value.

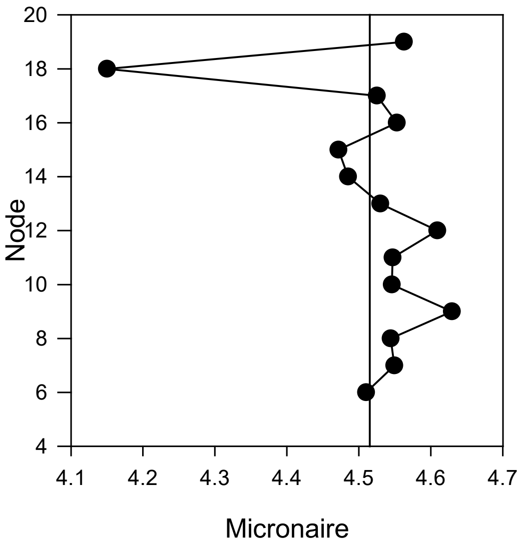


Figure 7: Average micronaire measured at different nodes using CottonSCOPE in this project (> 800 samples).

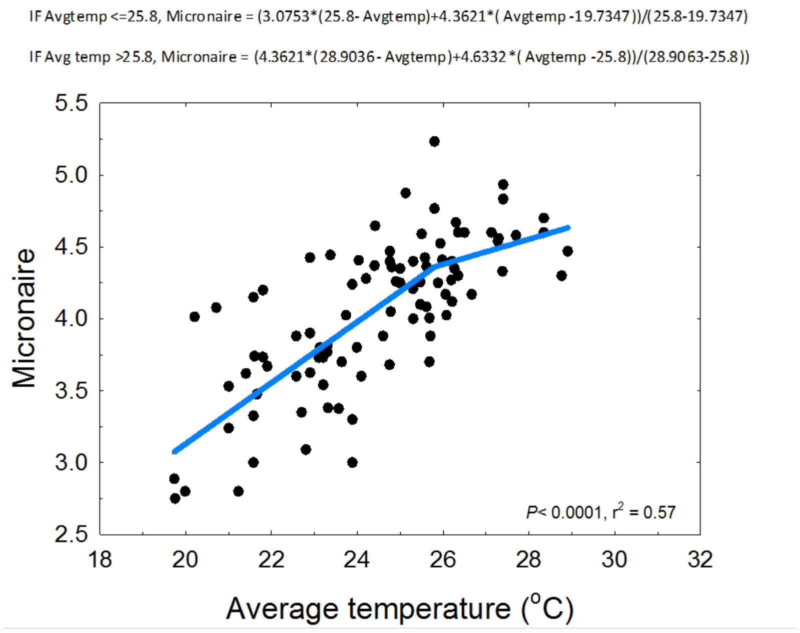
Objective 4 *- Assess methodologies that determine fibre quality before cotton is delivered to the gin.*

4.1 Improved Prediction of Micronaire and Neps using CottASSIST

A CottASSIST online tool called the micronaire predictor was completed and made available to industry for the 2013/2014 season. Outcomes of this development were reported in the project titled 'Supporting the adoption of myBMP for improved cotton crop productivity and sustainability by linking research, extension and my BMP. During the course of this project the following additions and improvements were made to the tool that:

1. Improved the predictability of micronaire from average temperature during the boll filling period.
2. Estimate the nep risk linked to the predicted final micronaire generated by the micronaire predictor. Situations where total neps are greater than 250 neps/g are flagged.
3. Highlight the impact of changes in defoliation timing on final micronaire and neps.
4. Predict the impact of lint cleaning passages on nep level.

Through the addition of extra data collected from planting time experiment conducted during the course of this project, a new function that related final micronaire at harvest to canopy temperature during the boll filling period was developed. Briefly, the approach estimates the crop boll-filling period during which the majority of the bolls that contribute to yield and quality are thickening their fibres. Estimates of the period are based on a high-yielding crop with 10 fruiting branches. Estimates of default day degrees (DD) given in Bange et al. (2010) titled 'A method to estimate the effects of temperature on cotton micronaire' were used to estimate the date of first flower (777 DD) and the midpoints of the following ranges: flowering (210 DD), fibre elongation (250 DD) and fibre thickening (660 DD). The function was able to: firstly represent a slowdown in micronaire increase at higher temperatures (Figure 8); and when applied to validation data (provided by CSIRO and CSD – 270 observations) it was better able to predict micronaire compared to the original linear response used (Figure 9). The root mean squared deviation between the observed and predicted micronaire was substantially reduced from 0.42–0.33. The new response was published in papers generated in climate change modelling undertaken by Qunying Lou (project No. UTS1301). The title of the paper was 'Environment and cotton fibre quality' published in the journal Climatic Change in 2016 (DOI 10.1007/s10584-016-1715-0)



IF Avgtemp <=25.8, Micronaire = (3.0753*(25.8- Avgtemp)+4.3621*(Avgtemp -19.7347))/(25.8-19.7347)

IF Avg temp >25.8, Micronaire = (4.3621*(28.9036- Avgtemp)+4.6332*(Avgtemp -25.8))/(28.9063-25.8))

Figure 8: The response of micronaire to average daily temperature during the fibre thickening phase.

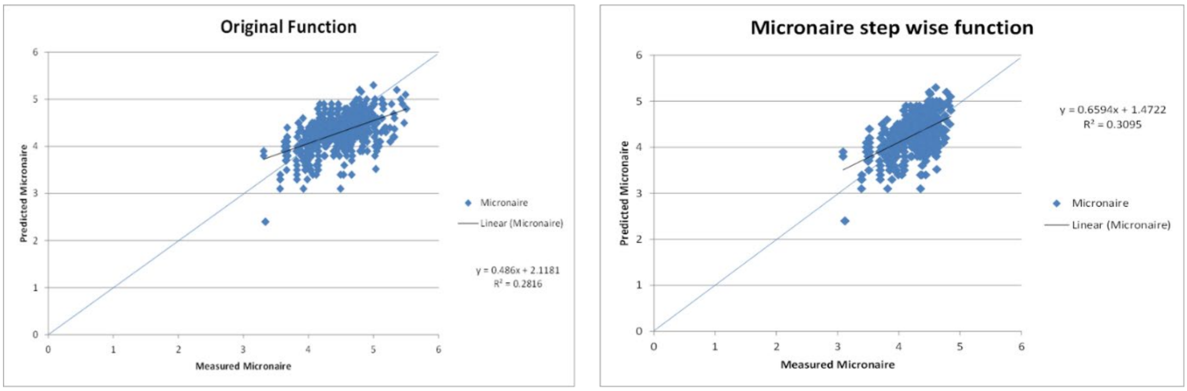
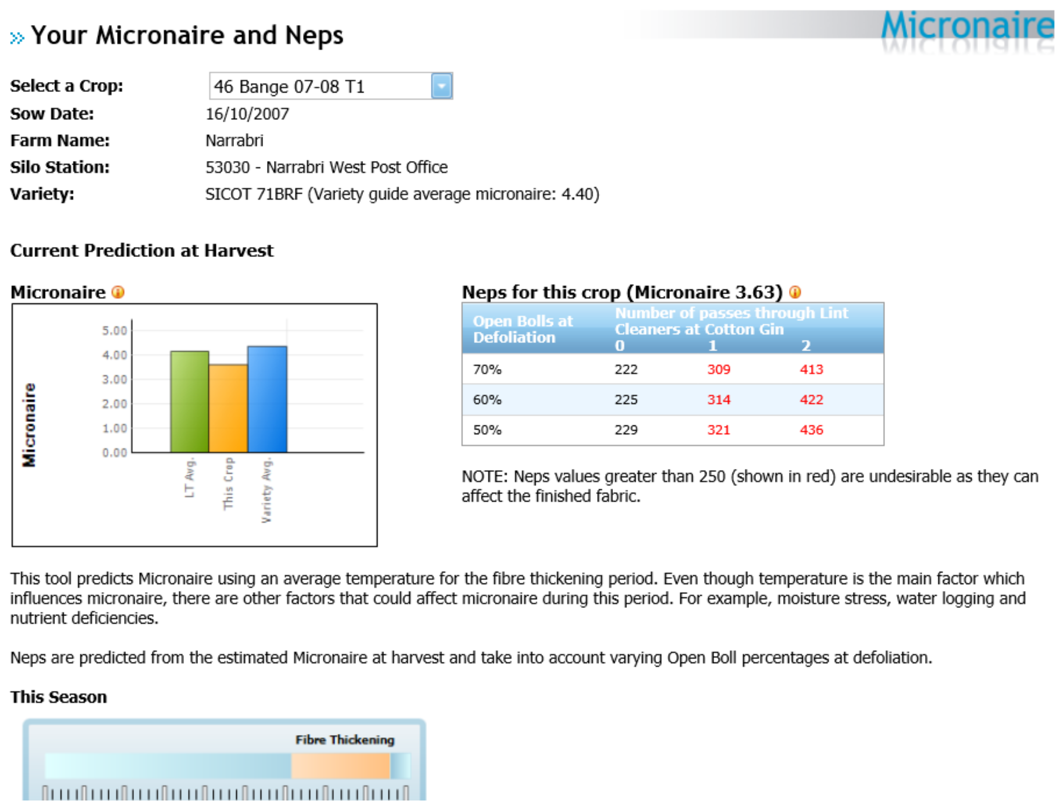


Figure 9: CSIRO and CSD data used to validate the approaches used in the development of the CottASSIST online micronaire predictor. Closer the points are to the 1:1 line the better the prediction. Note that the new stepwise function (Figure 8) above was able to improve the overall predictability of micronaire.

During the course of the project the micronaire tool was updated using the new temperature function and responses published in Bange et al. (2010) that related micronaire to the levels of neps. As well as predicting the micronaire the tool now estimate the level of neps at a particular micronaire and at a specific time of defoliation (% bolls open). It also highlights the risk associated with different lint cleaning treatments when cotton is delivered to the gin (Photo 2).

A Cottongrower article was developed to promote the tool and Mike Bange promoted it during the 2014 field to fabric road show. At this time there was extensive interest in the tool to assess micronaire because of the heatwaves experienced during the season. A chart of the use of the CottASSIST micronaire prediction tool is shown below (Figure 10):



» **Your Micronaire and Neps**

Select a Crop:	46 Bange 07-08 T1
Sow Date:	16/10/2007
Farm Name:	Narrabri
Silo Station:	53030 - Narrabri West Post Office
Variety:	SICOT 71BRF (Variety guide average micronaire: 4.40)

Current Prediction at Harvest

Micronaire

Neps for this crop (Micronaire 3.63)

Open Bolls at Defoliation	Number of passes through Lint Cleaners at Cotton Gin		
	0	1	2
70%	222	309	413
60%	225	314	422
50%	229	321	436

NOTE: Neps values greater than 250 (shown in red) are undesirable as they can affect the finished fabric.

This tool predicts Micronaire using an average temperature for the fibre thickening period. Even though temperature is the main factor which influences micronaire, there are other factors that could affect micronaire during this period. For example, moisture stress, water logging and nutrient deficiencies.

Neps are predicted from the estimated Micronaire at harvest and take into account varying Open Boll percentages at defoliation.

This Season

Photo 2: A screen shot of the micronaire tool with addition features highlighting the risk of neps with different timings of defoliation and number of lint cleaning passages. The estimates are linked to the estimate of micronaire predicted using seasonal temperatures.

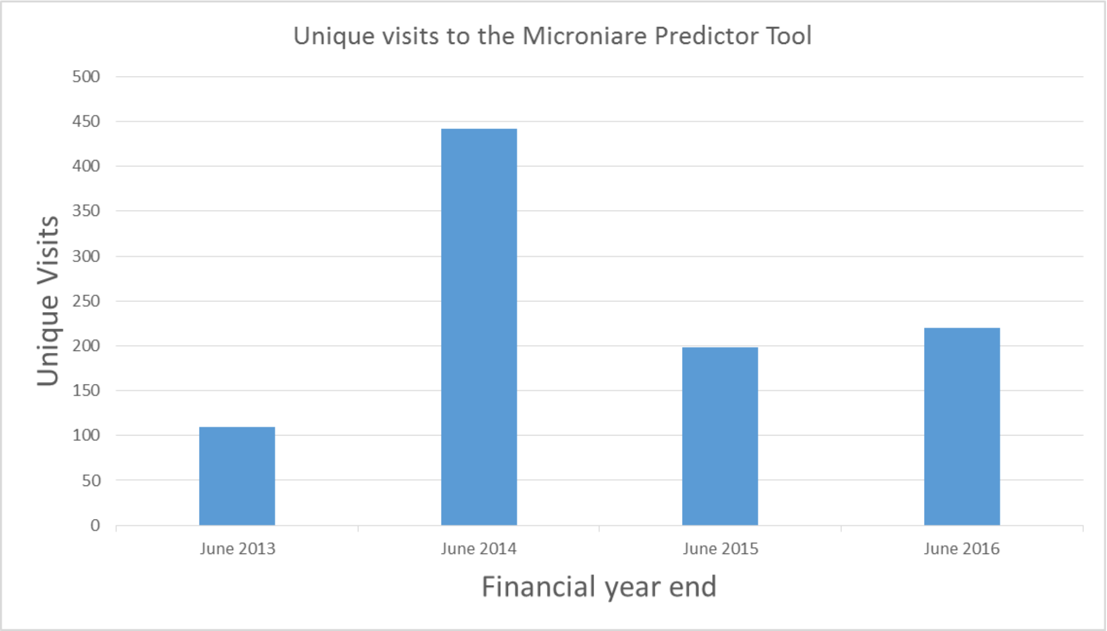


Figure 10: A plot of the unique visits to the Micronaire Prediction Tool as part of the CottASSIST web tool suite. The date represents the end of a financial year.

4.2 Precursory Review of Instruments that Potentially Could Measure In-Field Fibre Quality

During the course of the project we compiled a list of reference material that highlighted the use of portable instruments that have been used in the field to measure fibre quality (principally those employing Near-infrared reflectance (NIR)). This information is summarised in Table 18. We continued to explore the concepts and based on the review conducted by Rodgers et al. in 2010 at the USDA where the use of portable NIR (and other, e.g. acoustic) technologies were used to measure cotton fibre micronaire. Ultimately a portable technology that can determine the micronaire of unopened cotton bolls will enable researchers to better pre-empt the micronaire of ginned cotton lint and allow better management of defoliation timing to maximise yield and avoid penalties for cotton micronraire outside of the G5 range (3.5 to 4.9). The issues regarding portable NIR technology include the type of detector used (spectral range), the wavelength resolution of spectra (n=nm), the light source employed by the instrument (e.g. halogen lights or LED's), the ratio of meaningful signal to un-meaningful noise, contingencies included in acquiring spectra outdoors under varying ambient temperature and lighting (e.g. sunlight), spectral acquisition time, the size of the area of acquisition (e.g. diameter of collecting front end or optic) and mode of collection (e.g. diffuse reflectance of transmittance), size and weight, and instrument cost. Table 19 includes some technical specifications for some portable instruments; the intention is to expand this table and source full technical specs on these instruments and explore what other portable technologies are available and if we can source an instrument for future research. The following section of this highlights validation of research where the identification of immature bolls and their quality can be used to predict final micronaire.

Table 18: Summary of papers that discuss use of portable instruments to measure fibre quality in the field.

Year	Author	Key points
2010	(Rodgers et al., 2010b)	Used NIR technology to measure fibre Mic, Fin, Mat. Compared benchtop and portable units. Stronger relationships for Mic. Samples were all in lab in holder. Conceded that NIR is measuring physical not chemical with ball milled fibre spectra having no relationships with fibre properties.
1997	Stark et al.	Used a diode array (500 to 1700 nm) to measure cotton fibre fineness and maturity. Fibre presented in lab in a sample holder. No info about calibration robustness/ performance only that samples could be tasted at 240samples/hr
1997	Montalvo and Faught	Discusses that Micromat FMT was used as the reference for Stark etal.
2010	Rodgers et al	Portable NIR used to measure micronaire, using ginned lint. R^2=0.87. Described Brimrose 5030 portable and Polychromix portable NIR instruments (wave length range; 1100 – 2400nm)
1997	Buco et al	Diode array instrument 400-1700nm. Calibrations with Micromat FMT parameters: PL, PH, Mic, Fineness, wall thickness ($R^2 > 0.95$), Perimeter (R^2=0.86), AFIS Perimeter and wall thickness (R^2>0.92) . Similar results across raw, card, Shirley cleaned.
1995	(Thomasson and Shearer, 1995)	Pacific Scientific lab based scanning 1100-2500nm correlations for colour, trash, Mic (R^2=0.88), Str (R^2=0.53), L (R^2=0.72) and others. Academic non-portable.
2010	(Rodgers et al., 2010a)	Bromrose portable 1100-2300nm AOTF instrument, sample presented with and without glass port. 3 min sample processing time. Good calibrations with Mic R^2= 0.91but was presented raw fibre
2011	(Liu et al., 2011b)	Fourier transform infrared spectroscopy of seed and lint cotton to measure cotton fibre maturity. Thought to be a better technology to more directly measure fibre maturity with in mind rapid determination of less processed fibre. Small sample size (0.5 mg). Calibrations with 104 ref set Mat R^2=0.60. Would be good to know what the relationship is with Mic.

2011	(Liu et al., 2011a)	Used FOSS reflectance 400-2500nm or Jasco uv/vis/nir instrument 220-2200nm (Lab based instruments), attempt calibrations with fibre strength. Not so good for str alone (R^2=0.42) but better when str/Mic ratio used (R^2=0.87).
2011	(Vogt et al., 2011)	Rational was to try and measure Mic with NIR using a portable instrument. Used reflectance Brimrose portable (like Rodgers) 1100-2300nm asesed 5 g sample. 191 ginned cottons and PCR chemometrics. Examined different pretreatments and exclusion of water band (1900-2000nm). Best 'percentage' of predicting Mic in 'acceptable' range (+or- 0.3) was 94%.
2011	Rodgers et al	Discussed the benefits of measuring Mic in remote locations (e.g. in or near the cotton field) using portable NIR. Concerns were raised on the effect of different ginning methods (hand, saw or roller) on Mic results.
2017	Rodgers et al	Assessed calibrations using 4 NIR instruments to measure Mic, Fin and Mat. Used the 104 reference set from Eric Hequet's Lab. Reasonable model performance. Better calibrations for Mic. Still all secondary relationships since cross sectional parameters will likely not vary significantly chemically from the standpoint of what IR is measuring.

Table 19. Summary of some portable NIR instruments having potential for the non-invasive assessment of cotton fibre micronaire. Full instrument specifications are still being sort from the respective manufacturers.

Instrument	**Spectral range (nm) and manufacturer**	**Resolution (nm)**	**Detector type**	**Light Source**	**Signal to noise**	**Acquisition time**	**Designed for outside use (ref/ source spectra)**	**Sampling area and mode**	**Validation performance for micronaire**	**Size/weight, and Cost**
Thermo scientific microPHAZIR RX	1200-2400	10.5		Tungsten		<3 secs	Yes (CSIRO forestry uses this on raw timber)	6 mm diam diffuse reflectance	R^2 0.35 (poor)	1.25kg Circa $45K
Brimrose 530	1100-2300	2	AOTF			20 secs		6 mm diam	R^2 0.89 (good)	
Integrated spectronics portable	400-1100		Zeiss MMS1 PDA							
JDSU MicroNIR 2200	1150-2150	8				6 secs				

4.3 Validation of the Boll-Cutting Technique to Determine Immature Boll Fibre Micronaire to Estimate Final Crop Micronaire

During the course of this project three seasons of data were collected and compiled from experiments that varied the timing of defoliation (approximately from 20 to 100% open bolls) that were able to generate differences in the age of immature bolls and their quality. The different defoliation timings also change the final fibre quality measured at harvest, especially micronaire. In a previous project around fibre quality we were able to generate stable responses of the measured micronaire of immature bolls and relate this to final crop micronaire (Figure 11). This research was published in a journal paper by Bange and Long (2011) in the Agronomy Journal titled ‘Optimizing Timing of Chemical Harvest Aid Application in Cotton by Predicting Its Influence on Fiber Quality’. Validation on independent datasets will help to support the use of this approach. We collated data from three season where crops were defoliated at a range of times. In addition the crops had fruiting branches removed in an attempt to create variable canopies. One season had the first five fruiting branches were removed, and one had fruiting branches 3 and 7 removed early in flowering.

We assessed the approach by taking the two functions relating immature boll fibre micronaire to final micronaire presented in the paper by Bange and Long (2011) and calculated the final micronaire of the three experiments in this study from the measured immature boll fibre quality. The difference in the two functions are that one includes the measurement of % open bolls as a variable in the function. We then plotted the predicted micronaire with the measured final micronaire (Figure 12). Both functions were able to estimate final micronaire reasonable well. There was some variation and this was not associated with any experiment or timing of defoliation. It is most likely that there is greater error in the measurement of the micronaire of the immature boll samples as some are only just large enough to be taken on a HVI. There was no substantial improvement in the function when % open bolls was included as a variable in the prediction.

Results from this study can be applied in few ways. First, a method to estimate the final fibre micronaire following the impact of application of harvest aids was demonstrated. Second this information could be applied to predict the consequences of later harvest aid applications. Using the final micronaire predicted at the time of initial boll cutting (with an impending harvest aid application), adjustments of the final micronaire prediction could be made using functions reported in Bange et al. (2010) that estimate the change in final micronaire with percent open bolls. Finally if an instrument/approach that could estimate the maturity of bolls and or their fibre quality in the field can be reliably established these functions can be applied to estimate final quality with different management strategies applied at the end of the season.

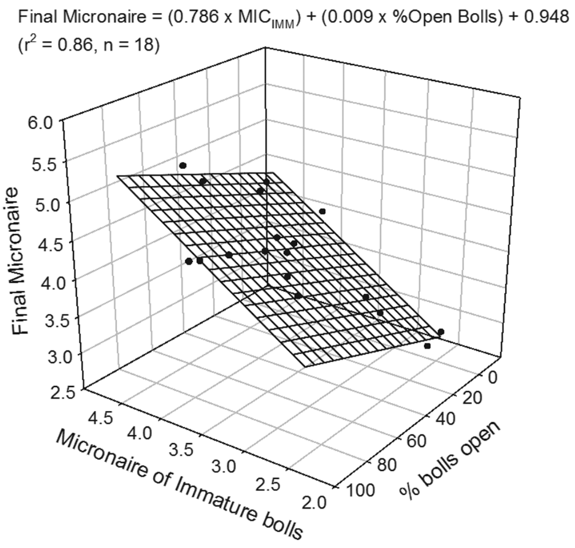


Figure 11: Response of final micronaire of the crop taken at harvest with micronaire of immature bolls and % open bolls at the time of harvest aid application. Published by Bange and Long 2011 in Agronomy Journal.

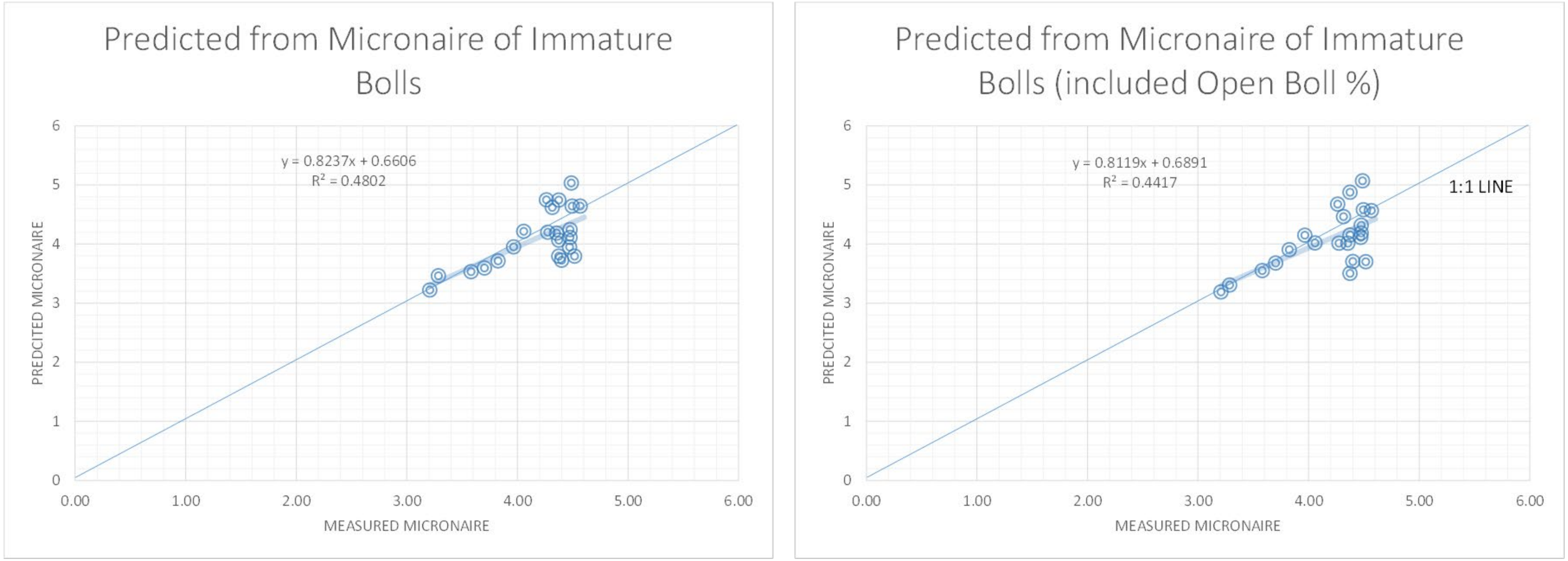


Figure 12: Measured versus predicted final crop micronaire predicted using previously published functions that relate fibre quality of immature bolls to final micronaire. This is new data collated in this project to validate the functions. Closer the points are to the 1:1 line the better the prediction.

Objective 5 *- Elucidate fibre properties that affect variation in yarn and fabric quality.*

The intention of this objective was to enable research to be undertaken examining areas that looked to measure different fibre properties, or to use alternative fibre measurement approaches, and the augmentation of cotton fibres via chemical alteration or blending with other fibre types, so as to improve the processing ability or performance of cotton fibre.

5.1 Assessing the influence of gin rib insert and gin saw configurations, and surface treatments, on fire risk, and some ginning production attributes (see Appendix A CSP1308 Student report A).

Summary

This work was conducted with the assistance of Mr Michael Robard from Arts et Métiers ParisTech, France. The ginning point in a gin rib is where cotton fibre is removed from the seed, and removable inserts at this point enable worn ribs to be upgraded. This work assessed different insert configurations (standard, v-cut CSIRO developed insert, with and without physical finishes), as well as different surface finishing treatments to gin saws (the circular rotating device that pulls fibre through the gin ribs). The aim was to examine how modifications to these machine components could reduce friction and fire risk, and their effect on gin turnout. Some significant outcomes of the work included:

- Friction coefficient values were determined for the surface of gin saws coated with Teflon, and with a knurling finish.
- A bond graph model and associated program was developed to simulate the temperature evolution and interaction between the interacting elements cotton, the insert, and rib.
- The thermal power generated as a function of either insert treatment or saw treatment was quantified.
- The best combination to minimise the amount of thermal power generated was a standard saw surface, and a Teflon coated standard shape rib insert.
- The combination of standard saw surface with Teflon coated ginsert, gave a 9% improvement in % gin turnout (49% turnout cf. the control 45% turnout).

5.2 Cotton cross-sectional properties for developing Upland and Pima cotton genotypes – this work contributed to an honours thesis undertaken by Mr Amitoj Singh at Deakin University (see Appendix B CSP1308 Student report B).

Summary

While pima cotton varieties are not popular in Australia due to significant yield penalties, research that helps to quantify and understand the fibre quality differences between upland and pima cotton will provide practical information for researchers developing new upland varieties, and management strategies to appropriately process such varieties, with finer (smaller perimeter, i.e. pima-like) fibre.

A glass house experiment conducted in the previously supported project allowed first position fruit to be harvested from individual cotton plants for a commercial upland variety (Sicot 71BR), a commercial pima variety (Sipima 280) and a new stronger un-released pima line 65221-2334. Fruit were harvested in 4-5 day intervals from approx. 25 days after first flower (DAFF) until approx. 50 DAFF. Fibre from fruit were subjected to analysis via the CSIRO Cottonscope instrument to measure maturity, fineness and a new parameter ribbon width.

While Cottonscope's two fibre maturity techniques could be compared (Birefringence Maturity Index and calculated Maturity Ratio) (data not shown), the average width of fibres was measured for the first time during fibre development (See Figure 13). Pima fibres were finer than upland fibres, which changed little up until 40 DAFF at which point average fibre width decreased (for all three varieties). This is attributed to the narrowest view of fibres increasing and the widest view of fibres decreasing as fibres fill. Fibre width, albeit affected by a combination of perimeter and maturity, is a unique measure that is likely to contribute to understanding how fibres pack together and interact together in a yarn structure.

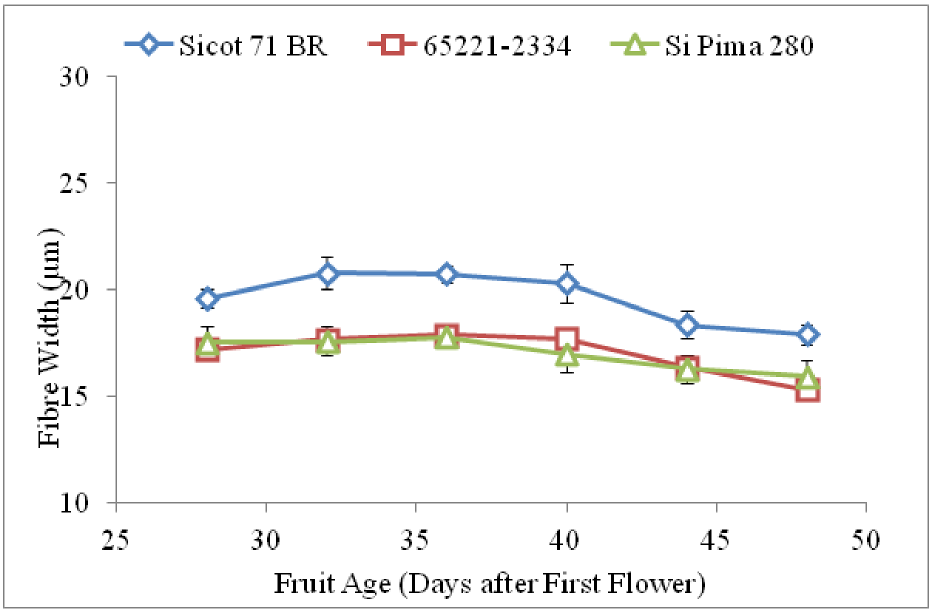


Figure 13: Fibre width at varying fruit age for first position fruit harvested from Sicot 71 BR, Pima 65221-234, and Si Pima 280.Values are average fibre width, and standard deviation for 3 fruits per cultivar per harvest (fruit age).

The fibre width measurement offered by the Cottonscope allows a full width distribution to be captured, which will be affected by a combination of natural perimeter variation (minimal and genetically pre-determined), and as affected by the variation in the field of view of each fibre snippet; which randomly captures either a thin, thick, or somewhere in between, portion of the width of each snippet. This will be highly influenced by the degree of circularity (or ellipticity) of fibres which is influenced by fibre maturity.

Thus an estimation of the shape (ellipticity) of developing cotton fibres was calculated. Theoretical populations of data were contrived by mathematically assessing the width distribution of ellipses changing in the degree of ellipticity across 90 degrees in single degree increments, and then defining the relationship between the degree of ellipticity and the coefficient of variability (CV) for these populations (Figure 14).

Actual cotton fibre width CV values from developing fruit were used in conjunction with the theoretical relationship quantified in Figure 14 to calculate the degree of ellipicity of cotton fibres during development. All varieties had similar ellipicity until 35 DAFF, from which point the upland variety became markedly less elliptical than the pima varieties which were similar to each other (Figure 15). This also indicated that fibres of the pima varieties didn’t ‘fill out’ or mature to the same degree compared to the upland variety.

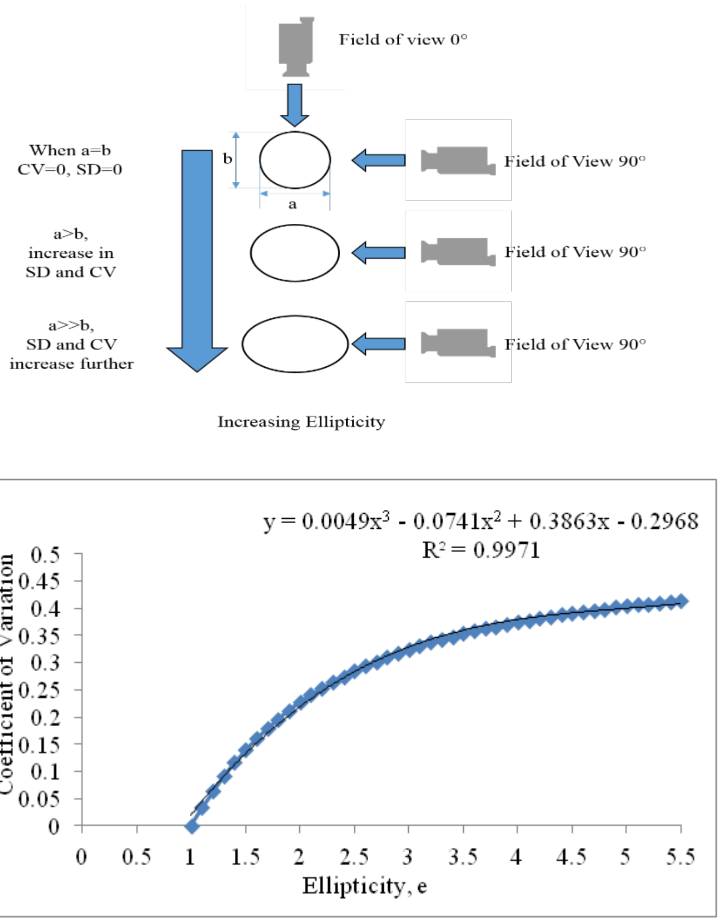


Figure 14: Diagrammatic representation of the different field of view of theoretically changing ellipses, and the relationship between the degree of fibre ellipticity and the normalised error (CV) across different fields of view (in one degree increments across 90 degrees).

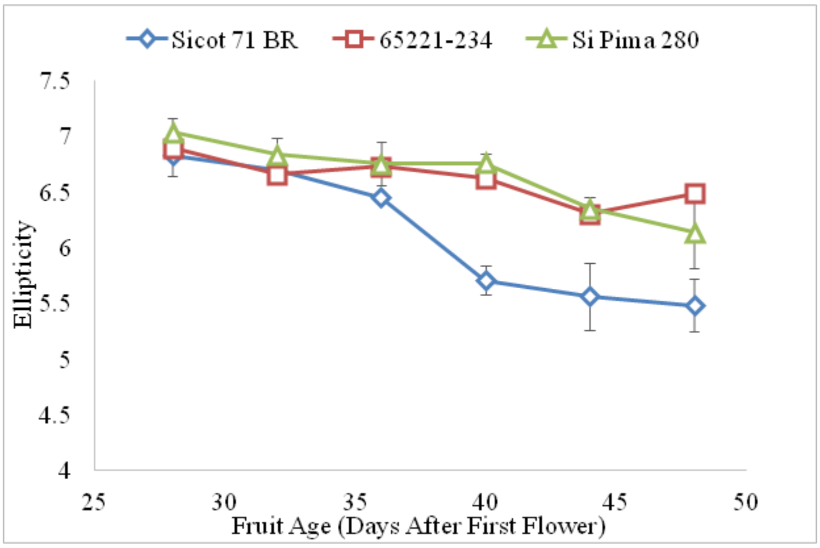


Figure 15: Cotton fibre ellipticity at varying fruit age for first position fruit harvested from Sicot 71 BR, pima breeding line 65221-234, and Si Pima 280.Values are average ellipticity, and standard deviation for 3 fruits per cultivar per harvest (fruit age).

5.3 Assessing the wet processing of low wax cotton fibre. This work was conducted with the assistance of Ms Marianne Sivet from the Ecole Nationale Supérieure de Chimie, de Biologie et de Physique, France (see CSP1308 Student report C)

Summary

The work utilised traditional caustic cotton scouring techniques and alternative enzymatic scouring methods, to scour raw cotton fibre. Currently the wax layer on the surface of cotton acts as a lubricant during processing, but is also a barrier to effective dyeing. The intention was to augment the surface chemistry of cotton with in-mind a potential future cotton that might be developed that has low or modified wax to make fabric scouring cheaper, easier, or to be avoided during cotton fabric dying and finishing.

5.4. This work was conducted with the assistance of Ms Albane Birault from the Ecole Nationale Supérieure de Chimie, de Biologie et de Physique, France. It continued characterisation work of fibre scoured with traditional and enzymatic methods (see Appendix D CSP1308 Student report D).

Summary

Further fibre characterisation of both traditionally de-waxed caustic scoured fibre and alternative enzyme scoured fibre has been undertaken. The general premise of this is to emulate a 'low wax' cotton alternative; currently cotton fabric needs to be scoured under boiling conditions to remove a significant portion of the outer hydrophobic wax layer to allow dye uptake into the fibre. This work is aimed at understanding more comprehensively the science of cotton wax. While work to date has been conducted within this project, results are the pre-cursor to a new CRDC PhD project about cotton wax.

For example traditional caustic scoured (TS) cotton HVI micronaire tended to be lower than the untreated control, while enzyme scoured (ES) cotton was higher than the control (Table 20). This demonstrates that subtle fibre surface differences can effect an air-flow quality measure like micronaire, allow the chemical treatments didn't effect fibre density as measured by gas (helium) pycnometry (Table 1). Scouring also markedly effected the ability of fibre to retain moisture and or for fibre cellulose to absorb the same amount of moisture as control fibre. Further work looking to understand this phenomenon would be useful considering that cotton moisture cotton (or 'regain') is related to the superior comfort ratings that are made for cotton in comparison to polyester.

Table 20: Some HVI properties and gas pycnometer density results for traditional caustically scoured (TS) and enzyme scoured (ES) fibre.

Treatment	Micronaire	Gas pycnometer density g/cm^3	Moisture content (%)
Control	4.45	1.68	8.22
TS 0.5 g/L 30min	4.34	1.66	6.40
TS 0.5 g/L 120min	4.32	1.67	5.78
TS 2.5 g/L 30min	4.44	1.68	5.35
TS 2.5 g/L 60min	4.37	1.68	5.11
TS 2.5 g/L 120min	4.33	1.67	5.47
ES1 1 g/L	4.45	1.68	5.28
ES1 4 g/L	4.54	1.67	5.57
ES1 7 g/L	4.51	1.67	5.32
ES2 2.5 g/L	4.55	1.69	5.24
P	**	n.s.	***
SED	0.04		0.31

Fourier-transform infrared (FT-IR) attenuated total reflectance (ATR) spectroscopy measurements highlighted changes in the main impurities by characterizing the carboxyl acids and esters that are present in pectins and waxes, which do not exist in the cellulose structure. For example in the spectrum of raw cotton fibre two distinguished peaks correspond to the symmetric and asymmetric stretching mode of methylene groups (-CH2 group) in a long alkyl chain which is clearly visible at 2852 and at 2918 cm^{-1}, respectively (Figue 16). In spectra of both conventional caustic scoured and enzyme scoured cotton fibres these peaks are not evident, which indicates wax removal due to the treatment. Similarly, the spectrum of raw cotton showed a small absorbance band of C=O stretch at 1749cm^{-1} (data not shown), which indicates free fatty acids and cutin of wax and free and esterified carboxylic groups of pectin.

In the case of scoured treated fibres it was only represented as a weak absorbance, indicating removal of these impurities.

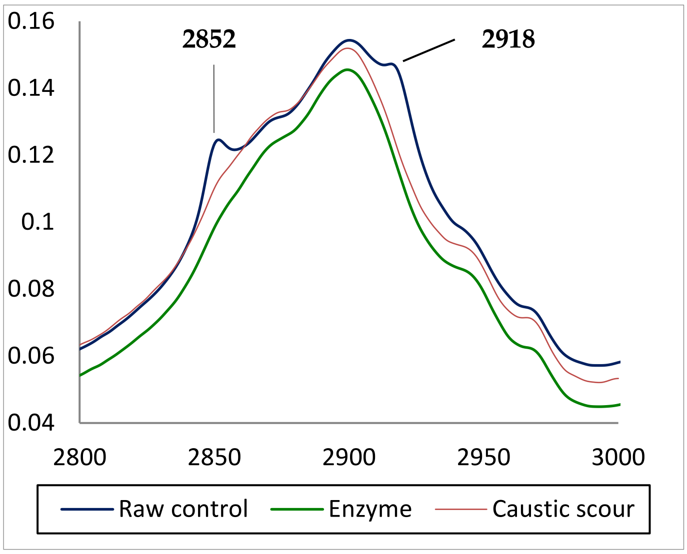


Figure 16: FT-IR ATR spectra showing absorbance (A on y axis) at wavelength 2800 – 3000 cm^{-1} (x axis), for raw untreated cotton, enzyme scoured and traditionally caustic scoured cotton fibre.

Intellectual Property register

No changes are required to the Intellectual Property register.

Extension Opportunities

Where applicable research undertaken in this project has been included in the edited version of FIBREpak. The exact form of a revised delivered version of FIBREpak is yet to be decided.

List the publications arising from the research project

Peer reviewed papers

van der Sluijs, M.H.J., Long, R.L. (2016) The effect of seed cotton moisture during harvesting on - part 1- fiber quality. Textile Research Journal 86, 1925-1934.

van der Sluijs, M.H.J., Long, R.L., Bange, M.P. (2015) Comparing cotton fiber quality from conventional and round module harvesting methods. Textile Research Journal 85, 987-997.

Long, R.L., Bange, M.P., Delhom, C.D., Church, J.S., Constable, G.A. (2013) An assessment of alternative cotton fibre quality attributes and their relationship with yarn strength. Crop & Pasture Science 64, 750-762.

Bange, M.P., Long, R.L. (2013) Impact of harvest aid timing and machine spindle harvesting on neps in upland cotton. Textile Research Journal 83, 651-658.

Industry extension and conference publications

Long, R. (2016) New small sample spinning technology at CSIRO Geelong. The Australian Cotton Grower, June-July pp.62-64.

van der Sluijs, R., Long, R. (2016) The effect of seed cotton moisture on fibre quality during harvesting. The Australian Cotton Grower, April-May pp.56-59.

Long, RL., Bange, MP. (2015) Management for premium cotton fibre. Proceedings of the 17th Australian Society of Agronomy Conference, 20 – 24 September 2015, Hobart, Australia. Web site (http://www.agronomy2015.com.au/papers/agronomy2015final00396.pdf). Peer reviewed conference proceedings.

van der Sluijs, R., Long, R., Bange, M. (2015) Fibre quality in traditional and round module harvesting systems. The Australian Cotton Grower, April-May pp.46-47.

Long, R.L., Bange, M.P., Delhom, C.D., Church, J.S., Constable, G.A. (2014) Alternative cotton fibre quality attributes – tensile properties. The Australian Cottongrower 35 (no. 4): 40-43.

Long, R.L., Bange, M.P., Delhom, C.D., Church, J.S., Constable, G.A. (2013) An assessment of alternative cotton fibre quality attributes and their relationship with yarn strength. Proceedings of The Fiber Society Spring Technical Conference, Geelong: p.117.

Long, R.L., Bange, M.P., Delhom, C.D., Church, J.S., Constable, G.A. (2013) An assessment of alternative cotton fibre quality attributes and their influence on yarn strength. Beltwide Cotton Conferences, San Antonio, Texas, January 7-10. p. 803.

Bange, M.P., Long, R.L. (2013) Impact of defoliation timing and machine spindle harvesting on neps in cotton. The Australian Cottongrower 34 (no. 4): 43-45.

Bange, M.P., Long, R.L. (2013) Impact of defoliation timing and machine spindle harvesting on neps in cotton. Beltwide Cotton Conferences, San Antonio, Texas, January 7-10. pp 902-903.

Online Resources

Research undertaken in this project has contributed to the development and enhancements to the micronaire predictor tools as part of the CottASSIST web tool suite.

https://www.cottassist.com.au/Micronaire/Micronaire.aspx

The project successfully captured interactions between cultivar (genetic) x season (environment) x field management x post processing (ginning) variables. It demonstrated that targeted irrigation at flowering in combination with growth regulator applications, affected fibre length and the amount of entanglements (neps) in cotton lint. It also showed that the level of trash (leaf matter) in ginned cotton had a strong influence on colour grades and premium and discount levels, compared to other fibre quality parameters which played a more important role in determining yarn performance. While 'premium' cultivars have relative merits for some markets, the typical negative association between higher quality and lower fibre yield, was supported, with yield ultimately having the largest influence on production gross margins. Further, a fully integrated operation (e.g. controlling farm, gin, mill) would potentially benefit by producing more premium fibre with less intensive ginning. A novel management approach for influencing fibre quality was also assessed. A field experiment that used the growth regulator ethephon was used to remove fruit to shift the timing of the fruiting period. The approach was successful in influencing quality and shows promise for moving the fruiting period to improve quality in stressed environments.

Micronaire is a combined measure of fibre fineness and maturity and significantly influences the valuation and performance of cotton. New research was able to better define the environmental and genetic influences that effect fibre perimeter (inherent fineness), and better models for micronaire were developed, which in-turn allowed better predictions for neps. In addition, the boll cutting technique was validated, which assisted in understanding the influence that defoliation has on fibre quality. In light of this, the 'CottASSIST' on-line management tool was updated to: 1. Improve the predictability of micronaire from average temperature during the boll filling period. 2. Estimate the neps risk linked to the predicted final micronaire generated by the micronaire predictor. 3. Situations where total neps are greater than 250 neps/g are flagged. 4. Highlighted the impact of changes in defoliation timing on final micronaire and neps, and 5. Predict the impact of lint cleaning passages on nep level. The last effective flower tool was updated to highlight risks of delaying cutout on the time for the last harvestable boll to mature in time for harvest.

Some new sensor technology and portable instruments were listed and reviewed that had potential to assist in measuring crop status components to be subsequently used in modelling fibre quality. This was undertaken to assist in the development of future project ideas. Linked to this outcome we were able to properly validate techniques that estimated fibre quality at maturity as well as identifying the risk of neps at defoliation.

Research assessing some modifications to gin saws and the removable rib inserts, showed that a standard saw surface finish in combination with a Teflon coated CSIRO v-shaped modified insert, improved gin out-turn.

Using cotton fibre width ('ribbon width') data collected by the Cottonscope instrument enabled the modelling of the change in fibre ellipticity for developing Upland and Pima cottons. This gives new insight into how cotton fibre pack together in a yarn structure, and how these new objective data form Cottonscope can contribute to predicting the processing performance of cotton.

The natural wax layer on the surface of cotton is an impermeable barrier that needs to be caustically scoured to allow effective dyeing. Significant work was undertaken characterising this wax.

A review of the FIBREpak book was undertaken and areas of improvement identified. Research undertaken in this project was also included for a potential republication.

For more information about this research please contact: Dr Mike Bange (Michael.bange@csiro.au) or Dr Robert Long (Robert.long@csiro.au).