



FINAL REPORT

Part 1 - Summary Details

Cotton CRC Project Number: 4.02.01

Project Title: Linking Farming Systems to Fibre Quality and Textile Performance

Project Commencement Date: 01/07/2006 **Project Completion Date:** 30/06/2009

CRC Program: The Product

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Background

Australian cotton is purchased for a premium on the basis of quality and consistency. However, coarse (high micronaire) fibre, high nep counts and excessive short fibre are industry concerns. Quality is affected by many interacting factors e.g. variety, seasonal conditions and crop and harvest management. Appropriate varieties, management for each region's climate, and processing to minimise damage to fibre are opportunities to improve fibre quality. Through a significant combined research effort this project aimed to optimise cotton fibre quality of Australian cotton by: direct influences of on-farm agronomic management and climate on fibre development; and post-harvest research that investigated the degree of these influences on textile performance in the mill.

The project was initiated in July 2006 and Robert Long (Post Doctoral Fellow) was appointed soon after to primarily undertake post harvest research on fibre quality linked to research on climate and management. During the first year of this project a concurrent project titled 'Cotton Crop Management for Improved Fibre Quality' was supported to investigate management and climate effects on fibre quality. This project was finalised in June 2007. Following this, a decision was made to combine both the in-field and post harvest research activities into a single project that is reported here. Consequently the project objectives and milestones were reviewed at the time and adjusted accordingly. This document therefore reports on three years of post harvest research and only two years of specific in-field research activities.

Project Aims and Objectives

The project aimed to optimise cotton fibre quality and enhance 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 investigated the degree of these influences on textile performance in the mill.

Specific aims were:

1. Targeted research to improve the understanding of the effects of different climate, and crop management factors on fibre quality (specifically micronaire and neps), and how textile performance in the mill may influence crop management recommendations.
2. Utilise agronomy and physiology research tools such as OZCOT simulation to integrate research results and so develop regionally specific management guidelines to optimise yield and fibre quality.
3. Identify linkages between on farm parameters and fibre quality from a textile perspective.
4. Extend and strengthen agronomic research from this project by means of the 'Field to Fabric', BMP and FIBREpak initiatives.

Table 1: Project objectives and milestones are summarised in the table below:

| Objective | Milestone | Performance Indicator | Achieved |
|---|--|--|--|
| Develop understanding of the degree that management impacts on micronaire | Undertake field experiments in different regions that compare sowing time, plant size, boll load variety and their interactions. | Completed four field experiments across regions, results analysed and documented. Relationships between climate and fibre properties established in OZCOT. | ✓ Season 2008/09 fibre quality samples are still being processed. |
| Improve understanding of the impact of management and climate on fibre fineness | Undertake a small pilot glasshouse experiment that investigate the impact of temperature on initiated fibre fineness | Completed one experiment, results analysed and documented. | ✓ Experiment investigated development of fibre maturity of two cotton species with the use of SiroMat. |
| Validate management guidelines to limit neps from the field. | Undertake field experiments that validate management approaches that define the number of immature bolls that cause unacceptable levels of neps in cotton samples. | Completed field experiments, results analysed and documented. | ✓ |
| Collect information that can be used to promote Australian cotton as a premium commodity to meet market needs and can be used for extension and education purposes. | Undertake micro-spinning and fabric manufacturing at Geelong of cotton collected from field studies. | Cotton processed and fabric manufactured. Results analysed and documented. | ✓ |
| | Complete fibre testing of samples using HVI, AFIS, Cottonscan & SiroMat. | Samples tested, results analysed and documented. | ✓ |
| | As appropriate, undertake larger scale (one bale lot size) spinning/processing trials to scale up promising results from micro-spinning trials. | Cotton processed and fabric manufactured. Results analysed and documented. | ✓ Some processing of samples still occurring |
| Communicate results of studies to scientific community and industry | Publish articles and participate in conference and/or industry presentations | 2 journal articles, 2 cottongrower articles, at least one major industry presentation per year, participate in fibre to fabric course. | ✓ |
| Improve management guidelines to maintain fibre quality | Update FIBREpak guidelines and BMP information | BMP guidelines aligned to information provided in FIBREpak | ✓ |

Project Methodology

The on-farm component of this research sought to: i) Derive a better understanding of the effects of crop management and climate on micronaire. Field experiments in a number of regions were used to quantify the interaction of management practices that affect micronaire (region x variety x sowing time x plant size x boll load). ii) Identify if environmental effects influence fibre fineness. iii) Validate crop management guidelines for neps reduction through on-farm experiments. iv) Extend research findings through involvement in Field to Fabric, BMP, and FIBREpak initiatives and contribute to the fibre simulation capabilities of the OZCOT crop simulation model.

The post-farm textile performance research linked to the in field research sought to: i) Investigated fibre quality from field experiments that varied agronomic practices and varieties by utilising HVI measurements with new fibre instrumentation at CMSE including the AFIS PRO, Cottonscan, and SiroMat. ii) Identify relationships between fibre, yarn, and fabric from cotton taken from field experiments that varied agronomy and variety that can suggest textile quality or performance that are not revealed by HVI alone. iii) Assess performance of current, and potential elite cotton varieties in meeting textile performance criteria. iv) Reinstated the use of micro-spinning technologies for assessing current and future comparisons of cotton fibre taken from a range of agronomy and variety experiments for textile performance.

Results and Outcomes

Results and outcomes from this project are summarised below under major heading associated with specific project objectives. Where research has been published the appropriate reference in the list of publications is given.

Develop understanding of the degree of management impacts on micronaire

In recent years spinners have complained about the high micronaire, short fibre and high neps of Australian cotton. A series of warm dry seasons coupled with intensive management for high yield of high retention crops such as Bollgard II® has led to many circumstances of high micronaire. In the four harvests up to 2007 an average of 41% of the crop had micronaire values between 4.6 and 4.9, with another 6% above micronaire 5.0 (ACSA 2007). Analysis has indicated that management, varieties and high temperature have been significant components of that result (Kelly et al. 2006). The balance between boll load and crop canopy size can be significant, with high boll loads having lower micronaire (more desirable in this case), presumably from competition (Brook, Hearn and Kelly, 1992; Kelly, Bange and Constable, 2006).

Micronaire is definitely a complex trait, but management can help to address the problem. A variety with inherently lower micronaire (preferably fine and mature) is required. Our research hypothesis is that to achieve mid range micronaire (3.8 - 4.5), crop management to optimise agronomic inputs such as water, fertilizer and growth regulators should manage vegetative growth in balance with boll setting pattern, by using a variety with appropriate plant type for the region and climate; and sow on the appropriate date for the variety and climate to avoid boll filling of early crops in hotter periods or late crops in cooler periods.

Management packages tailored to optimise micronaire across regions and specific climates are required. This project is part of an initiative to explore the potential of crop management specifically targeted at current challenges such as micronaire, neps and short fibre. A series of experiments were conducted to assess and quantify the ability to manipulate micronaire.

This information will help develop management strategies that can help meet fibre micronaire (fibre maturity/fineness) targets.

Specifically experiments were undertaken to develop better understanding to what degree fibre micronaire can be manipulated in different climates by measuring the effect and interaction of:

- Choice of variety (Inherent high and Inherent Low)
- Sowing date (temperature during boll filling)
- Plant size during boll development
- Boll load

Methods

During the course of the project five field experiments were conducted. Two large scale experiments were conducted over two seasons at Narrabri, while three smaller experiments were conducted in collaboration with Cotton Seed Distributors in Goondiwindi, Moree and St George.

The treatment utilised in the full experiments conducted in Narrabri were:

- 3 x Varieties – Sicot 71 BR (Average Micronaire 4.7).
Sicot 70BRF (Average Micronaire 4.2).
Sicot F-1BRF (Average Micronaire 4.1).
- 2 x Sowing Times – Normal (Around 1st October).
Late (Late October to early November).
- 6 x Crop Manipulations – Normal Plant size (no fruit removed).
Normal Plant size (half fruit removed).
Large Plant size (no fruit removed).
Large Plant size (half fruit removed).
Small Plant size (no fruit removed).
Small Plant size (half fruit removed).

An increase in plant size (larger leaf area index) was attempted by tipping out plant prior to first square and the use of the Sicot F-1BRF variety. A smaller plant size was achieved by utilising Mepiquat Chloride (PIX) applied around early flowering.

The experiment conducted at the other sites only used one variety (Sicot 70BRF) and utilised a single sowing. This report will only report on the large scale experiment conducted in the first year in Narrabri. Due to delays associated with the HVI problems at ACRI samples for the other sites and years are only now being processed.

Results and Discussion

In the first year of experiments in Narrabri sowing time, variety, manipulation of plant size, and fruit removal all significantly affected micronaire (Table 2). Yield was also significantly affected by sowing time, variety and fruit removal, but not from manipulation of plant size (Table 2). There were no significant interactions between the variables for both micronaire and yield. As expected: sowing time substantially delayed sowing time reduced micronaire and yield; variety differed; and removal of fruit increased micronaire but lowered yield. Unexpectedly however, the smaller plant size raised micronaire. Only Sicot 70BRF had higher micronaire when the plant size was reduced. A second season of data is needed to confirm this response.

Table 2: Summary of the effect of sowing time, variety, manipulation of plant size and fruit removal on micronaire and yield in the first experiment conducted in Narrabri.

| Treatment | | Micronaire | Yield (kg/ha) |
|---------------|----------------|------------|-----------------------------|
| Sowing Time | Normal | 4.05 | 2678 |
| | Late | 3.92 | 2217 |
| Variety | Sicot 71BR | 4.30 | 2529 |
| | Sicot 70BRF | 3.84 | 2549 |
| | Sicot F-1BRF | 3.49 | 1920 |
| Plant Size | Small (pix) | 4.15 | Not significantly different |
| | Normal | 3.88 | |
| | Large (tipped) | 3.99 | |
| Fruit Removal | None | 3.91 | 2871 |
| | Half | 4.06 | 2036 |

Future work will involve combining data collected from all sites and years once fibre quality analyses (including fibre maturity with SiroMat and linear density/fineness with Cottonscan) are completed. This will assist in developing responses that reflect changes in micronaire to management and environmental impacts that change fruit number with changes in plant size (leaf area). This knowledge will also help in the development of a fibre quality routine for the OZCOT crop simulation model that will predict influences of changes in management and effects of climate change/variability.

Assess differences in the development of fibre maturity of two cotton species with SiroMat

A large glasshouse experiment was undertaken to better understand the development of fibre maturity of cotton species. This could be undertaken in detail because the SiroMat instrument that measures fibre maturity ratio could handle small samples taken from individual bolls. This research has been published in the Textile Research Journal (Publication No. 3) and is best summarised in the abstract taken from the paper below:

‘Cotton fibres are trichome cells composed primarily of cellulose. Mature fibres have more cellulose and a greater degree of cell wall thickening, and perform better than less mature fibres during textile processing. An automated polarized light microscope instrument called Siro- Mat that measures cotton fibre cell wall thickening was employed to assess the maturity of developing fibres from single cotton fruit. Fruit were taken from the first fruiting branch and position on glasshouse grown *Gossypium hirsutum* L. (Upland) and *G. barbadense* L. (Pima) plants, sequentially harvested from 24 days postanthesis (dpa) at approximately four-day intervals up until approximately 50 dpa. The instrument assessed an average of 13,000 fibre snippets per fruit. Upland fibres matured at a slower rate than Pima fibres up to 35 dpa. However, after 45 dpa Upland fibres had achieved a higher average maturity (i.e. 0.99 birefringence maturity index (BMI), cf. 0.79 for Pima) (Figure 1). For both species the uniformity of fibre maturity increased as fibres matured up until 35 dpa for Upland and 29 dpa for Pima (i.e. the BMI coefficient of variation decreased as BMI increased during fruit development) (Figure 2). It is envisaged that SiroMat will be a useful tool in helping to

understand and manage fibre maturity by characterizing the maturation dynamics of varieties with different inherent fibre properties, and for varieties subjected to different environmental and agronomic conditions.'

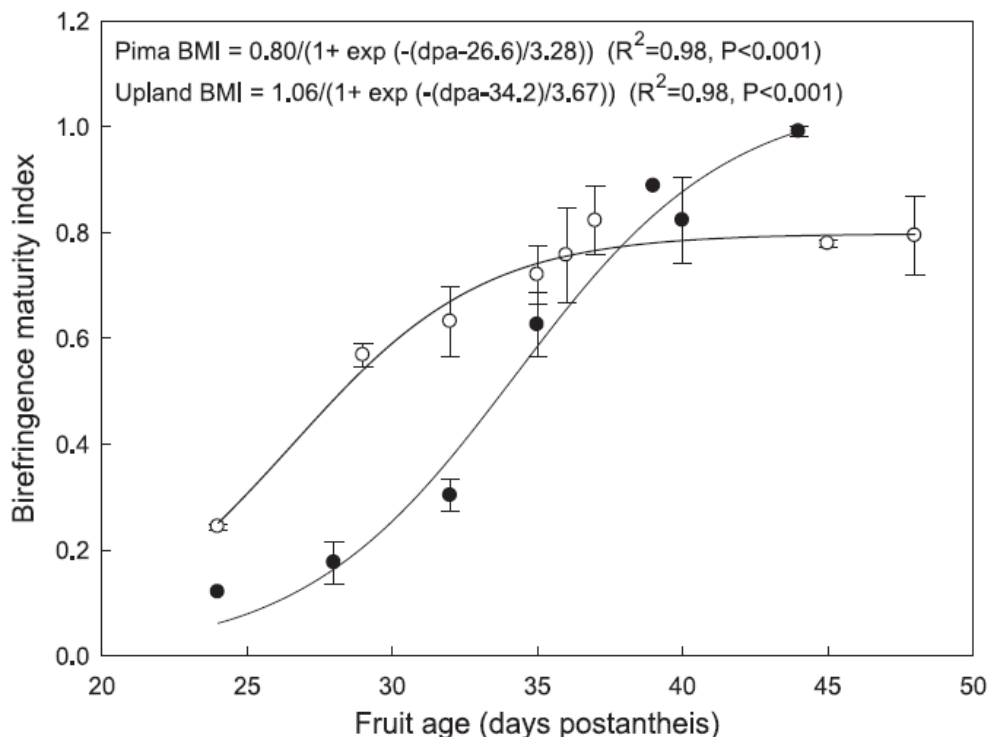


Figure 1: Cotton fibre birefringence maturity index (maturity ratio) for first position fruit from glasshouse grown Upland (●) and Pima (○) plants following flowering (anthesis). Values are mean ± standard deviation of two SiroMat measurements taken on each fruit.

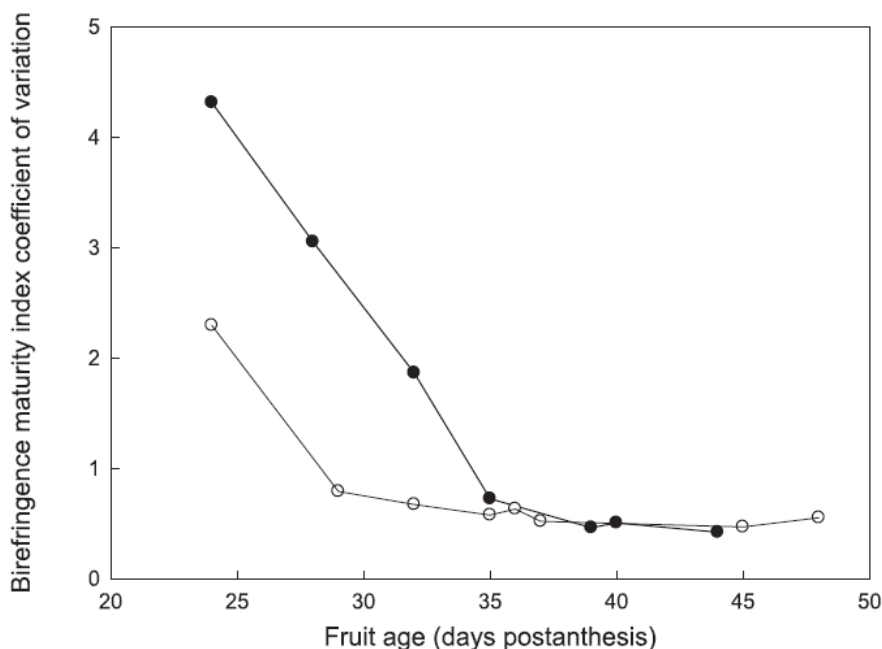


Figure 2: Birefringence maturity index coefficient of variation of first-position fruit from glasshouse grown Upland (●) and Pima (○) plants. This value reflects the variation in maturity of the fibres in the sample. A higher value means there is greater variation in the maturity of fibres at the time of sampling.

These experiments will be repeated to confirm the differences between the species and assess the development of fibre maturity of other Australian varieties.

Validate management guidelines to limit neps from the field

During the course of this project three field experiments over three seasons were conducted to quantify the effects of early harvest preparation on the level of fibre immaturity and neps. The study's objectives were:

- To quantify nep levels caused by early harvest aid applications, and relate these levels to measurements of crop status at the time of application.
- To assess the effects of lint cleaning (after ginning) and establish if there were substantial increases in neps when extra lint cleaning passages were used on cotton that was more immature.
- To assess the textile performance of samples collected from cotton that had increased immaturity and neps from earlier harvest aid treatments.

Crop Management and Lint Cleaning Effects on Neps

This research has been written up for submission in the 'Agronomy Journal' (Publication No. 2) and is best summarised in the abstract taken from the paper below:

'Substantial amounts of immature cotton fibres and neps (small entanglements of cotton fibres associated with immature and/or fine fibre) in ginned cotton will affect textile quality. While penalties to growers are incurred for low micronaire (a measure of fibre linear density and maturity) there are rarely penalties for high neps, however their presence in cotton at spinning mills can affect overall industry reputation. In field studies over three seasons, the timing of harvest aid applications was systematically varied on maturing cotton crops to generate different amounts of immature fibre and neps. Earlier harvest aid treatment increased neps and was best related to fibre linear density ($r^2 = 0.78$) (Figure 3). The effects of these harvest aid treatments were then related to measures of crop status at the time of harvest aid application. Quantitative relationships of changes in yield and fibre quality (micronaire, maturity ratio, linear density, and neps) to % open bolls, number of immature bolls, % immature bolls, and % immature lint mass at the time of harvest aid application were developed. Each crop status measurement used in this study explained changes in yield and fibre properties, although the % immature bolls measure utilizing the boll cutting technique to assess the maturity of bolls predicted ($r^2 > 0.67$) the effects of harvest aid timing and can be applied when crops are non-uniform in their maturity, and when they contain fruiting gaps (Figure 4). Relationships that predicted the effects of additional lint cleaning passages on nepping potential with crop status were also developed and captured the effect of an interaction between earlier harvest treatments (with substantial immature lint) and lint cleaning (Figure 5). On average across experiments an additional lint cleaning passage contributed between 95 and 141 count g^{-1} more neps, while a second passage added between 101 and 181 count g^{-1} more neps. On the basis of yield, micronaire, fibre maturity and neps, the results in this study supported the current recommendation of applying harvest aids at 60% in uniformly maturing cotton crops, and showed both yield and quality attributes were consistently reduced prior to 60% open bolls. 60% open bolls were analogous to 4.4 Nodes Above Cracked Boll (NACB), 45 immature bolls m^{-2} , 29% immature bolls, and 24% immature lint mass. It is anticipated that this information may be used to refine crop monitoring and harvest preparation strategies (utilizing a range of approaches) that aim to optimize both lint yield and fibre quality (including the reduction in neps).'

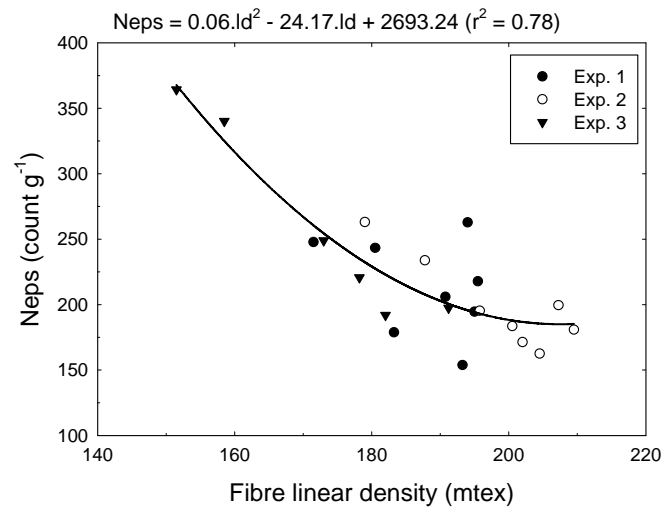


Figure 3: The relationship that predicts the levels of neps (with no lint cleaning) with fibre linear density (ld).

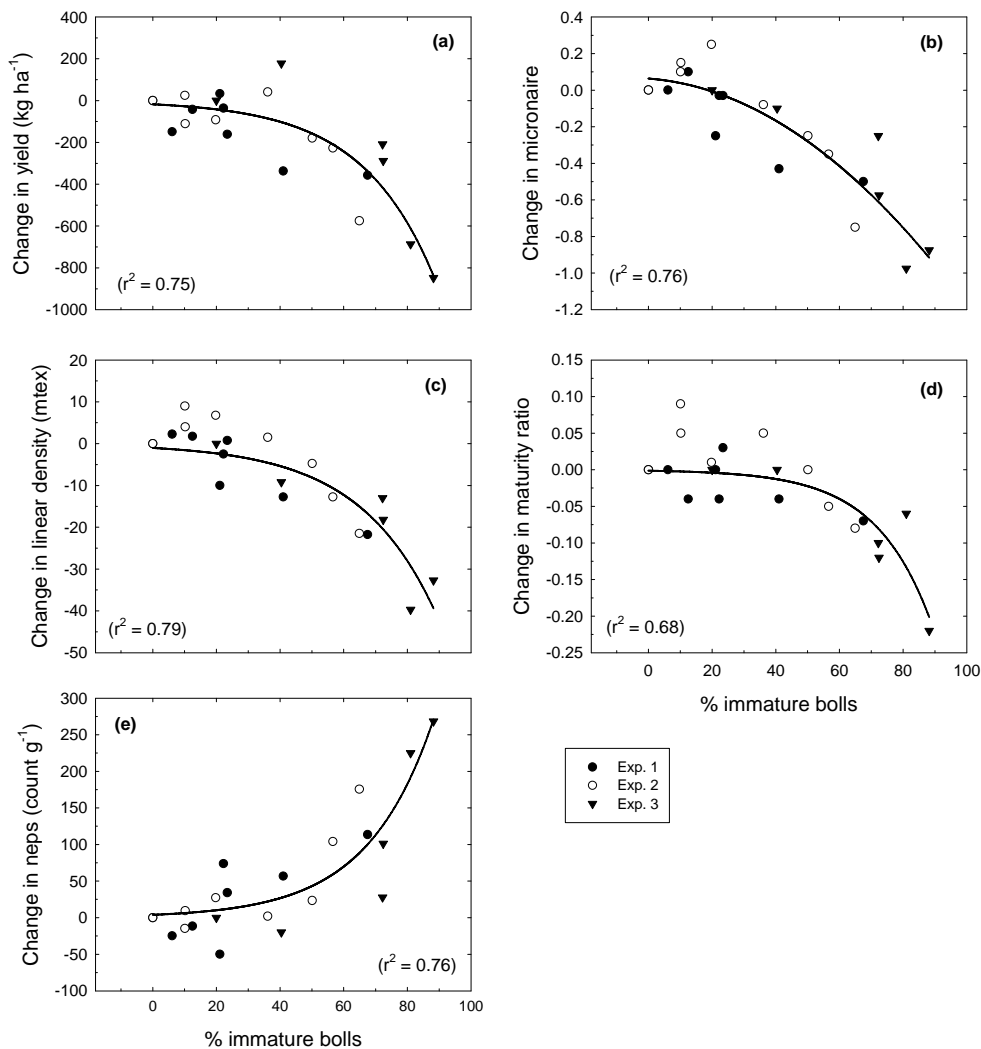


Figure 4: An example of response of changes in (a) lint yield, (b) micronaire, (c) linear density, (d) maturity ratio, and (e) neps with crop status (% immature bolls) at harvest aid treatment across all experiments (Exp.). The change in variable is calculated as the change from the control harvest aid treatment for each experiment. Nep change is for one lint cleaning passage.

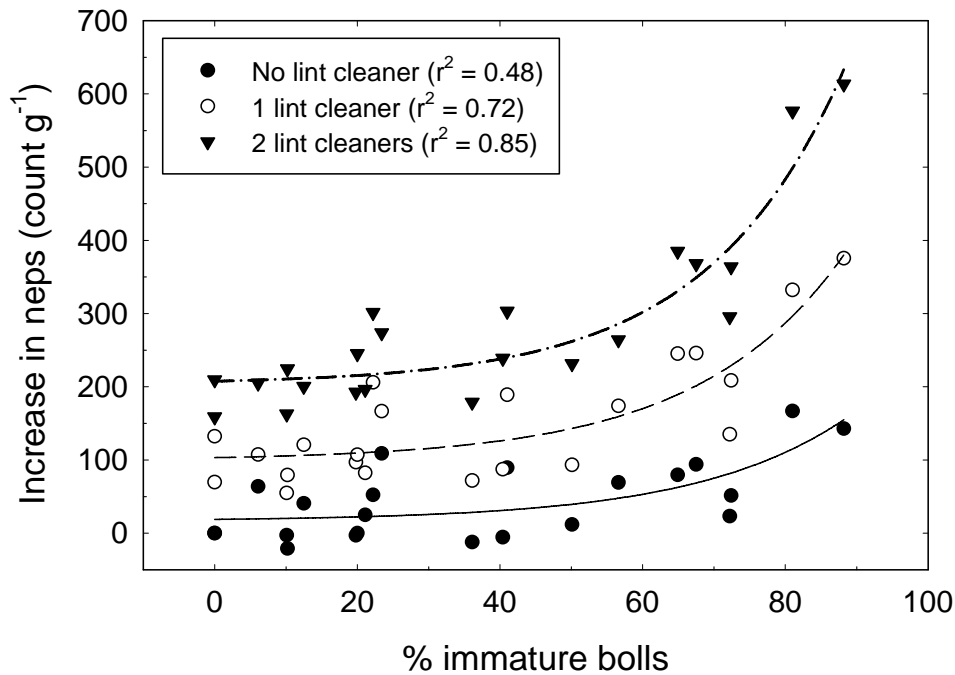


Figure 5: An example of the response of change in lint neps with crop status at harvest aid treatment associated with different numbers of lint cleaning passages across all experiments. Change in neps is calculated as the change in neps from the control harvest aid treatment with no lint cleaning for each experiment.

Future research is assessing the approaches used in this study with crops that have fruiting gaps. Results of this study have also been published in FIBREpak. Preliminary investigations of these impacts on textile performance will now be discussed.

Crop Management Affecting Neps and Textile Performance

Initial investigations (only results from Experiment 1 described previously) have been written up for the Beltwide Cotton Conference (Publication No. 7) and an Australian Cottongrower magazine in 2008.

Methods

Fibre samples collected from the field studies described above are being manufactured into yarn, then knitted and dyed.

One hundred and sixty eight grams (4 x 42 g lots) of machine harvested ginned lint (not lint cleaned) were sub-sampled from each experimental sample and subjected to the microspinning (details provided in the next section of this report). One yarn bobbin per sample was tested for count, twist, evenness and imperfections (Uster tester 4-SX), and tensile properties (Uster Tensorapid 3).

Following this yarns were knitted with a cover factor of 1.32 (a tightness factor of 15.4 mm⁻¹) on a Lawson Hemphill 10 Inch F.A.K. knitting machine. Knitted fabric was scoured and dyed with Cibacron blue LS3R (1%) reactive dye. Reflectance colorimetric measurements were taken of fabrics using a Gretag Macbeth Color-Eye 7000A spectrophotometer. Three measurements were acquired per experimental sample. Colour differences between the dyed

fabric samples were measured in terms of ΔE , which describes the mathematical distance between two colours, where 1 in this case is the control harvest aid treatment (100% open bolls). We identify ΔE values near or greater than one between any two fabrics here as being significant on the basis of the monochromatic nature of the dyed samples and the fact that in industry the samples would be viewed side-by-side as adjacent bands in knitted fabric.

Results and Discussion

No significant differences were noted across treatments for important yarn performance parameters such as yarn irregularities, imperfections and tenacity (Table 3). For fabric dye uptake analysis, early treatments (at 29% and 42% open bolls) displayed ΔE values greater than 1, which was in-line with these two early treatments having significantly more positive b^* (blue to yellow reflectance) values than later treatments (Table 4). This change in the intensity of b^* is corroborated by a reasonable linear relationship between the timing of harvest aid application and b^* ($R^2 = 0.69$) (Figure 6). More mature fibres will have absorbed more blue dye molecules and thus appear a more intense blue hue indicated by a more negative b^* value.

Table 3: Spinning results for cotton subjected to different harvest aid treatments: percent loss during miniature carding, yarn evenness and imperfections, and yarn strength attributes for carded 20 tex ring spun yarns. Values are the average of 4 replicates.

| Harvest aid treatment (% open bolls) | Card loss (%) | CVm% | Thin -50% | Thick +50% | Neps +200% | Elongation (%) | Tenacity (cN/tex) |
|--------------------------------------|---------------|------|-----------|------------|------------|----------------|-------------------|
| 29.2 | 14.0 | 17.3 | 15.0 | 408.1 | 326.9 | 5.6 | 14.7 |
| 41.9 | 13.8 | 18.1 | 50.0 | 516.3 | 371.3 | 5.7 | 15.1 |
| 56.0 | 13.9 | 18.2 | 33.1 | 485.6 | 382.5 | 5.5 | 14.2 |
| 68.4 | 14.0 | 18.7 | 51.9 | 507.5 | 383.1 | 5.5 | 13.2 |
| 76.9 | 13.1 | 17.4 | 17.5 | 405.0 | 344.4 | 5.5 | 15.1 |
| 85.9 | 12.6 | 17.7 | 23.1 | 413.8 | 318.8 | 5.3 | 13.8 |
| 93.0 | 13.6 | 17.6 | 36.3 | 443.1 | 358.1 | 5.4 | 13.6 |
| 100.0 | 13.4 | 18.1 | 49.4 | 422.5 | 343.8 | 5.6 | 15.0 |
| LSD | NS | 0.9* | NS | NS | NS | NS | NS |

Table 4: Colour space results for reflectance colorimetric analyses of fabric dyed with Cibacron blue LS3R (1%), for different harvest aid timing treatments. Values are the average of 4 replicates.

| Harvest aid treatment (% open bolls) | a^* | b^* | ΔE from 100% open bolls |
|--------------------------------------|--------|----------|---------------------------------|
| 29.2 | -2.207 | -27.910a | 1.10 |
| 41.9 | -2.258 | -28.015a | 1.29 |
| 56.0 | -1.998 | -28.370 | 0.68 |
| 68.4 | -2.015 | -28.344 | 0.28 |
| 76.9 | -2.124 | -28.262 | 0.21 |
| 85.9 | -1.921 | -28.577 | 0.96 |
| 93.0 | -1.958 | -28.562 | 0.77 |
| 100.0 | -2.110 | -28.340 | 0 |
| LSD | NS | 0.322** | - |

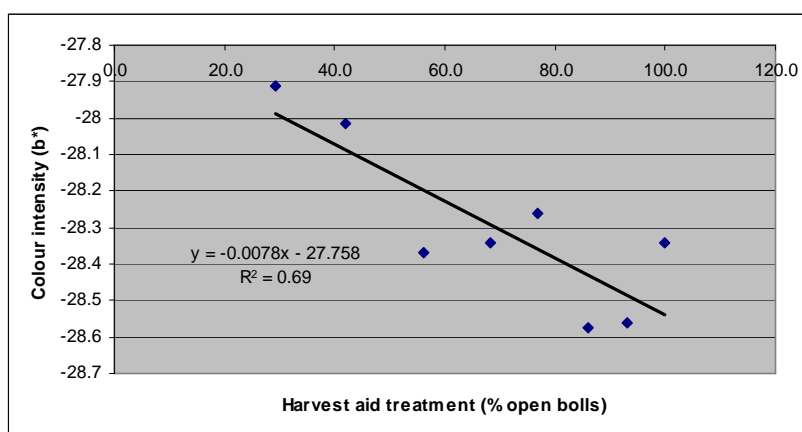


Figure 6: Colour space result (b*) for reflectance colorimetric analysis of fabric dyed with Cibacron blue LS3R (1%), for different harvest aid timing treatments (% open bolls).

Samples from Experiments 2 and 3 from this study are still being processed in Geelong. When results from all years are eventually combined a re-assessment to optimise agronomic recommendations from the first part of this study (described above) will be undertaken.

Collect information that can be used to promote Australian cotton as a premium commodity to meet market needs and can be used for extension and education purposes

Textile performance of some Australian genotypes

In delivering improved overall quality within an industry it is important to understand the contribution of all factors in the supply chain that limit quality. This includes differences attributed to genetics, management and the environment in which crops are grown, and processing and handling of cotton prior to delivery to the spinning mills. This part of the project compared some current and potential future Australian cotton genotypes with a range of fibre properties from a textile perspective grown in standard field grown conditions. Fibre quality attributes of each genotype were measured to ascertain whether differences led to changes in fibre neps levels and yarn performance; this included the measurement of quality parameters via new instrumentation unique to the Australian industry. The development of a consistent testing protocol for future genotype assessment was also an outcome of this part of the project.

Methods

Over the course of the project two experiments over two consecutive growing seasons were conducted in Narrabri to compare the in-field and textile performance of current and future potential Australian cotton varieties.

Genotypes bred by CSIRO were used in these experiments, and included the commercially available *Gossypium hirsutum* L. (Upland) varieties Sicot 71BR, Sicala 350B (Stiller 2005) and the *G. barbadense* L. (Pima) variety Sipima 280 (Stiller 2008). Experimental Upland breeding lines CHQX12B, CHQX377 and CHQX90 were also assessed. Sipima 280 and CHQX90 were only grown in Exp. 2. Sicot 71BR was the most widely grown Bollgard II®/Roundup Ready® variety, and was popular because of its high yields; in the 2005/06 and 2006/07 seasons Sicot 71BR occupied 21 and 41 % respectively of the area grown to cotton in Australia. The other genotypes were evaluated as possible niche or premium fibre types. For example, Sicala 350B is a variety with significantly longer fibres than Sicot 71BR, however its uptake by growers has been minimal due to its lower yields.

Experiments were machine-harvested with a John Deere spindle cotton picker. Upland seed cotton was ginned on a Continental Eagle 100 saw gin with one lint cleaning passage, located at Cotton Seed Distributors. Pima cotton was ginned with a Continental Eagle roller gin located at Clyde Agriculture, Bourke. Baled fibre was transported to CSIRO Materials Science and Engineering, Victoria, for textile processing.

Following ginning, manual classing of fibre was undertaken to determine the colour and leaf grades utilising USDA grade classification standards. Colour grade is determined by the degree of reflectance and yellowness, while leaf grade is a visual estimate of the amount of cotton plant leaf particles in the ginned fibre.

Fibre samples were subjected to HVI to determine upper half mean length (mm), bundle strength (g tex^{-1}), and micronaire, and for maturity ratio using CSIRO SiroMat, linear density or fineness (mtex) using the CSIRO Cottonscan, and fibre diameter (ribbon width) (μm) using the CSIRO Sirolan-Laserscan. Neps (numbers g^{-1}) were measured using an Uster Technologies Advanced Fibre Information Systems (AFIS PRO) instrument.

Fibre from field experiments was subjected to full scale commercial mill processing to produce 20 tex yarns with a twist factor ($\alpha\epsilon$) of 3.7 (798 turns per metre), which is considered a typical medium count range yarn used for manufacturing knitted fabrics. Yarn quality was tested for evenness [% coefficient of variation (% CV)], yarn neps (+200%), and for yarn strength (cN tex^{-1}). Yarn evenness is the measure of the variation in the mass of the yarn sampled every 10 cm for a 1000 m sample, yarn neps is the number of neps identified as being greater than twice the yarn thickness in a 1000 m sample, while yarn strength is the force to break the yarn normalised to the linear density of the yarn. Measures of yarn quality are an average taken from 10 bobbins of yarn randomly selected from the 30 produced per processing treatment.

Results and Discussion

Outcomes from this work are best summarised in the abstract that follows taken from a paper that is being reviewed for submission to Crop and Pasture Science (Publication No. 4):

‘Improving the quality of Australian cotton fibre is essential for maintaining industry viability. Desirable attributes are those that contribute to yarn strength and resist buckling and knotting (nep creation) during processing. Two field experiments were conducted to assess the fibre quality and textile performance of cotton genotypes produced by the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The work included the use of CSIRO instrumentation to measure fibre maturity ratio, fibre linear density, and fibre diameter (ribbon width). The strongest yarns were produced using genotypes with the longest and finest fibre [e.g. the strength of 20 tex carded ring spun yarns for the *Gossypium barbadense* L. variety Sipima 280 (length = 36.6 mm, linear density = 143 mtex, ribbon width = 13.7 μm) was 25.4 cN tex^{-1} cf. the *G. hirsutum* L. variety Sicala 350B (length = 32.5 mm, linear density = 185 mtex, ribbon width = 14.5 μm) yarn strength of 18.1 cN tex^{-1}]. Micronaire was shown to be an inferior indicator of yarn performance, e.g. although the *G. hirsutum* L. breeding lines CHQX12B and CHXQ377 had a micronaire of 4.35, CHQX12B spun weaker yarns due to its coarse and less mature fibre (for CHQX12B and CHXQ377, linear density was 199.0 and 192.1 mtex, maturity ratio was 0.89 and 0.95, and yarn strength was 16.7 and 19.9 cN tex^{-1} , respectively). Lint cleaning had the greatest influence on nep generation for *G. hirsutum* L. genotypes, generating on average 104 neps g^{-1} per lint cleaner passage. Although no clear relationships were noted between fibre quality attributes and fibre neps, generally finer, more mature, and stronger fibre resisted nep generation. There was a clear negative association between fibre quality and yield (e.g. the

correlation between fibre linear density and fibre yield was $r = 0.95$); and a simple cost benefit analysis showed that fibre yield was the dominant economic factor compared with any potential premiums gained from better fibre quality.’

The result of the textile performance are presented in Table 5 and the influence of their resulting fibre properties on yarn strength is summarised in Figure 7.

Table 5: Yarn performance attributes of 20 tex ring spun carded and combed yarns for Experiments evaluating the textile performance of some Australian genotypes in 2005/2006 (Exp. 1) and 2006/2007 (Exp. 2). (LSD – Least significant difference).

| Genotype | Strength (cN tex ⁻¹) | | Evenness (CV%) | | Neps (+200%) | |
|---------------------|----------------------------------|--------|----------------|--------|--------------|--------|
| | Exp. 1 | Exp. 2 | Exp. 1 | Exp. 2 | Exp. 1 | Exp. 2 |
| <i>Carded</i> | | | | | | |
| <i>Yarn</i> | | | | | | |
| Sicot 71BR | 15.2 | 14.9 | 18.4 | 16.7 | 564 | 265 |
| Sicala | | | | | | |
| 350B | 19.1 | 18.1 | 17.0 | 16.1 | 500 | 359 |
| CHQX12B | 16.7 | 16.9 | 18.2 | 17.4 | 522 | 586 |
| CHQX377 | 19.9 | 19.2 | 16.7 | 15.2 | 457 | 336 |
| CHQX90 | - | 17.2 | - | 16.5 | - | 554 |
| Sipima 280 | - | 25.4 | - | 15.4 | - | 569 |
| <i>Combed</i> | | | | | | |
| <i>Yarn</i> | | | | | | |
| Sicot 71BR | 16.6 | 16.7 | 14.8 | 14.1 | 182 | 54 |
| Sicala | | | 12.8 | | | |
| 350B | 21.1 | 19.7 | | 13.0 | 119 | 74 |
| CHQX12B | 19.8 | 18.3 | 13.9 | 13.5 | 154 | 86 |
| CHQX377 | 21.3 | 20.4 | 13.7 | 13.1 | 70 | 63 |
| CHQX90 | - | 19.4 | - | 12.8 | - | 84 |
| Sipima 280 | - | 27.4 | - | 12.1 | - | 136 |
| LSD | | | | | | |
| Genotype | 0.5*** | 0.5*** | 0.5** | 0.4*** | n.s. | 141* |
| LSD Card vs. Combed | 0.3** | 0.3*** | 0.4*** | 0.3*** | 32*** | 81*** |
| LSD | | | | | | |
| Interaction | n.s. | n.s. | n.s. | 0.6** | n.s. | n.s. |

* Significant at $P < 0.05$

** Significant at $P < 0.01$

*** Significant at $P < 0.001$

n.s. - not significantly different

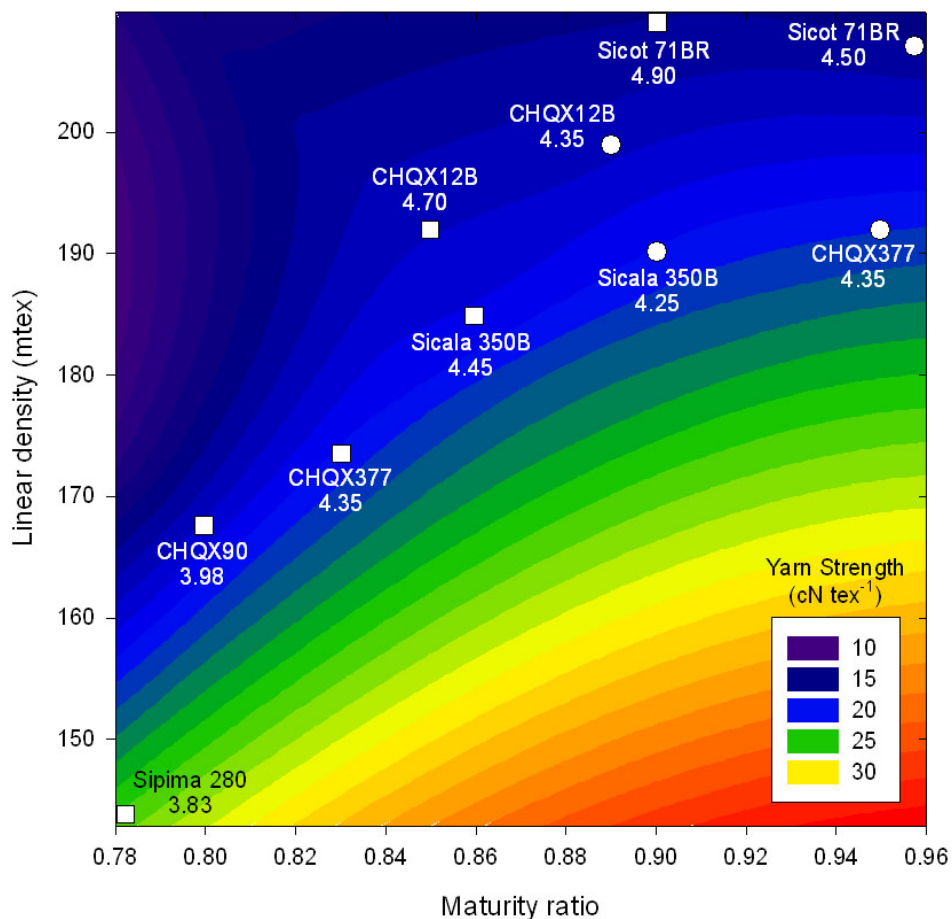


Figure 7: Graphical representation of the effects of micronaire and its influencing components (linear density and maturity ratio) on carded 20 tex yarn strength for genotypes in Exp. 1 (2005/ 2006) (○) and Exp. 2 (2006/ 2007) (□). Note the differences in yarn quality, fibre linear density (fineness) and maturity ratio, of some genotypes with similar micronaire.

Future research investigating textile performance of genotypes will continue, but will most likely utilise the micro-spinning technology that has been reinstated in Geelong. This means that harvested samples from breeding experiments will provide enough lint for textile performance assessment. These experiments helped to validate the micro-spinning approach against full scale spinning. This will now be discussed.

Reinstating the micro-spinning technology at Geelong

The requirement for spinning small amounts of cotton derived from field experiments gave rise to the refurbishment of a ‘Shirley’ miniature spinning plant, and the development of a spinning protocol that better represents a full-scale commercial operation. This research has been reported at a recent Beltwide cotton conference (Publication No. 15), and in a grower article (Publication No. 20). This effort is best summarised in an adapted version of the abstract taken from the conference paper below:

‘Australian cotton is well known for its high and consistent quality, although agronomy, physiology and breeding research continues to ensure Australian cotton stays competitive from a quality standpoint. The testing of fibre in yarn and fabric form means the selection of new varieties and field treatments is based on outcomes important to the end user. Such field experimentation inevitably produces large numbers of small (< 1kg) lint samples that need to be processed through to yarn and fabric. To meet this need, an alternative miniature spinning system which is actually a hybrid spinning system was created utilizing a combination of the

‘Shirley’ miniature spinning plant and industrial-scale spinning machinery. This process uses the miniature system for carding and a single drawing passage, while industrial-scale machinery are employed for a second draw passage, the creation of twisted roving and ring spinning (Figure 8). The experimental sample required for this protocol is small, being only 170 g. This study showed that there was no significant difference between industrial-scale and the new hybrid miniature spinning system for yarn strength for both Upland and Pima cotton, although the miniature spinning protocol produced yarns that were less even (Table 6). We conclude that this miniature spinning system is adequate for assessing the strength of medium count, carded ring spun yarns manufactured from small amounts of lint.’

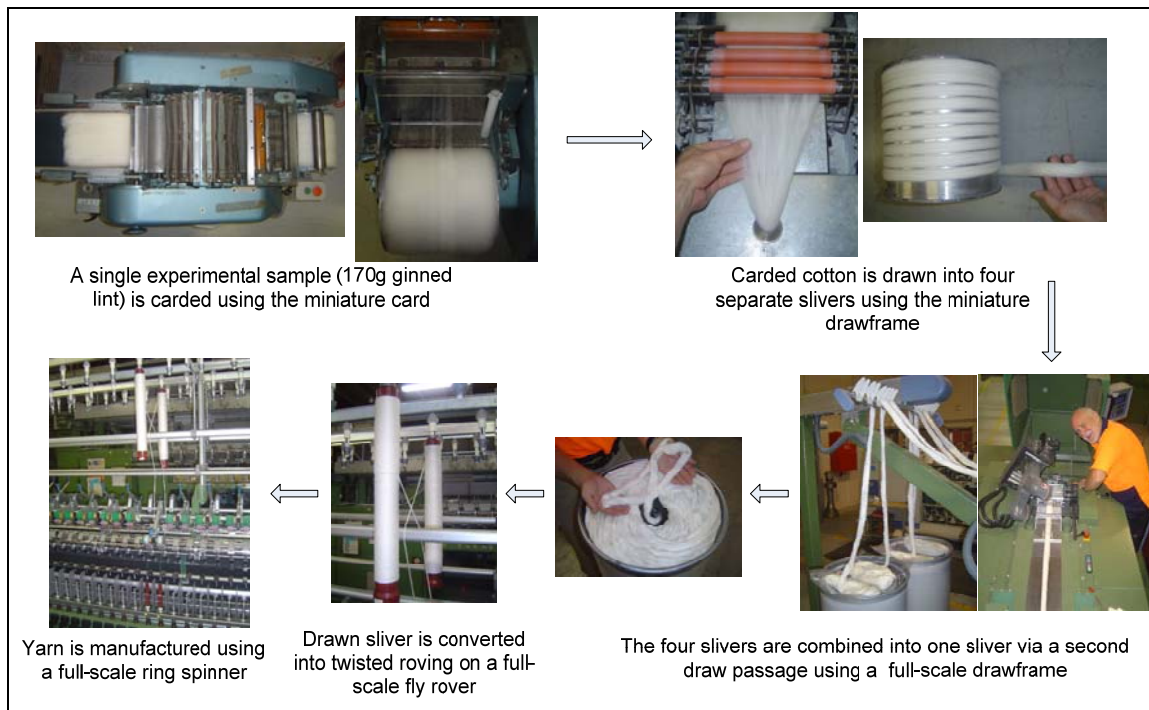


Figure 8: Yarn processing route for miniature spun yarns

Table 6: Yarn results for 20 tex (30 Ne) yarns prepared on both on the full scale spinning system and micro-spinning system.

| Spinning | Strength (cN/ tex) | CV% of Strength | Evenness (CV _m %) | Thin places (-50%) | Thick places (+50%) | Neps (+200%) |
|-------------------------|--------------------|-----------------|------------------------------|--------------------|---------------------|--------------|
| Upland | | | | | | |
| Full-scale | 14.6 | 8.8 | 16.5 | 33 | 318 | 242 |
| Miniature | 14.4 | 14.1 | 19.5 | 121 | 544 | 443 |
| Pima | | | | | | |
| Full-scale | 25.7 | 8.1 | 14.9 | 0 | 264 | 365 |
| Miniature | 25.1 | 10.6 | 17.1 | 16 | 212 | 323 |
| ANOVA <i>P</i> Spinning | n.s. | <0.01 | <0.01 | <0.01 | <0.05 | <0.01 |
| ANOVA <i>P</i> Variety | <0.01 | <0.05 | <0.01 | <0.01 | <0.01 | n.s. |
| LSD interaction | n.s. | n.s. | n.s. | 40* | 109** | 45*** |

* Significant at $P < 0.05$, ** Significant at $P < 0.01$, *** Significant at $P < 0.001$, n.s. not significantly different

Improve management guidelines to maintain fibre quality

This project provided key research that was included in the development of FIBREpak which was released in August 2009 in print and electronic form. Text taken from the introduction of FIBREpak outlines its key purpose.

‘To fully realise the benefits of improving quality all sections of the industry need to work together to address the challenges and opportunities for improving quality. The task is for the industry to optimise fibre quality in all steps from strategic farm plans, variety choice, crop management, harvesting, and ginning. We have termed this ‘Integrated Fibre Management’ (IFM) to emphasize the importance of a balanced and complimentary approach to managing fibre quality across the whole production chain (see Figure 9). Along with the industry’s BMP program that seeks to improve quality by providing assurances in production, classing and ginning, new technologies, instruments, research and extension programs and communication will all help together to facilitate IFM.’

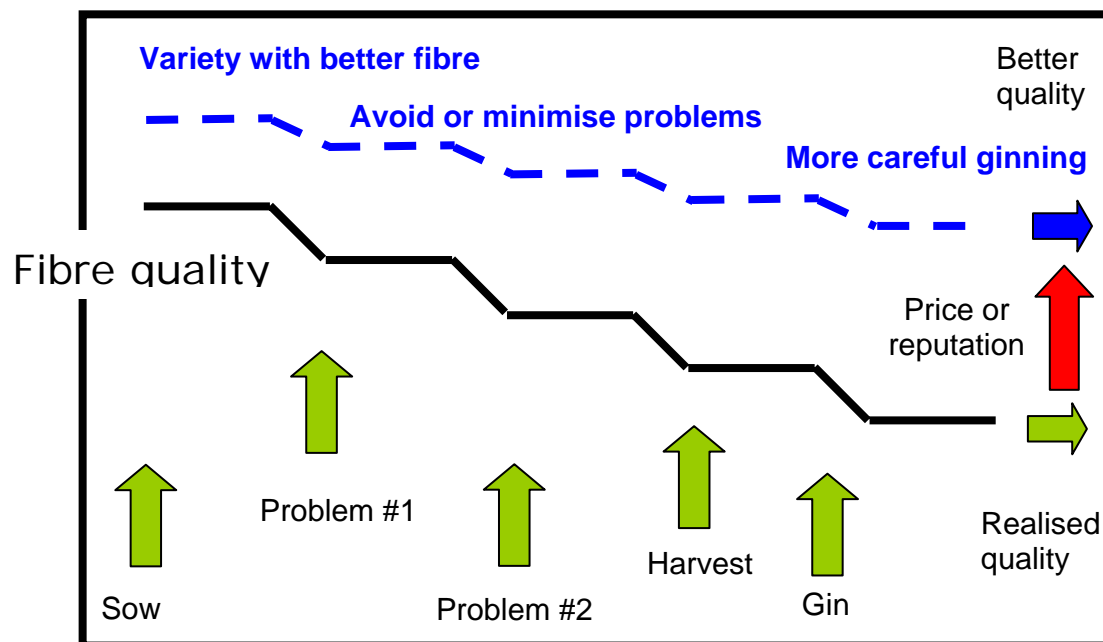


Figure 9: Concept of ‘Integrated Fibre Management’ (IFM) to improve industry fibre quality. The aim is to raise quality by minimising the damage to fibre quality along the whole production chain. Note in comparing the dotted line with the solid line how starting with better fibre properties and avoiding or minimising problems through the production and processing chain can substantially improve fibre quality outcomes.

Assistance was also provided during the course of this project in developing the draft guidelines of the industry’s BMP fibre quality module.

Conclusion

Linking research on crop management with textile performance can be applied to optimise fibre quality. This project was successful in providing new knowledge on fibre quality issues through:

- Improved understanding of the changes in crop management practices that affect micronaire and its components of linear density and maturity. Information generated in this project specifically attempted to quantify the effects of management practices that influence boll number and plant size on micronaire.

- Improved understanding of fibre development in terms of fibre maturity. This study utilised for the first time the use of the SiroMat instrument to measure differences in developing fibres for maturity ratio between Pima and upland cotton species.
- The effects of early harvest preparation on fibre immaturity and neps was quantified and related to measurements of crop status. The effects of these treatments with extra lint cleaning on neps were also assessed. Results showed little interaction between lint cleaning and immature fibre that would lead to substantial increases in neps. The current industry recommendation of application of harvest aids at 60% bolls open is adequate to limit neps, and reduce the risk of yield losses.
- Large-scale spinning trials were conducted in Geelong to assess the comparative performance of some current varieties and breeding lines. Assessments showed that all genotypes produced adequate quality yarns. The research again highlighted the inadequacies of the micronaire measurement to reflect the quality that led to differences in textile performance, and also demonstrated the use of new instrumentation for measuring fibre quality parameters that better relate to textile performance (e.g. maturity, linear density and ribbon width). A cost benefit analysis showed that yield was the dominant economic factor compared to any premiums gained from better fibre quality.
- Micro-spinning technology was reinstated in Geelong, and detailed studies showed that it produced comparable results (for yarn strength) to full-scale spinning mill capabilities. The Micro- spinning system was used to assess the textile performance of early harvest preparation experiments.
- Research generated in the study was used in the development of FIBREpak and the industry's BMP fibre quality module.
- Continued to raise the awareness of the effects of climate and management on fibre quality through the Geelong 'Field to Fabric' course, FIBREpak, and various other industry forums.

Ongoing on-farm research into fibre quality has been supported through the ongoing project 'Agronomic management to optimise textile performance' supported by CSIRO, the Cotton CRC and CRDC. New research will build on those advances made in the project reported here and will continue to provide management guidelines to growers that will seek to reduce neps and improve consistency of cotton from the field; gain improved knowledge of the effects of environmental and crop stress on micronaire and its components of fineness and maturity; develop guidelines that establish the value of in-field blending/or segregation of harvested lint based on quality attributes; and elucidate other key properties of Australian cotton that may be exploited to maintain marketing advantages.

This project will maintain research capability and activities into fibre quality research. It brings together two projects that are fully coordinated and integrated, that have synergy and no duplication. Collaboration will be maintained with other research and breeding on fibre quality to ensure information feeds into research on the development of optimised management strategies for future cotton systems on-farm and post farm gate. Specifically this project would support an experienced technical officer (Jane Caton) in Narrabri working with Dr Bange to conduct field experiments, as well as research scientist Dr Robert Long and 1 technical assistant based in Geelong to undertake post harvest assessments.

This project will create new knowledge and solutions to challenges associated with Australian fibre quality by:

(i) Undertaking field research to test alternative end of season management practices to improve the consistency of fibre quality. Practices include the use of late season pix (growth regulator), changes in defoliation and last irrigation timing and plant type/variety. (ii) Establishing experiments to assess techniques to monitor crops to predict neps. Treatments will include plants that have fruiting gaps (from fruit loss) and are variable in their maturity. This approach will be used to develop management of such treatments to reduce neps. (iii) Conducting experiments to measure and quantify the effects of plant stress with management on micronaire and its components of fineness and maturity. Treatments will vary boll load, temperature and water stress. This research will have relevance to climate change effects on fibre quality. (iv) Initiating studies that consider benefits (both from economic and textile perspectives) of in-field segregation or blending of lint based on fibre quality. The segregation may occur in-field or at the gin. Future precision agriculture technologies as well as new harvesting technologies (producing small round bales) may facilitate these approaches. We will determine economic and textile performance thresholds for segregation and use this information to design a field research program to evaluate potential benefits. Field studies will involve planting varieties with different fibre quality in layouts that will allow cotton to be harvested to enable segregation or blending of the lint. Lint will also be blended at ginning using CSIRO's new ginning facility in Geelong.

Publication List

Refereed Journal Articles

1. Abbott, A.M., Higgerson, G.J., Long, R.L., Lucas, S.R., Naylor, G.R.S., Tischler, C.R., Purnalis, M.M. (2009) An instrument for determining the average fibre linear density (fineness) of cotton lint samples. In press.
2. Bange M.P., Long R.L., Constable G.A., and Gordon, S.G. (2009). Minimizing immature fibre and neps in Upland cotton (*Gossypium hirsutum* L.) at harvest. In preparation for submission to Agronomy Journal.
3. Long, R.L., Bange, M.P., Gordon, S.G., and Constable, G.A. (2009). Measuring the maturity of developing cotton fibres using an automated polarised light microscopy technique. Textile Research Journal. In press.
4. Long R.L., Bange M.P., Gordon, S.G., van der Sluijs, M.H.J., Naylor, R.S., and Constable G.A. (2009). Fibre quality and textile performance of some Australian cotton genotypes. In preparation for submission to Crop and Pasture Science.

Refereed Conference Papers

5. Bange, M.P. and Roche, R. (2008). Do sowing rules change for high fruit retention transgenic cotton? Proceedings of the 14th Australian Agronomy Conference, 22-24 September 2008, Adelaide, South Australia.

Conference Papers

6. Bange, M.P., and Constable, G.A. (2008). Cotton farming systems for a changing climate. In Proc. 14th Aust. Cotton Conf. 12-14 August, Gold Coast Aust. The Aust. Cotton Growers Research Organisation
7. Bange, M.P., Long, R., Constable, G.A., and Gordon, S. (2009). Evaluation of In-Field Monitoring Methods to Reduce Neps (in Australian Cotton). In Proceedings Beltwide Cotton Conference 6-9 January, San Antonio, Texas.
8. Gordon, S., Long, R., Bange, M.P., Lucas, S. and Phair-Sorensen, N. (2007). Measurement of average maturity and maturity distribution statistics by SiroMat in cotton fibre picked from plants subjected to defoliation timing treatments. In Proceedings Beltwide Cotton Conference January, New Orleans, Louisiana.

9. Gordon, S.G., Long, R.L. Lucas, S., Phair-Sorensen, N. L. (2008). Using SiroMat to distinguish fibre maturity related issues in the mill. Proceedings Beltwide Cotton Conference; Nashville, T.N. National Cotton Council of America and The Cotton Foundation.
10. Gordon, S.G., Long, R.L., Naylor, G.R.S. (2009) The measurement of cotton fibre linear density and maturity and its potential value to textile processing. Textile Institute Conference, NZ, In Press.
11. Higgerson, G., Le, C.V., Long, R.L., Lucas, S.R., Naylor, G.R.S., Purmalis, M.M. (2007) Inter-laboratory evaluation of the cottonscan instrument for determining average fibre linear density (fineness) of cotton lint samples. Proceedings World Cotton Research Conference-4, Lubbock, Texas USA.
12. Kelly, D., Bange, M.P., and Constable, G.A. (2008). Unravelling the micronaire challenge. In Proc. 14th Aust. Cotton Conf. 12-14 August, Gold Coast Aust. The Aust. Cotton Growers Research Organisation.
13. Long, R., Bange, M.P., Gordon, S.G. (2008). Assessing the impact of harvest aid timing on fibre quality and textile performance. In Proceedings Beltwide Cotton Conference January, Nashville, Tennessee.
14. Naylor, G. R., Gordon, S. G., Long, R.L., van der Sluijs, M. (2008). The role of long staple upland and pima cotton – opportunities for medium and ELS types. Australian Cotton Conference, Gold Coast, Queensland Australia
15. Van der Sluijs, M.H.J., Long, R.L., Gordon, S.G. (2009) An alternative miniature cotton spinning system. Proceedings Beltwide Cotton Conference, San Antonio, T.X. National Cotton Council of America and The Cotton Foundation.

Grower Magazine Articles

16. Bange, M., Roche, R., Caton, J. and Hodgson, D. (2008). Does Bollgard II perform differently in dryland systems? The Australian Cottongrower. 29(7). pp. 36-39.
17. Kelly, D., Bange, M.P., and Constable, G.A. (2008). Unravelling the micronaire challenge. The Australian Cottongrower. 29(6). pp. 24-26.
18. Long, R., Bange, M., Gordon, S., Van der Sluijs, M., and Constable, G. (2007). Linking farming systems to quality and textile performance. The Australian Cottongrower 28(1). pp.28-30.
19. Long, R., and Bange, M. (2008). The impact of defoliation timing on fibre quality and textile performance. The Australian Cottongrower 29(4). pp.10-13.
20. Long, R.L., Van der sluijs, M. (2008) An alternate miniature cotton spinning system. The Australian Cottongrower. 29(no. 3):38-40.
21. Van der sluijs, M., Gordon, S., Long, R. (2008) A spinner's perspective on fibre fineness and maturity. The Australian Cottongrower. 29(no. 1), 30-32.

Others Publications

22. Bange M.P., Constable, G.A., Gordon, S.G., Long, R.L., Naylor, G.R.S. and Van der Sluijs, M.H.J. (2009) FIBREpak A guide to improving Australian cotton fibre quality. CSIRO and the Cotton Catchment Communities Cooperative Research Centre. ISBN 978-0-9775317-1-4.

Extension and Education Activities

2007/ 2008

- M. Bange presented at the Field to Fabric course in Geelong.
- R. Long presented a seminar to staff and students at Deakin University (Waurin Pounds) about the current 'Linking Farming Systems' research.

- R. Long while attending a scientific exchange in the U.S. presented seminars for staff at the USDA's Southern Regional Research Centre (New Orleans, Louisiana), and for staff and students at the Division of Textiles and Clothing (University of California, Davis).
- R. Long presented a story about cotton processing and yarn formation to Network 10's children's science program 'Scope'. It was aired on June 2nd 2008.
- Michael Bange presented at the Macquarie field day and discussed the concept of integrated fibre quality management.

2008/2009

- Robert Long, Mike Bange and Stuart Gordon presented 'Linking farming systems' work at the Australian Cotton Conference as part of a hands on workshop on fibre quality.
- R. Long and M.Bange presented work at UNE's Cotton course
- M. Bange presented at the Field to Fabric course in Geelong and in Narrabri.
- M. Bange gave a keynote presentation titled 'Cotton in a Climate of Change'.
- M Bange gave presentations a part of the CSD dryland tour. Results on fibre quality changes with different row configurations were discussed. Presentations were given in Bellata, Moree, Goondiwindi and Dalby.
- M. Bange presented a CSD web on Wednesday on choice of row configuration including fibre quality.
- M. Bange presented to UNE and Sydney University Students on crop physiology including fibre development as part of their excursion to Northern NSW.
- M. Bange gave a lecture at Sydney University on cotton agronomy and physiology including fibre development and management.
- M. Bange presented at the Macintyre field day on row configuration choice (including fibre quality).
- Robert Long was interviewed for CSD's Web On Wednesday and spoke about the effects of manipulating maturity through defoliation timing on textile performance.
- A number of articles were presented in CRDC's 'SpotLight' magazine about the Linking Farming Systems project.
- Michael Bange and Robert Long presented at the CRC Science Forum in 2008.

Final Report Executive Summary

Linking Farming Systems to Fibre Quality and Textile Performance

Principal Researchers M.P. Bange, R.L. Long (Researchers)/J. Caton (Technical Officer)
Supervisors G.A. Constable, S.G. Gordon

Australian cotton is purchased for a premium on the basis of quality and consistency. However, coarse (high micronaire) fibre, high nep counts and excessive short fibre are industry concerns. Quality is affected by many interacting factors e.g. variety, seasonal conditions and crop and harvest management. Appropriate varieties, management for each region's climate, and processing to minimise damage to fibre are opportunities to improve fibre quality. This project combined efforts to optimise cotton fibre quality through research into direct influences of agronomic management and climate on fibre development and post-harvest research that measured influences of fibre differences on textile performance in the mill

Specific aims were: 1. Targeted research to measure the effects of different climate, and crop management on fibre quality (specifically micronaire and neps), and how results of textile performance may influence crop management recommendations. 2. Utilise agronomy and physiology research tools to develop regionally specific management guidelines to optimise yield and fibre quality. 3. Identify linkages between on farm parameters and fibre quality from a textile perspective. 4. Strengthen agronomic research to meet the future needs of the 'Field to Fabric', BMP and FIBREpak initiatives.

This project was successful in providing new knowledge on fibre quality issues through:

- Measurement of crop management practices that affect micronaire and its components of fibre linear density and fibre maturity. Information generated in this project specifically attempted to quantify the effects of management practices that influence boll number and plant size on micronaire.
- Measurement of fibre maturity development. This study utilised for the first time the use of the SiroMat instrument to measure differences in developing fibres for maturity ratio between Pima and upland cotton species.
- The effects of early defoliation on fibre immaturity and neps was quantified and related to measurements of crop status. The effects of these treatments with extra lint cleaning on neps were also assessed. Results showed little interaction between lint cleaning and immature fibre that would lead to substantial increases in neps. The current industry recommendation for defoliation at 60% bolls open is adequate to limit neps, and reduce the risk of yield losses.
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- Micro-spinning technology was reinstated in Geelong, and detailed studies showed that it produced comparable results (for yarn strength) to full-scale spinning mill capabilities. The Micro-spinning system was used to assess the textile performance of early defoliation experiments.
- Research generated in the study was used in the development of FIBREpak and the industry's BMP fibre quality module.
- Continued to raise the awareness of the effects of climate and management on fibre quality through the Geelong 'Field to Fabric' course, FIBREpak, and various other industry forums.

Ongoing on-farm research into fibre quality has been supported through the ongoing project 'Agronomic management to optimise textile performance' by CSIRO, the Cotton CRC and CRDC. New research will build on those advances and will continue to provide management guidelines to growers to reduce neps and improve consistency of cotton from the field; gain improved knowledge of the effects of environmental and crop stress on micronaire and its components of fineness and maturity; develop guidelines that establish the value of in-field blending/or segregation of harvested lint based on quality attributes; and elucidate other key properties of Australian cotton that may be exploited to maintain marketing advantages.