



FINAL REPORT

Part 1 - Summary Details

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

Cotton CRC Project Number: 4.04.02

Project Title: Commercial Preparation of SiroMat

Project Commencement Date: 1/7/05 **Project Completion Date:** 30/6/07

CRC Program: The Product

Part 2 – Contact Details

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Part 3 – Final Report Guide (due within 3 months on completion of project)

(The points below are to be used as a guideline when completing your final report.)

Background

1. Outline the background to the project.

Cotton fibre maturity is a central property because it determines how well fibres process both from a chemical and physical perspective. Immature cotton fibre, that is fibre with little or no fibre wall thickening, is associated with the formation of small entanglements called neps, irregularities in processed fibre assemblies including finished yarns, non-uniform dyeing of fabrics and decreased processing efficiency. At the moment there is no fast and accurate test method for testing fibre maturity for commerce and industry.

SiroMat is an instrument that has been developed to measure cotton fibre maturity directly and accurately. The instrument measures the proportion of particular interference colors transmitted by cotton fibre snippets viewed between crossed polars of a polarizing light microscope. The interference colours measured by SiroMat are directly related to a cotton fibre's maturity or cell wall thickening.

The advantages of SiroMat are that it measures fibre maturity directly and because it does this on individual fibre snippets it is able to measure the fibre maturity distribution in a sample. The distribution of mature and immature fibres in a sample is important from the perspective of predicting textile problems, such as nep formation and dye uptake variation. Moreover, the speed of the SiroMat test means that it has excellent potential for use as a stand alone, medium volume instruments in mill and merchant laboratories, replacing indirect maturity methods such as the 'Shirley' FMT, the Lintronics FQT and the AFIS Pro.

Objectives

2. List the project objectives and the extent to which these have been achieved.

- 1 Build a third SiroMat instrument.

- Three SiroMat instruments are currently built. Two of these are updated versions of the SiroMat instruments built before the end of 2005 (DMLSP1 & DMLSP2) and the third is a brand new instrument (DME4) recently commissioned.

In late 2006 the older DMLSP instruments were fitted with crystalline (glass) wave-plate compensators and these were set to a fixed position (a 45 degree position to the crossed polars) to reduce the variation in colour space that occurred between old instruments, which used polymer compensators that were not consistent across their field-of-view (FoV) and that were not set in a fixed position.

The updated instruments required re-setting of the colour space and a re-check against the old calibration. At the same time a new instrument based around a newer microscope base was commissioned (DME4). This instrument is nominally the same as the updated SiroMats in that it uses exactly the same camera, objective, fixed position compensator and analyser, and a similar (filament) light source. However, it uses a crystalline polarizer as opposed to the film polarizers used in the older

SiroMat instruments. No difference has been measured or is anticipated between these polarizers.

A day-light filter is also now used on the new (DME4) and updated (DMLSP) instruments to bring the colour space transmitted by the new wave-plate compensators back to the 'old' colour space originally transmitted by the polymer compensators and allowing the old calibration to be applied.

2 Streamline the current user interface.

- A MATLAB-based program has been successfully written to integrate all hardware, data acquisition, image analysis and data analysis controls in SiroMat. The advantages of MATLAB over other software systems are many; they include its large library of already written functions, particularly with respect to colour analysis and transformations, its conciseness and its ability to integrate all required computer-controlled functions. The software now runs on all instruments.

3 Conduct inter-laboratory trials within Australian research laboratories and merchant classing houses, including the ACRI laboratory.

- Extensive inter-laboratory trials have not been conducted as yet due to unforeseen difficulties and time delays in matching and then correcting the colour-spaces of the various optical components, e.g. the light source, camera, lenses and filters, of each SiroMat instrument.

Trials to date have shown generally good agreement between SiroMat and reference data measured on Upland cotton. However, in some trials anomalies have appeared between SiroMat Pima readings and reference data. We are unsure at this time whether the fault lies with the SiroMat or reference data. In response we are examining in more detail the properties of Pima cottons in order to be sure of this situation – see Appendix A1.

4 Apply SiroMat data to breeding, agronomy, ginning and spinning projects funded by the CRDC and the CCC CRC to determine the value of its data to research efforts in these areas.

- Cotton samples from a wide range of CRDC, CCC CRC and industry funded projects have been measured using the 'standard' SiroMat (the instrument against which all other SiroMats will be calibrated) to determine the value of SiroMat data to industry and research. Important demonstrations on the application of SiroMat data to agronomy, ginning and spinning data have been published in the Beltwide Cotton Conference proceedings. These reports appear in Appendices B1 to B3.

5 Present results of the above trials at local cotton grower, ginner and merchant forums as well as at international forums such as the Bremen ITMF Cotton Test Method Committee Meetings and thus engage potential users and manufacturers of the SiroMat technology.

- See above. Reports on SiroMat, the development of SiroMat and the potential from SiroMat have been made at a number of public and private company forums. Important forums have included the:
 - i. The ITMF International Cotton Test Method Committee Meetings in Bremen, Germany March 2006 – see Appendix C1
 - ii. Discussion with Uster Technologies in Knoxville, TN January 2007 – see Appendices A1, A2 and A3

- iii. ICAC Recorder Article published July 2006 – see Appendix C2.
- iv. CCC CRC Conference in Narrabri August 2007

Methods

3. Detail the methodology and justify the methodology used. Include any discoveries in methods that may benefit other related research.

A study in mid 2006 using a spectrophotometer connected by an optical fibre mounted to the top of the body tube of a polarizing microscope was used to record the wavelength of the interference colours transmitted by mature and immature cotton fibres regions. In order to make the spectrum correspond to a particular spot on the image a centralised cross in the eyepiece was used. The set-up enabled exact regions of interest to be examined with both the spectrophotometer and a digital camera, allowing comparison between the wavelength of light measured by the spectrophotometer and the digital colour spaces. The work was conducted to confirm earlier work – see Gordon, S. G. and Phair, N. L., An investigation of the interference colours transmitted by mature and immature cotton fibre under polarised light microscopy, *proceed.* Beltwide Cotton Conferences, New Orleans LA, 2005.

An approach to bringing the SiroMat instruments in-line with each other has been developed and is currently being tested in the new CCC CRC project entitled ‘Support and Extension of SiroMat (Generation I)’. It involves establishing a validated calibration on a ‘standard’ instrument using the 104 International Textile Center cottons from Texas Tech, measuring the colour space associated with this ‘standard’ instrument calibration and mathematically transforming the colour space measured by other SiroMat instruments to the standard. At this point in time a ‘standard’ instrument (DMLSP2) has been nominated. The value of having a ‘standard’ instrument that records a good correlation between measured colour, e.g. measured as RGB, and maturity reference data means that a physical calibration of a colour standard is not required.

Outcomes

4. Describe how the project’s outputs will contribute to the planned outcomes identified in the project application. Describe the planned outcomes achieved to date.

See above and in the attached appendices.

5. Please describe any:-
 - a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.);

Progression of full international patent: Gordon, S. G., Lucas, S. R. and Phair, N. L., ‘Method and Apparatus for Testing Fibres’, Patent No. AU2005000061, 2005

- b) other information developed from research (eg discoveries in methodology, equipment design, etc.); and
- c) required changes to the Intellectual Property register.

Conclusion

6. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. What are the take home messages?

Refer to 'Business Case Report to the CRDC and ACGRA, Support and Extension of SiroMat (Generation I)', CRC Project Number 4.04.02, Milestone 1.1 submitted August 2007.

Extension Opportunities

7. Detail a plan for the activities or other steps that may be taken:
 - (a) to further develop or to exploit the project technology.
 - (b) for the future presentation and dissemination of the project outcomes.
 - (c) for future research.

Refer to 'Business Case Report to the CRDC and ACGRA, Support and Extension of SiroMat (Generation I)', CRC Project Number 4.04.02, Milestone 1.1 submitted August 2007.

8. A. List the publications arising from the research project and/or a publication plan.
(NB: Where possible, please provide a copy of any publication/s)

Refer to Appendices A, B and C.

- B. Have you developed any online resources and what is the website address?

NA

Part 4 – Final Report Executive Summary

Provide a one page Summary of your research that is not commercial in confidence, and that can be published on the World Wide Web. Explain the main outcomes of the research and provide contact details for more information. It is important that the Executive Summary highlights concisely the key outputs from the project and, when they are adopted, what this will mean to the cotton industry.

SiroMat is an instrument that measures fibre maturity directly and accurately. Its advantage over other test methods is that it measures maturity directly and is able to measure the fibre-to-fibre distribution of maturity in a specimen. Moreover the test time is around two minutes, which is comparable with other low volume instrument test times. SiroMat is currently undergoing technical trials with a view to preparing it for commercialisation.

In order for SiroMat to be taken up by the wider industry its utility needs to be realised by the wider research and commercial cotton testing and marketing segments. During a recent meeting with Uster Technologies (USA) interest was expressed in the SiroMat on this basis. In order to continue to highlight its value SiroMat data will be recorded on samples from a wide number of Australian and international industry sponsored cotton breeding, agronomy and textile projects.

Appendices A1, A2 and A3

Reports from ongoing comparative testing and discussions with Uster Technologies, January through November 2007

Appendix B1

Gordon, S. G., Long, R. L., Bange, M., Lucas, S. R. and Phair-Sorensen, N. L., Measurement of average maturity and maturity distribution statistics by SiroMat in Cotton fibre subject to differential defoliation timing treatments, *proceed.* Beltwide Cotton Conferences, National Cotton Council, New Orleans LA, Jan 2007

Appendix B2

Gordon, S. G., Long, R. L., Lucas, S. R. and Phair-Sorensen, N. L., Using SiroMat to distinguish fibre maturity related issues in the mill, *proceed.* Beltwide Cotton Conferences, National Cotton Council, Nashville TN, Jan 2008

Appendix B3

Long, R. L., Bange, M., Gordon, S. G. and Van der Sluijs, M. J. H., The effect of different harvest aid timing treatments on fibre quality and textile performance, *proceed.* Beltwide Cotton Conferences, National Cotton Council, Nashville TN, Jan 2008

Appendix C1

Presentation (PowerPoint) to ITMF Cotton Test Method Committee Meetings, Bremen Germany, March 2006

Appendix C2

Gordon, S. G. and Naylor, G. R., New research and development work from Australia in cotton fineness and maturity assessment, ICAC Recorder, **24(2)**:13-18, 2006

Proposed Uster/CSIRO SiroMat Evaluation Trials 2007

Background

Following a demonstration of the SiroMat polarized light microscopy instrument at Uster Technologies in Knoxville TN on January 8th 2007 it was proposed that Uster, as a party interested in the SiroMat technology, combine with CSIRO to evaluate the instrument according to the two objectives detailed below.

Under the proposal CSIRO will provide Uster with information describing the performance of the SiroMat in differentiating cotton of same micronaire but different maturity. In return Uster can provide feedback, samples and direction with regards to this assessment.

Furthermore, CSIRO will provide test statistics on the inter-instrument variation between SiroMat instruments.

Objective A:

Test ability of SiroMat to distinguish cotton with same micronaire but different maturity. It was noted during discussions at Uster that the SiroMat had ranked a set of 10 cotton samples (supplied by Uster) differently in terms of fibre maturity – see the report ‘Comparison between CSIRO SiroMat and AFIS test results on maturity’ by Dr. Roger Riley and Anja Schleth. Thus in this objective the ability of SiroMat to distinguish maturity will be measured on two sets of fibre samples containing cottons with the same micronaire. The sample sets have been supplied from the ITC at Texas Tech and CSIRO Plant Industry.

The ITC set (set one) is a sub-set of samples from the 104 international cottons that have been cross-sectioned according to Dr. Devron Thibodeaux and measured for theta, wall area and perimeter by image analysis by Dr. Bugao Xu. SiroMat maturity values for cottons in the ITC set will be compared with cross-sectional reference data from the ITC set and maturity measured on the ITC and CSIRO AFIS instruments.

The CSIRO samples (set two) contain pairs of cottons with similar micronaire values but different maturities. Cottons from this set will be tested on HVI, AFIS and SiroMat, spun into 20 tex yarn, knitted into the same fabric and dyed together in the same dye bath. SiroMat values for this set will be compared with dye uptake and fabric appearance tests including colorimetry tests on fabric created from each fibre sample. Selected fibre property values for each set are listed in Tables I and II.

Objective B:

Demonstrate agreement between (3) SiroMat instruments and partition variation according to each optical component i.e., camera, waveplate, illumination (lamp and power supply) and between replicate specimens.

Materials:

Two sets of cotton have been gathered. Set one contains (10 g) samples from the ITC International set of cross-sectioned cottons (Table I). The sub-set has been selected on basis of same micronaire (X) but different fibre maturity (M). The maturity values in this sub-set are corroborated by cross-sectional data. Set two contains samples (200+ g) of pre-release varieties that have same micronaire but different maturity and fineness co-ordinates (Table II).

Table I – Sub-set of samples from ITC International set of cross-sectioned cottons for analysis by SiroMat

ID	X	M*	T	P
2684	3.4	0.88	0.52	45.8
3170	3.4	0.83	0.432	55.7
2952	4.0	0.89	0.536	47.7
3119	4.0	0.83	0.474	54.8
3122	4.22	0.91	0.542	49.4
3138	4.22	0.85	0.451	57.7
3152	4.32	0.89	0.513	53.3
3165	4.32	0.84	0.53	53.1
3042	4.49	0.90	0.517	50.6
3159	4.49	0.82	0.49	58.1
3143	5.12	0.95	0.594	50
3196	5.12	0.87	0.578	52.7

* AFIS determination

Table II – Set of samples from CSIRO for analysis by SiroMat

ID	X	M**	H**
531 mv - 55	4.8	0.96	207
531 mv - 50	4.8	0.95	202
531 mv - 44	4.9	0.99	183
531 mv - 58	4.7	0.99	182
531 mv - 38	4.4	0.93	183
531 mv - 67	4.4	0.93	183
531 mv - 71	4.4	0.97	174
531 mv - 70	4.4	0.98	173

** FMT determination

Timeline and Reporting:

April07 – Feedback to CSIRO on proposal and sample sets to be tested

May07 – SiroMat and CSIRO AFIS testing complete

Jul07 – CSIRO samples spun and knitted

Aug07 – CSIRO fabric samples dyed and colorimetry

Oct07 – Report on inter-instrument variation

Jan08 – Full report describing completion of objectives A and B

Mar08 – Full report given at Bremen ITMF Committee Meeting

Comparison between CSIRO SiroMat and ITC test results on maturity

Stuart Gordon

28 August 2007

A sub-set of 12 cottons from the ITC reference set of 104 cottons¹ was used to compare fibre maturity test results from the CSIRO SiroMat with maturity reference results (theta) from cross-sectional analysis. The sub-set was also tested on CSIRO's AFIS instrument. Samples in the sub-set were purposely chosen to represent both a wide range of Micronaire values (3.40 to 5.12) and different fibre maturities (as measured by cross-sectional analysis) at the same Micronaire (see Table I).

Table I – Cross-Sectional (XS) Test Data with Maturity Ratio (MR) as Measured by SiroMat (SM) and (AFIS – place)

ID	MIC ITC	XSttheta ITC	XSMR ITC	XSPeri ITC	MR (SM)	sd MR (SM)	MR (AFIS - ITC)	MR (AFIS - CTFT)
No. reps /fibres	40	>4000	>4000	>4000	>10,000	>10,000	?	15,000
2684	3.40	0.520	0.90	45.8	0.83	0.50	0.88	0.91
3170	3.40	0.432	0.75	55.7	0.82	0.50	0.83	0.84
2952	4.00	0.536	0.93	47.7	0.81	0.51	0.89	0.93
3119	4.00	0.474	0.82	54.8	0.83	0.48	0.83	0.86
3122	4.22	0.542	0.94	49.4	0.91	0.42	0.91	0.93
3138	4.22	0.451	0.78	57.7	0.87	0.47	0.85	0.87
3152	4.32	0.513	0.89	53.3	0.85	0.48	0.89	0.92
3165	4.32	0.530	0.92	53.1	0.88	0.46	0.84	0.86
3042	4.49	0.517	0.90	50.6	0.89	0.44	0.90	0.93
3159	4.49	0.490	0.85	58.1	0.87	0.45	0.82	0.84
3143	5.12	0.594	1.03	50.0	0.94	0.40	0.95	0.94
3196	5.12	0.578	1.00	52.7	0.92	0.41	0.87	0.88

The two test results highlighted in bold font in Table I are Pima-type cottons; although not labeled as such in [1] they have Pima attributes, i.e. small perimeter and long fibre. These test results are also highlighted as black points in the Figures comparing the various fibre maturity measures that follow.

Figure 1 shows the theoretical relationship between XS theta and MR, calculated as $MR = 1.733T$ according to Peirce and Lord².

Whilst all relationships between XS theta values and SM and AFIS MR test results were significant – the relationships are challenged by sources of error and bias not identified here. The SM appears to show a distinct bias against Pima cottons (sample nos. 2684 & 2952). Figure 2 shows the relationship measured between XS theta and MR (SM). The two Pima-cottons show distinctly lower SM maturity values and both fall outside the

¹ Creation of a Set of Reference Material for Cotton Fiber Maturity Measurements, Hequet, E. F., Wyatt, B., Abidi, N. and Thibodeaux, D. P., *Textile Res. J.*, **76(7)**, 576-586, 2006

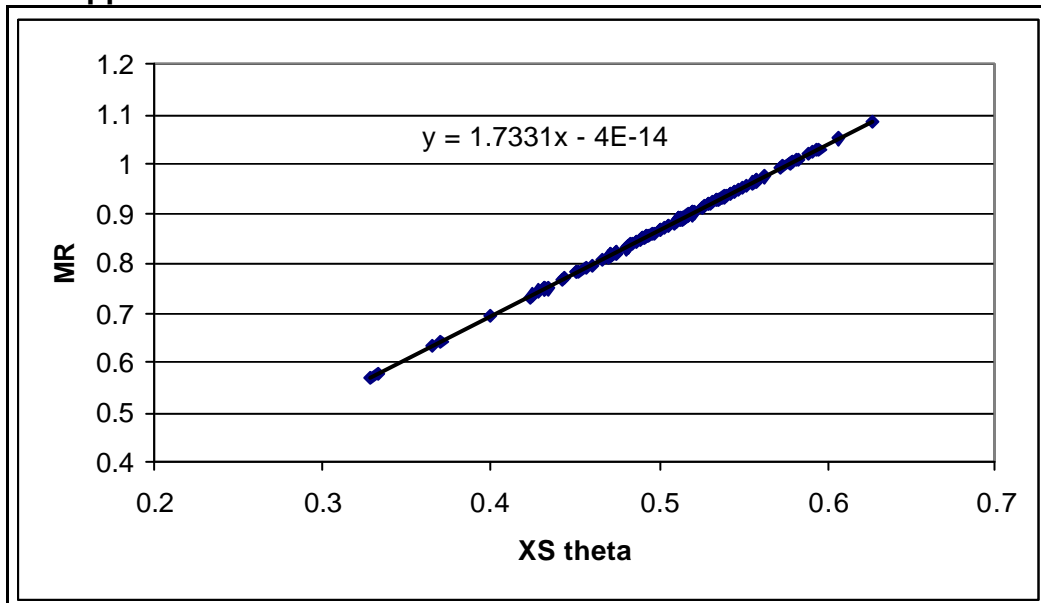
² Peirce, F. T. and Lord, E., The Fineness and Maturity of Cotton, *J. Textile Inst. (trans.)*, T173-T210, 1939

95% confidence interval (CI) applied to the set. The AFIS instruments were no better than SM in matching the XS test results; see Table II, which lists the differences between XS MR values calculated using the relationship observed in Figure 1 and MR measure by SM and the AFIS instruments. The accepted tolerance is ± 0.02 MR units³. However the AFIS data does not show the same disregard for the Pima samples, i.e. the Pima samples appear contained within the set tested (Figures 3 and 4).

Table II – SM and AFIS differences in MR

ID	XSMR ITC	MR (SM)	MR (AFIS – ITC)	MR (AFIS – CTFT)	SM diff to XSMR	MR ITC diff to XSMR	MR CTFT diff to XSMR
2684	0.90	0.83	0.88	0.91	-0.07	-0.02	0.01
3170	0.75	0.82	0.83	0.84	0.07	0.08	0.09
2952	0.93	0.81	0.89	0.93	-0.12	-0.04	0.00
3119	0.82	0.83	0.83	0.86	0.01	0.01	0.03
3122	0.94	0.91	0.91	0.93	-0.03	-0.03	-0.01
3138	0.78	0.87	0.85	0.87	0.09	0.07	0.09
3152	0.89	0.85	0.89	0.92	-0.04	0.00	0.03
3165	0.92	0.88	0.84	0.86	-0.04	-0.08	-0.06
3042	0.90	0.89	0.90	0.93	-0.01	0.00	0.03
3159	0.85	0.87	0.82	0.84	0.02	-0.03	-0.01
3143	1.03	0.94	0.95	0.94	-0.07	-0.06	-0.07
3196	1.00	0.92	0.87	0.88	-0.08	-0.13	-0.12
MR within ± 0.02					3/12	4/12	4/12

Figure 1 – Relationship between Theta and MR as measured by Peirce and Lord and applied to the 104 ITC Reference Cottons



³ Riley, R. and Schleth, A., Comparison between CSIRO SiroMat and AFIS test results on maturity, 2007.

Figure 5 shows the relationship between SM MR and ITC MR, which is poor and not significant at the 5% level. The two Pima samples again fall outside the relationship described between these two sets of numbers.

The relationship between the two AFIS instruments; MR ITC and MR CTFT (Figure 6) is relatively good.

Action Points & Considerations

We are unsure about why the Pima cottons (samples) are not represented by SM in the same way as the Upland cottons. We note that the relationship between MR SM and XS theta improves significantly if the two Pima cottons are removed from the set. The same does not happen if these cottons are removed from the relationships between XS theta and MR ITC and MR CTFT.

We are currently using the 104 reference cottons to re-calibrate SM (with XS MR values) and will contact EH at ITC to ask him to highlight other Pima samples within the reference set so we can pay particular note to them. It may be that we have another SM calibration for Pima cottons. To this end we have obtained bale samples of Australian Pima and Upland cottons of this year's Australian crop grown on the same farm (located in an area that traditionally grows Upland rather than Pima cotton). We'll run the samples through the SM and AFIS to see what happens and compare them with MIC from HVI analysis.

With regards to using polarized light microscopy to measure the maturity of Pima cotton we note brief cautionary statements in the literature from previous workers in this field about interpreting the interference colours transmitted by Pima cotton but no experimental proof of any measured differences. In our own work we note that:

1. There is no difference in the hue or intensity of the interference colours transmitted by mature (yellow) fibres with a range of cell wall areas from across three species of cotton including Upland, Pima and tree cotton.
2. There is no change in hue when fibres are swollen in strong caustic soda.
3. It was difficult to find truly mature Pima fibre, i.e. bright yellow fibres, in the sample we used (an ICCS Pima) in the above survey of interference colours observed in cotton fibres.
4. In tracing the growth of Upland and Pima fibres from anthesis using SM; that Upland fibres matured more quickly and completely under glass house conditions than a Pima cotton.

Regression Analysis: MR (SM) versus XSttheta

The regression equation is

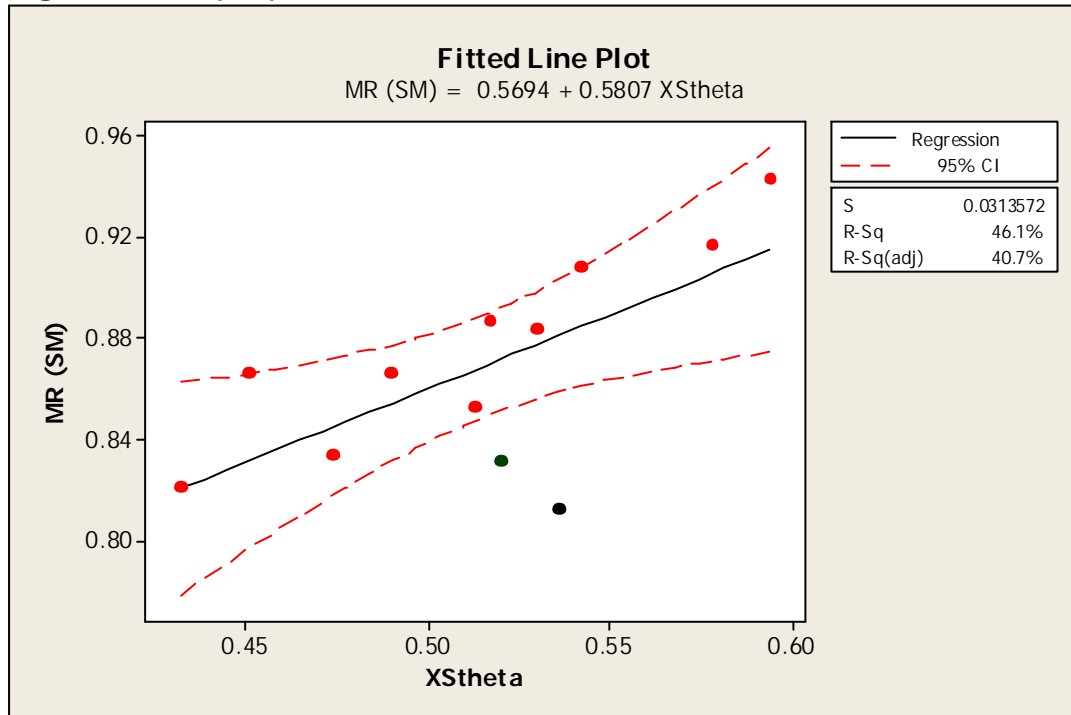
$$\text{MR (SM)} = 0.5694 + 0.5807 \text{ XSttheta}$$

S = 0.0313572 R-Sq = 46.1% R-Sq(adj) = 40.7%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0084065	0.0084065	8.55	0.015
Error	10	0.0098327	0.0009833		
Total	11	0.0182392			

Figure 2 - MR (SM) versus XSttheta



Regression Analysis: MR (ITC) versus XStheta

The regression equation is

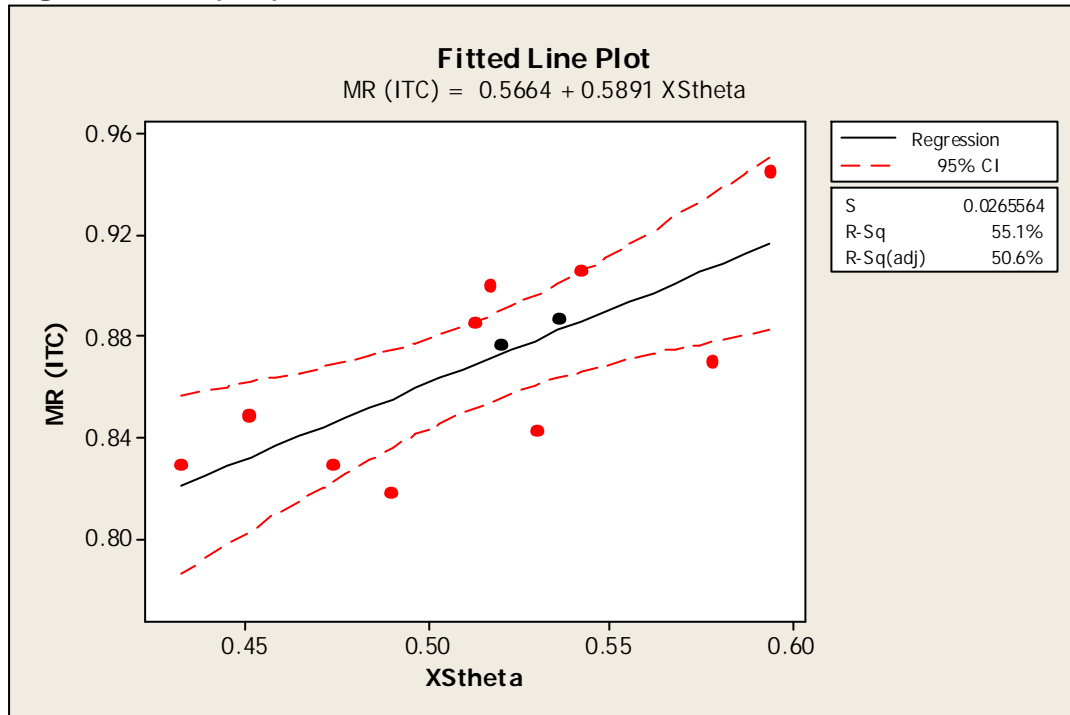
$$\text{MR (ITC)} = 0.5664 + 0.5891 \text{ XStheta}$$

S = 0.0265564 R-Sq = 55.1% R-Sq(adj) = 50.6%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0086505	0.0086505	12.27	0.006
Error	10	0.0070524	0.0007052		
Total	11	0.0157029			

Figure 3 - MR (ITC) versus XStheta



Regression Analysis: MR (CTFT AFIS) versus XSttheta

The regression equation is

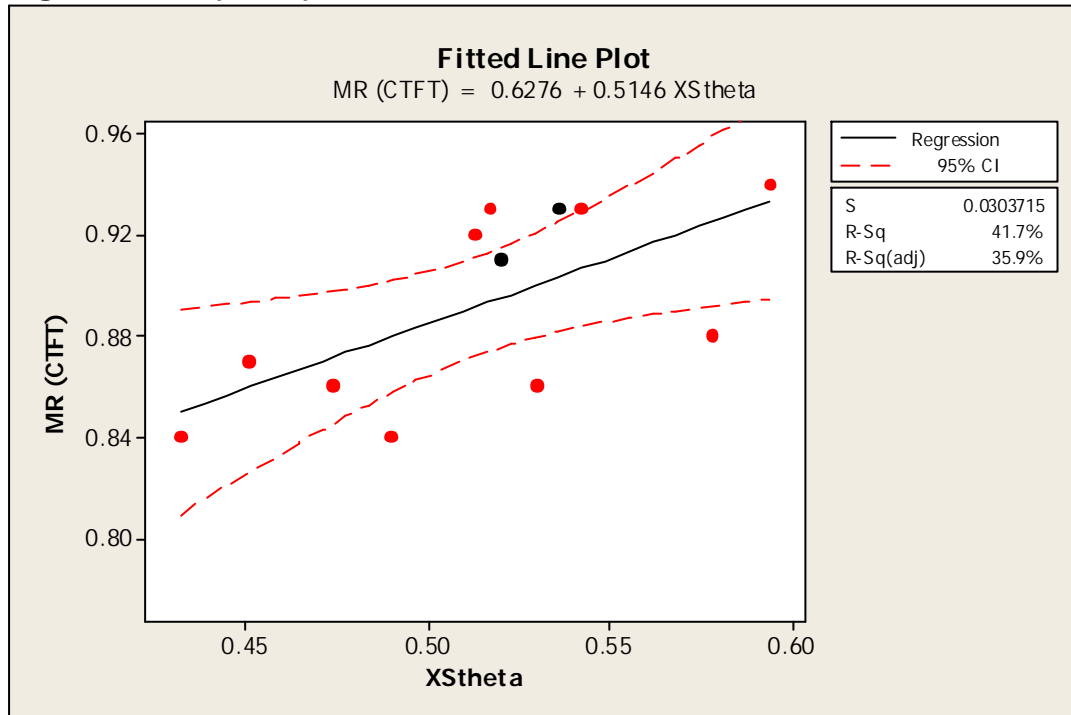
$$\text{MR (CTFT AFIS)} = 0.6276 + 0.5146 \text{ XSttheta}$$

S = 0.0303715 R-Sq = 41.7% R-Sq(adj) = 35.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0066007	0.0066007	7.16	0.023
Error	10	0.0092243	0.0009224		
Total	11	0.0158250			

Figure 4 - MR (CTFT) versus XSttheta



Regression Analysis: MR (SM) versus MR (ITC)

The regression equation is

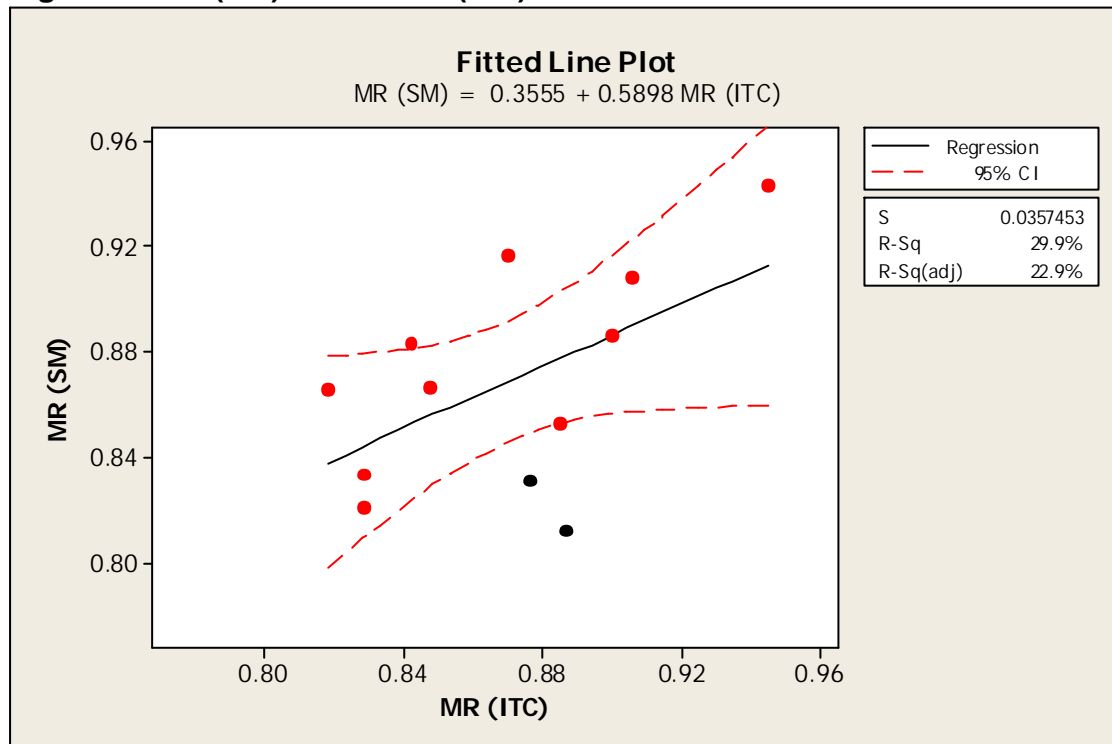
$$\text{MR (SM)} = 0.3555 + 0.5898 \text{ MR (ITC)}$$

S = 0.0357453 R-Sq = 29.9% R-Sq(adj) = 22.9%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0054620	0.0054620	4.27	0.066
Error	10	0.0127773	0.0012777		
Total	11	0.0182392			

Figure 5 - MR (SM) versus MR (ITC)



Regression Analysis: MR (ITC) versus MR (CTFT)

The regression equation is

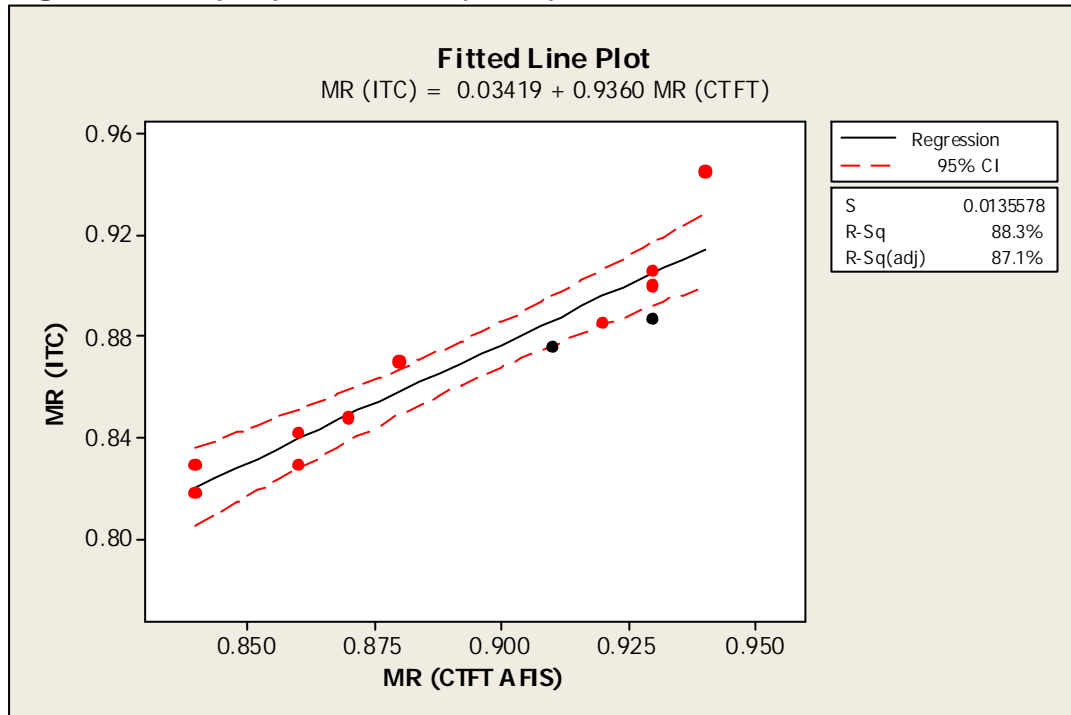
$$\text{MR (ITC)} = 0.03419 + 0.9360 \text{ MR (CTFT AFIS)}$$

S = 0.0135578 R-Sq = 88.3% R-Sq(adj) = 87.1%

Analysis of Variance

Source	DF	SS	MS	F	P
Regression	1	0.0138648	0.0138648	75.43	0.000
Error	10	0.0018381	0.0001838		
Total	11	0.0157029			

Figure 6 - MR (ITC) versus MR (CTFT)



Mill Processing Request

Project: SiroMat Commercialisation

Project Leader: Stuart Gordon

Customer: Uster/CRDC

Cost Code: LJ66A

Date: 10/9/07

Date Required: ASAP

Prepare ring-spun yarns from (8) cotton samples of similar MIC but different MAT provided by Greg Constable.

ACRI ID	CTFT ID
531 mv - 38	RLL GC 061
531 mv - 55	RLL GC 062
531 mv - 58	RLL GC 063
531 mv - 70	RLL GC 064
531 mv - 71	RLL GC 065
531 mv - 44	RLL GC 066
531 mv - 50	RLL GC 067
531 mv - 67	RLL GC 068

1. Prepare 3 x 42 gram replicates through miniature card and drawframe.
2. Draw each replicate through Truetzschler drawframe ready for roving.
3. Prepare roving of nominal weight ~740 tex; 1 roving bobbin per replicate.
4. Spin two yarn bobbins from each roving replicate; 20 tex yarn with twist factor $ae = 3.7$.
 - Test both yarn bobbins (Count, Uster Evenness Tester; CV, U%, IPI, hairiness and trash, and Tensorapid) before winding; to give 8 x 3 x 2 = 48 yarn tests.
 - Wind, clear and wax yarn bobbins from each replicate into small package for knitting; to give 3 x replicate yarn packages per cotton.
5. Knit replicate yarn packages in series with ID band between each replicate and each cotton. Use 3.5 inch FAK 24 gauge knit machine with cover factor of 1.37. Knitted sections should be same length, ~ 15 cm for each replicate and cotton.

Label fabric sections in small letters in lower left hand corner with an indelible pen in preparation for dyeing. Sample replicates should be marked as follows, RLLGC061.1, RLLGC061.2 and RLLGC061.3.

Please see Stuart Gordon or Rob Long if any questions .

Stuart Gordon – 10/9/07

MEASUREMENT OF AVERAGE MATURITY AND MATURITY DISTRIBUTION STATISTICS BY SIROMAT IN COTTON FIBRE PICKED FROM PLANTS SUBJECTED TO DEFOLIATION TIMING TREATMENTS

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Abstract

SiroMat is an automated version of the polarized light microscopy technique, which analyzes interference colors transmitted by cotton fibres when they are placed between crossed polars and a first order retardation plate. The percent areas of colors in images of fibre snippets relate directly to fibre maturity. Moreover, because fibres are analyzed on an individual basis a maturity distribution for a sample can also be measured. In this study SiroMat measurements are reported for blends comprising different proportions of cotton fibre picked from plants subjected to differential defoliation timing treatments. The proportion of immature fibres in each sample is correlated with measurements on the same samples of neps per gram made by the AFIS PRO. The motivation behind this study is based on the desire to manage the amount of immature fruit included in a crop, and how this relates to nep generation in the gin and spinning mill.

Introduction

A cotton fibre is a single elongated plant cell that grows from the surface of a cotton seed. How thick the cell wall becomes during its development is important because it determines how well the fibre will process from both a chemical and physical perspective. The term fibre maturity is applied to describe the degree of cell wall thickening. Immature fibres, i.e. those with little or no fibre wall thickening, are associated with the formation of small entanglements called neps, irregularities in processed fibre assemblies including finished yarns, non-uniform dyeing of fabrics and decreased processing efficiency.

Because fibres do not all develop in the same way, considerable dispersion about the mean cell wall thickening of a cotton is found. This dispersion is found in all samples of cotton, from samples sourced from baled cotton to fibres taken from one individual seed. While the importance of this dispersion is by no means certain, it has been suggested that knowledge of the spread and shape of this dispersion would be of value in managing problems associated with immature fibres.

CSIRO Textile and Fibre Technology have developed the SiroMat technology that measures fibre maturity directly and automatically. The SiroMat is based on polarized light microscopy, a technique that has long been used to investigate the crystalline structures of inorganic and inert organic materials. The technique has been used extensively in the identification of fibres that exhibit birefringent properties, i.e. fibres that behave like a uni-axial optical crystal. The optical axis in birefringent fibres is usually parallel to the fibre axis with the refractive index being dependent upon the plane of polarization of the incident light. When plane polarized light is transmitted through a birefringent object the light ray is split into two mutually perpendicular vibrating fast and slow rays, which propagate through the object at two different speeds. Upon emerging from the object a phase difference occurs between the fast and slow rays. When recombined into a single ray by passage through a second polarizer (analyzer) the rays interfere with each other, which in turn create different interference colors that highlight the crystalline oriented aspects of the specimen.

The interference colors assumed by cotton fibres are the result of the optical phenomena described above and have been classified by Grimes [1] in terms of the cotton fibre maturity they represent and incorporated into a well known ASTM Standard for determining cotton fibre maturity [2]. The disadvantage of the test is that the operator must make an arbitrary assessment of the colors assumed by the fibres and the subjective decision made by the operator contributes to large discrepancies in the results from different laboratories. The Standard in fact warns against using the method for acceptance testing because of poor precision. Furthermore, the test is too slow for routine test applications both in terms of specimen preparation and test time.

SiroMat overcomes these issues by automatically scanning and analysing fibres on the basis of their interference colors. The automation means that selection of fibres and interpretation of their color is no longer subject to operator interpretation. An algorithm is used to match the interference colors that cotton fibre snippets assume with their cotton fibre maturity to produce an average value and measures of the dispersion of maturity values for the specimen. Previous work by Gordon and Phair [3] has shown that specific interference colors relate directly with theta (θ) or degree of circularity, which is generally accepted as being the 'true' expression of cotton fibre maturity [4, 5]. However, on the basis of convention measurements are expressed in terms of maturity ratio (MR) according to Pierce and Lord [6]. A MR value of 1.00 equates to a mean θ value of 0.577.

In this study the SiroMat is used to test a set of cotton samples from the same crop but each with a different maturity by dint of blending by weight 10% increments of seed-cotton from two defoliation treatments applied to the same crop. The objective is to demonstrate the ability of the SiroMat instrument to differentiate the samples on the basis of their mean and dispersion statistics, in this case the standard deviation and skew of the maturity distribution within each specimen tested. The SiroMat data is also correlated with Uster AFIS PRO nep results as a first step in measuring how well maturity dispersion statistics predict neps in fibre.

Materials and Methods

Cotton samples

Cotton plants (*Gossypium hirsutum* L. Sicot 71BR, CSIRO Australia) were grown under normal industry standard irrigated conditions at the Australian Cotton Research Institute (ACRI) (Narrabri, New South Wales).

Plants were sown on the 19th October 2005. Plants were subject to leaf defoliant and boll opener applications (200 mL/ha of Dropp, 3 L/ha of Prep, 2 L/ha of DC-tron) at 174 and at 187 days after sowing (DAS). To facilitate an early immature crop, a block of plants was subjected to additional early chemical treatments at 133 and 155 DAS.

Cotton from immature and mature plants was machine harvested separately (International single row spindle harvester). Four replicates of (each blend) this mature and immature seed cotton were randomly selected from the harvest and thoroughly blended together by hand at 11 different proportions based on weight (100% mature: 0% immature down to 0% mature: 100% immature, in 10% increments). Samples were saw ginned using a 20 saw gin located at the ACRI.

Instrument Testing

Test samples for the SiroMat and AFIS PRO were blended through one passage of a 'Shirley' Analyser.

Samples for the AFIS PRO were passively conditioned for at least 48 hours under standard conditions (20°C +/- 2°C and 65% relative humidity +/- 3%) before testing and then prepared according to the manufacturers instructions.

Preparation of SiroMat specimens involves guillotining a fibre beard prepared using a 'Fibrosampler' to obtain between 2 to 3 mg of 1 mm snippets from two cuts near the aligned end of the beard. The snippets are collected and then spread in an annular pattern on a 5 cm x 7 cm glass slide using an OFDATM fibre spreader. A clean 5 cm x 7 cm slide is used to cover the specimen. Castor oil (refractive index = 1.477 – 1.481) is used as the mounting medium to enhance the contrast of the fibre snippets to their background.

Preparing the SiroMat instrument is relatively simple and involves adjusting the digital camera settings (U balance, V balance and shutter speed) and the microscope lamp intensity to match a prescribed background (magenta) color in terms of red, green and blue ratios. Background colors were also checked at regular intervals during testing to minimize drift in instrument readings.

Data Analysis

Four SiroMat and five AFIS PRO test specimens were drawn from each blend sample for testing. Table I lists the mean SiroMat and AFIS PRO values of each blend ratio along with the standard deviation and coefficient of variation of replicate measurements for each blend.

Differences in SiroMat values between 100% mature and 100% immature treatments were tested by way of a two-tailed Student t-test ($n = 16$). In order to examine the sensitivity of SiroMat data to variations in percent maturity, the mean and standard deviation of the distribution in each blend sample were regressed against the nominal percent mature fibre for each of the 11 blended 'maturity' portions (Figs. 2 and 3). Using percent mature fibre as the dependent variable, the standard error of estimate (SEE) was calculated to provide a measure of the SiroMat's accuracy and precision.

The relationship between SiroMat mean and dispersion measurements were also plotted to determine the significance of any correlation (Figs. 4 and 5). A highly significant correlation between a mean and the dispersion of values about it suggests that the dispersion statistic would be of little value in describing the sample further.

Finally the SiroMat mean and standard deviation and skew of the distribution around each mean were plotted against AFIS PRO nep results (Figs. 6, 7 and 8).

Results and Discussion

Figure 1 shows the accumulated distributions (for the four blend replicates) of 100% mature and 100% immature blend samples. Noticeable is the negative skew and long immature tail of each distribution. In our experience the characteristics of these maturity distributions are common to all cottons. Despite apparent similarities in distributions mean MR values for 100% mature and 100% immature blend samples were significantly different ($p = 0.0001$). Significant levels of difference also apply to measurements of the standard deviation of maturity distribution (SDMR) ($p = 0.0085$) and the skew of maturity distributions (SKMR) ($p = 0.0340$).

The regression of mean MR (as independent variable) with percent mature fibre (Fig. 2) gave a co-efficient of determination (r^2) of 0.975 with a SEE of 5.49% for percent mature fibres in each blend. Given the narrow range examined here; mean MR ranged from 0.88 to 0.98, these data demonstrate SiroMat's ability to distinguish small changes in fibre maturity. This predictive ability also extends to the SiroMat measure of SDMR measured in the blend samples (Fig. 3). As an independent variable SDMR produced a SEE of 7.90% for percent mature fibres in each blend. However, the high correlation, and the significant correlation observed between mean MR and SDMR (Fig. 4) suggests that at least in the case of the blend samples examined here, SDMR is of little extra value in predicting quality and processing problems in the cotton. The relationship between mean MR and SKMR shown in Fig. 5 is also significant although the correlation suffers somewhat from a higher SD between replicates of skew values. Further testing is required to determine whether or not the higher SD between reps is associated with random error or real differences between replicates.

The proposal that SiroMat data can be used to predict nep levels is examined in Figs. 6 to 8, which show scatterplots of mean MR, SDMR and SKMR versus AFIS PRO nep results. Each relationship is quite poor in terms of regression statistics, which in part is a reflection on the small amount of mechanical pressure applied to each sample; mechanical processing was limited to passages through a small laboratory gin and one passage of a 'Shirley' Analyser, and the narrow range of mean MR examined here. We note also that the SD between nep replicates decreased with increasing fibre maturity (Table I). We suspect the more immature fibre specimens behave differently during fibre individualization in the AFIS instrument.

In retrospect additional lint cleaning passages may have created a better illustration of the relationship between immaturity and nep creation. It is noted that more than 70% of neps measured in baled cotton are generated through two-lint cleaner passages [7]. Nevertheless the relationships between SiroMat values and nep count are consistent with expected theory, i.e. that nep levels increase with increasing proportions of immature fibre in the distribution. Further study is required to take into account factors such as fineness, fibre length, variety (inc. agronomic factors) and different gin conditions before more definite judgments on the relationship between mean MR, SDMR, SKMR and nep formation can be made.

Table I– AFIS PRO and SiroMat mean and replicate data

Sample % Blend	AFIS PRO			SiroMat Mean and Replicate Data							
	Neps	SD Nep Rep	Mean MR Dist	SD MR Rep	CV% MR Rep	SD MR Dist	SD SDMR Rep	CV% SDMR Rep	Skew MR Dist	SD SKMR Rep	CV% SKMR Rep
100% Immature	269	74	0.88	0.02	2.27	0.53	0.03	5.66	-2.70	0.27	10.00
90/10	233	51	0.89	0.02	2.25	0.51	0.03	5.88	-2.78	0.19	6.83
80/20	244	45	0.89	0.02	2.25	0.52	0.02	3.85	-2.83	0.21	7.42
70/30	297	79	0.90	0.02	2.22	0.51	0.01	1.96	-2.93	0.16	5.46
60/40	229	78	0.92	0.02	2.17	0.48	0.03	6.25	-2.98	0.25	8.39
50/50	270	80	0.93	0.01	1.08	0.48	0.01	2.08	-2.98	0.13	4.36
40/60	200	38	0.94	0.02	2.13	0.47	0.03	6.38	-3.10	0.21	6.77
30/70	252	26	0.94	0.02	2.13	0.46	0.02	4.35	-3.23	0.20	6.19
20/80	179	26	0.95	0.02	2.11	0.46	0.02	4.35	-3.20	0.13	4.06
10/90	162	22	0.96	0.02	2.08	0.45	0.02	4.44	-3.20	0.13	4.06
100% Mature	179	18	0.98	0.01	1.02	0.43	0.02	4.65	-3.30	0.11	3.33

SD = standard deviation, Rep = replicate, Dist = distribution, CV% = co-efficient of variation, SK = skew

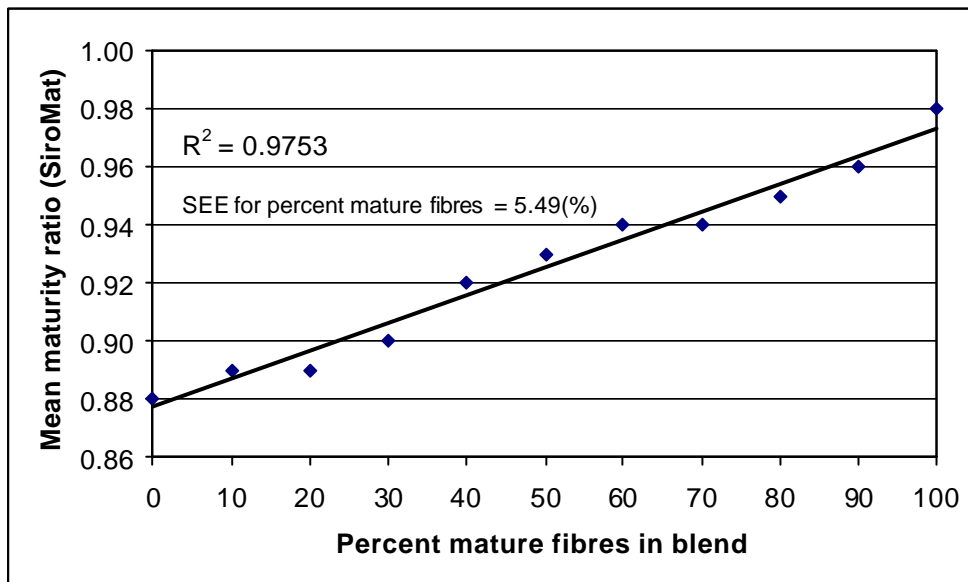


Figure 1 – Mean SiroMat maturity versus the nominal % maturity of each blend

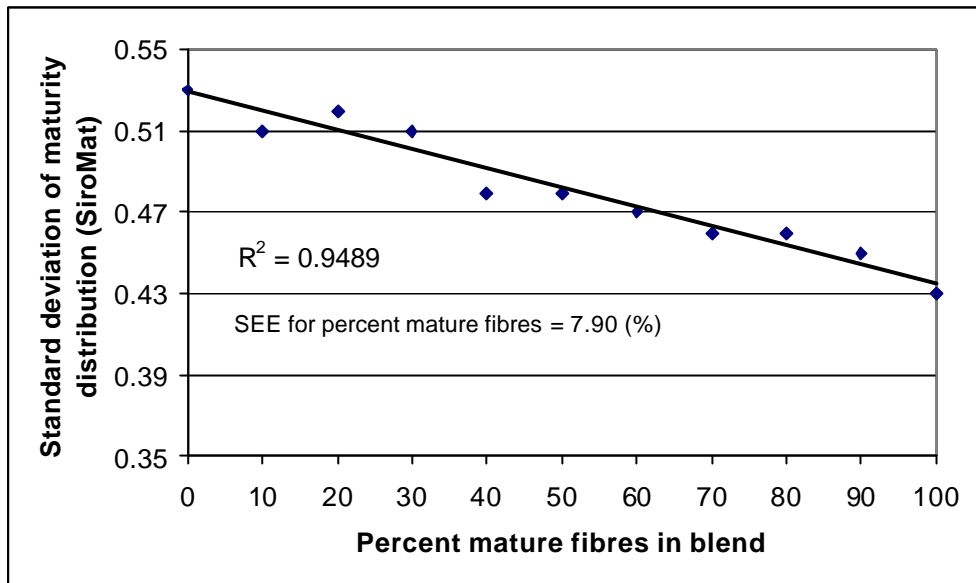


Figure 2 – Standard deviation of SiroMat maturity distribution versus the nominal % maturity of each blend

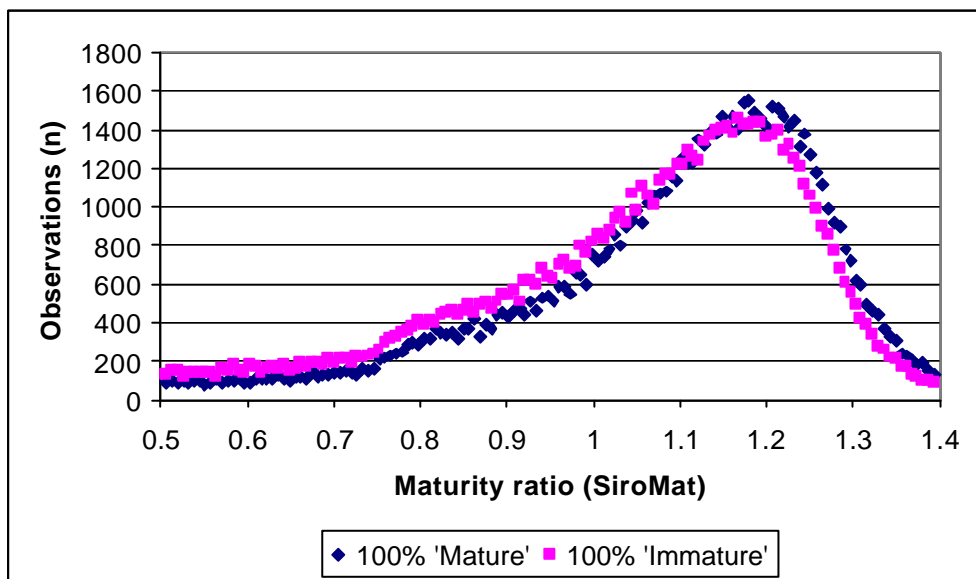


Figure 3 – SiroMat maturity distributions for 100% 'mature' and 100% 'immature' blends

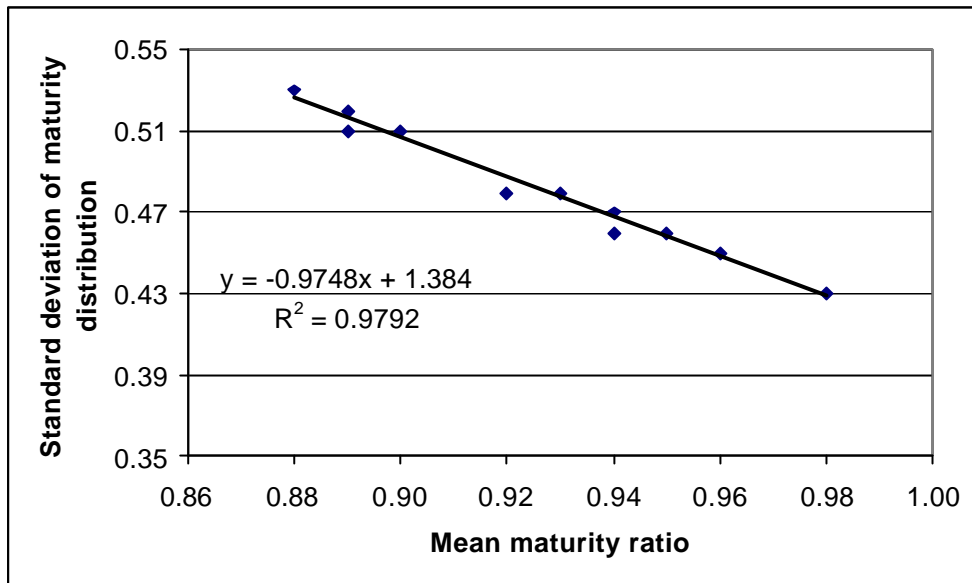


Figure 4 – Relationship between SiroMat mean maturity & the standard deviation of maturity distribution

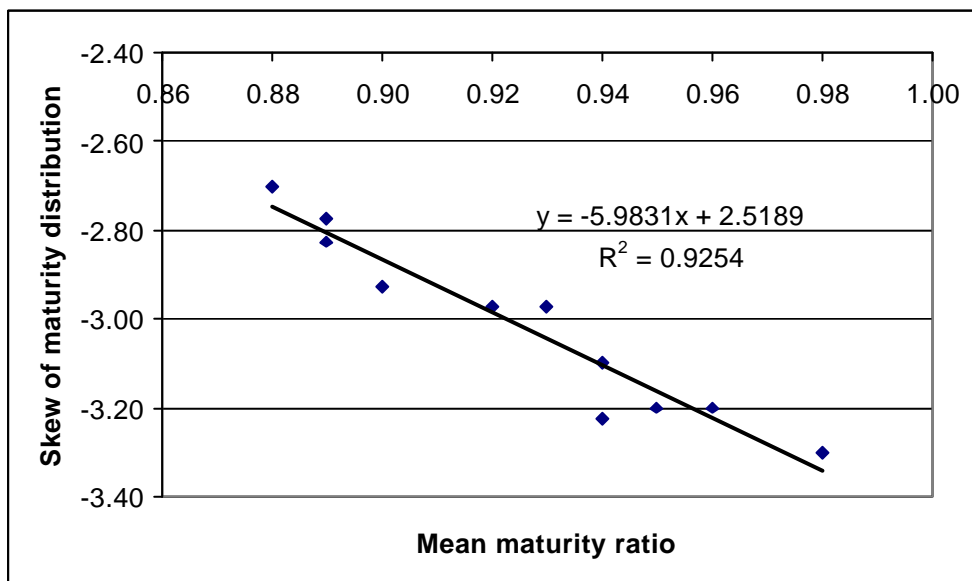


Figure 5 – Relationship between SiroMat mean maturity (ratio) & the skew of the maturity distribution

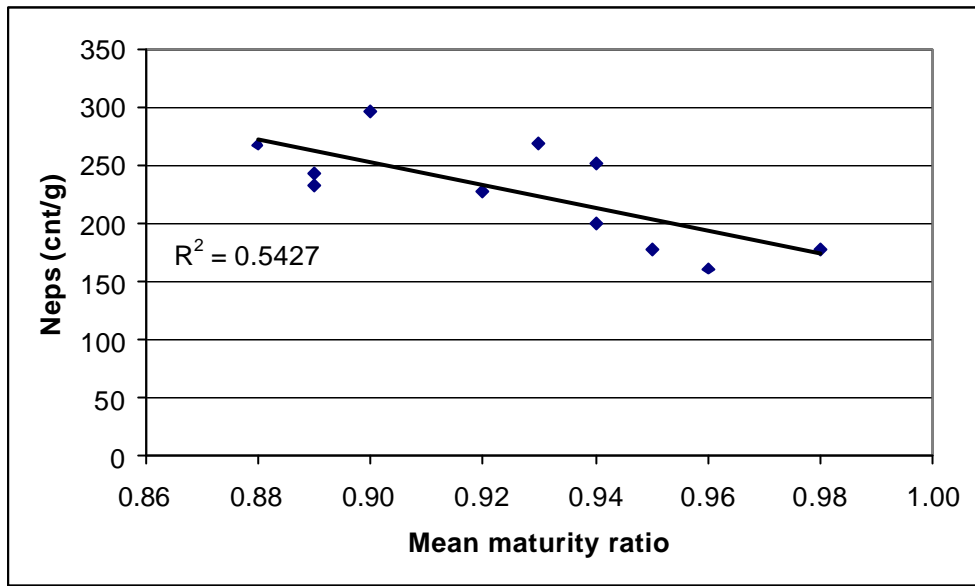


Figure 6 – Relationship between mean maturity ratio and AFIS PRO nep

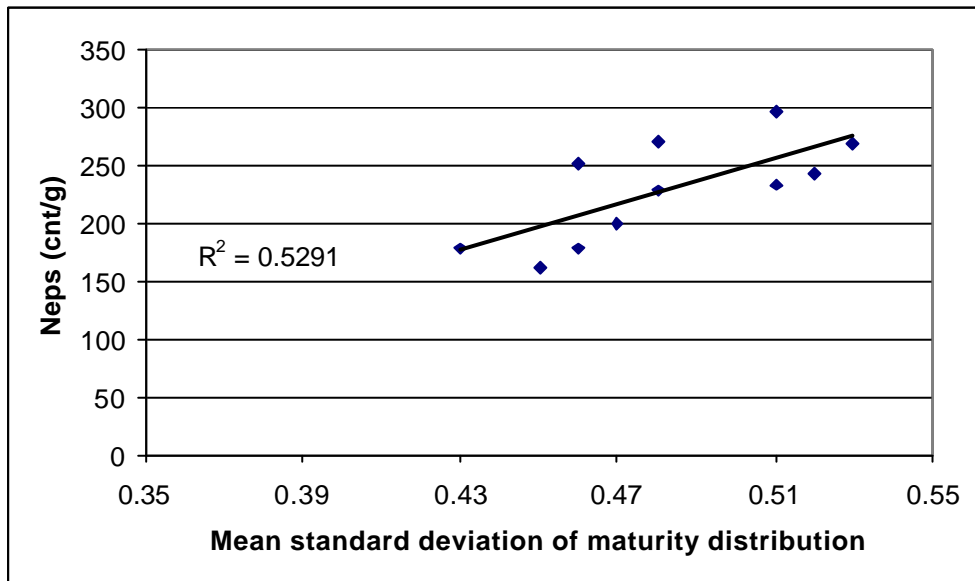


Figure 7 – Relationship between mean standard deviation of maturity (ratio) distribution & AFIS PRO nep

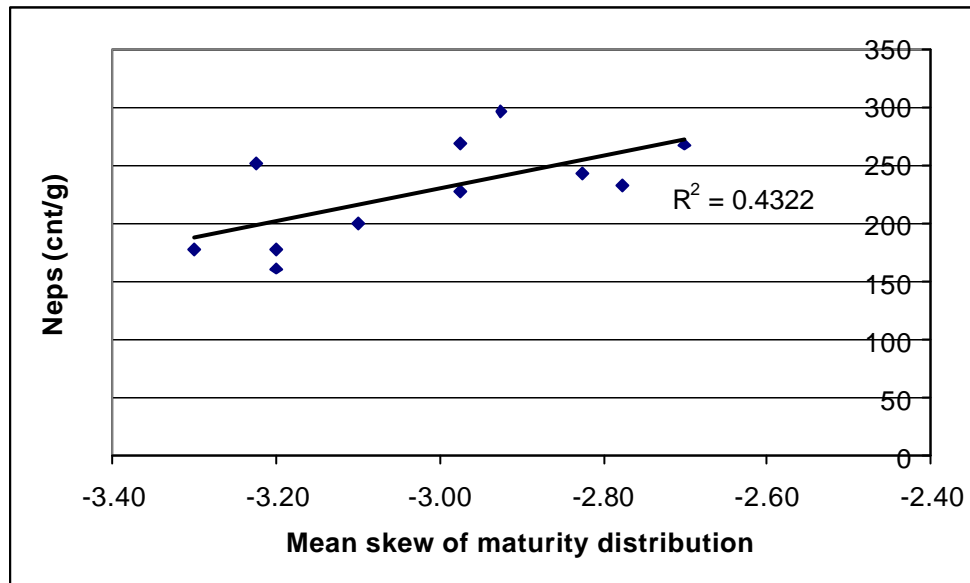


Figure 8 – Relationship between the mean skew of maturity (ratio) distribution & AFIS PRO nep

Conclusion

A set of SiroMat measurements on cotton samples that originated from two defoliation treatments shows the ability of the instrument to accurately and precisely measure the mean and the dispersion of fibre maturity in samples where the differences in mean maturity were thought to be quite small (the mean MR in this set ranged from 0.88 to 0.98). The SiroMat measurements demonstrated negative relationships exist between mean maturity and dispersion values such as standard deviation and skew. These dispersion statistics might be useful in determining nep potential or other processing problems, although it was noted that the high correlation between mean and dispersion values in this data set made the dispersion statistics redundant in terms of nep prediction. Further work is required on a sample set that includes different varieties raised and processed under different environmental, agronomic and gin conditions.

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USING SIROMAT TO DISTINGUISH FIBRE MATURITY RELATED ISSUES IN THE MILL

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Abstract

Fibre maturity is regarded as a central characteristic of cotton fibre through its direct and indirect correlation with physical and chemical properties of commercial and technical importance. SiroMat is an automated version of the polarized light microscopy technique, which analyzes interference colours transmitted by cotton fibres when they are placed between crossed polars and a first order retardation plate. The percent areas of colours in images of fibre snippets relate directly to fibre maturity. Moreover, because fibres are analyzed on an individual basis a maturity distribution for a sample can also be measured. In this study two sub-sets of cotton each with the same average Micronaire but with different fibre maturity values as measured by SiroMat were processed from raw fibre through to dyed finished knit fabric. The objective of the study was to examine the sensitivity of SiroMat average maturity and distribution values in predicting differences in grieve yarn and dyed fabric quality. Results of the study demonstrate the relevance of SiroMat test results in terms of predicting fibre maturity and fineness related quality problems and in particular the potential for SiroMat to be used as a tool for managing dye uptake problems at the mill laydown.

Introduction

From the spinners' perspective, both fibre maturity and fineness are key parameters in determining mill productivity and quality. For example, yarn is specified in terms of its weight per unit length and fibre linear density or fineness determines the number of fibres in a given yarn cross-section. The use of finer fibres increases the number of fibres in the cross section of a given yarn, which improves spinning efficiency and yarn evenness. Equally cotton fibre maturity is an important property to spinners and fabric manufacturers. Whilst many textile processing stages in the transformation of fibre through to fabric are sensitive to fibre properties that are contiguous with fibre maturity, the property of fibre maturity *per se* is more often not the dominant factor [1] in the same way that fineness, staple length and bundle strength dominate yarn quality parameters. The exception is perhaps the non-uniform dyeing of fabric; manifest as shade bands and repeats along fabric lengths, colour yield, barré and under-dyed or undyed neps, which is directly related to fibre maturity variations in the cotton being processed.

A central problem in managing fibre fineness and maturity has been the absence of accurate and convenient test methods to assess these properties. CSIRO Textile and Fibre Technology have developed the SiroMat technology that measures fibre maturity directly and automatically using polarized light microscopy [2]. The interference colors transmitted by cotton fibres under this system are the result of the optical phenomena where cotton fibres behave like uni-axial optical (birefringent) crystals under polarized light. Previous work has shown that specific interference colours vary directly with theta (θ) [3], which is generally accepted as being the 'true' expression of cotton fibre maturity [4].

By combining SiroMat values of maturity, which are calibrated in terms of maturity ratio, with the specimen's Micronaire value a measure of fineness can also be calculated using Lord's quadratic [5].

The objective of this study was to examine the sensitivity of SiroMat average maturity and distribution values (standard deviation and skewness values) in predicting differences in grieve yarn and dyed fabric quality. Results of the study demonstrate the relevance of SiroMat test results in terms of predicting fibre maturity related quality problems such as non-uniform dyeing, and the potential for SiroMat to be used as a tool for managing mill laydowns.

Materials and Methods

Eight, small fibre samples (150 grams) of CSIRO pre-release cotton varieties grown on experimental plots at the Australian Cotton Research Institute (ACRI) in Narrabri, NSW were selected and processed through to a dyed knit fabric. The fibre samples were selected on the basis of having the same or similar Micronaire value but different maturity and fineness combinations. Table I lists the primary properties of the samples (designated A through to H) determined by an Uster Technologies 1000 high volume instrument (HVI). Two equal sub-sets are evident in the set of samples collected; one sub-set with samples having Micronaire values around 4.8 and one with Micronaire values of 4.4.

Specimens of each cotton sample were prepared for SiroMat testing by blending them through one passage of a 'Shirley' Analyser. Specimen preparation then involves guillotining a fibre beard prepared using a 'Fibrosampler' to obtain between 2 to 3 mg of 1 mm snippets from two cuts near the aligned end of the beard. The snippets were collected and then spread in an annular pattern on a 5 cm x 7 cm glass slide using an OFDA™ fibre spreader. A clean 5 cm x 7 cm slide was used to cover the specimen. Castor oil (refractive index = 1.477 – 1.481) was used as the mounting medium to enhance the contrast of the fibre snippets to their background. Preparing the SiroMat instrument involved adjusting the digital camera settings (U balance, V balance and shutter speed) and the microscope lamp intensity to match a prescribed background (magenta) colour in terms of red, green and blue ratios. Background colours were also checked at regular intervals during testing to minimize drift in instrument readings. Three specimens were tested per sample.

SiroMat maturity ratio (M) results were combined with HVI Micronaire (X) results to calculate fibre linear density or fineness (H) using Lord's quadratic equation [5] – see Equation (1). Table II lists the measured and derived SiroMat test results for each cotton sample.

$$MH = 3.86X^2 + 18.16X + 13 \quad (1)$$

Spinning

One hundred and twenty-six grams (3 x 42 g lots) of machine harvested ginned lint (not lint cleaned) was sub-sampled from each experimental sample. Each 42 g lot was separately carded twice and drawn once using a 'Shirley' miniature spinning plant card and draw frame (Platt brothers, England); machine settings (e.g. roller distances and draft ratio) were constant for all samples. The four miniature drawn slivers were then drawn together once using a Trützschler HSR1000 draw frame. The resulting single sliver was converted into twisted roving using a Zinser 660 roving frame, which was then spun into yarn using a Zinser 350 ring spinning frame. For the full-scale processing, draft and twist was optimised for each sample to deliver a 20 tex yarn with a twist factor (ae) of 4.0 (798 turns per metre). Yarn bobbins were collected (two per sample) and tested for count, evenness (Uster Tester 4) and tensile (Uster Tensorapid) properties using industry standard methods. Table III lists standard yarn test results for each cotton sample.

Knitting and Dyeing

Yarn bobbins were waxed and wound but not cleared onto packages for knitting into fabric. Yarns were then knitted with a cover factor of 1.32 and a tightness factor of 15.4, on a Lawson Hemphill 10 inch F.A.K. knitting machine.

Knitted fabric was scoured and then dyed with Cibacron blue LS3R (1%) reactive dye. Colour measurements ($L^*a^*b^*$) were taken of fabrics illuminated using a D65 source at 10 degrees in a Gretag-Macbeth Color-Eye 7000A spectrophotometer. Average $L^*a^*b^*$ values (Table IV) represent nine spectrophotometric measurements taken in different places along the length of fabric from each cotton sample. Table V lists the ΔE values between each sample.

Selected dyed fabric samples (A, D, F & H) were also subject to extended pilling tests using the Atlas Random Tumble method [6]. Fabric samples were graded at 10 minute intervals up to 30 minutes and then subject to an additional 30 minutes treatment in the device. Fabric weight was recorded before and after the treatment in order to determine fibre loss.

Data Analysis

Fibre, yarn and fabric property results for each sample were cross-correlated using Minitab 15.1 to determine significant inter-relationships between samples in the set, and the fibre properties best used to predict yarn and fabric quality. The emphasis in this analysis is to investigate the ability of the SiroMat instrument to predict product quality in a mill. Table VII lists the primary fibre, yarn and fabric properties examined in the discussion. Significance was measured in terms of the Pearson Correlation Co-efficient (r) and the (linear) relationship probability. Whilst a linear relationship may not accurately describe particular relationships here, it is satisfactory in describing the significance of differences between extreme values in the small sets ($n = 8$) examined here.

Colour differences between the dyed fabric samples were measured in terms of ΔE on the CIELAB system [7], which allows for differences to be better recognised in surface colours. ΔE describes the mathematical distance between two colours, e.g. $L_1a_1b_1$ and $L_2a_2b_2$, where $L_1a_1b_1$ might, although not in the case here, be a reference colour – see Equation (2).

$$\Delta E = \text{SQRT} (L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2 \quad (2)$$

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

The cotton samples were grown and harvested under near commercial conditions and as such reflect fibre maturity and fineness values that might be expected in similar grade cottons for a particular season. The range of maturity values in the set as measured by SiroMat was 0.90 to 0.98. According to Lord and Heap [3] this range qualifies all cottons in the set as being ‘mature’ or ‘above average’ in maturity; the ‘mature’ range extending from 0.85 to 0.95 and the ‘above average’ range extending from 0.95 – 1.00. From this perspective none of the cotton samples selected rate as being dangerous in terms of the impact their maturity (or fineness) might have on processing efficiency or product quality.

Of the samples in the set, sample H is nominally the best on the basis of its length (1.31 inches), strength (35.3 g/tex), fineness (171 mtex) and maturity (0.98). These properties clearly enabled a yarn with the best evenness and tensile properties to be spun (see Table III). In terms of fabric properties, sample H achieved a deeper colour (lowest L^* value) as dyed fabric, and exhibited, albeit together with a sample (F) with the lowest measured maturity, the best pilling grade after extended tumbling treatment. The pilling results whilst completed in triplicate and conducted according to the ASTM Standard [6] rely on subjective assessment and must therefore be viewed with caution.

Following the above example, examination of the correlation coefficient matrix (see Table VII) shows that fibre fineness measured either as Micronaire or linear density, staple length and bundle strength have a strong influence on basic yarn quality parameters such as evenness, imperfections and tenacity. No fibre maturity measurements were highlighted as being significant contributors to yarn properties.

However, average SiroMat maturity ratio and the SiroMat measure of the skew of the fibre maturity ratio distribution were strongly associated with bulk dye uptake measured in this study by reflectance (L^*) (lightness) measurements on the dyed fabric. Fabric samples constructed from more mature fibre, e.g. a maturity ratio > 0.94 , dyed a deeper blue colour (lower reflectance) than samples with maturity ratio values < 0.94 by virtue of the greater uptake of blue dyestuff by the secondary cellulose of the more mature cotton. Skew values indicate that more mature cottons have a longer immature tail. This relationship has been described previously [8]. Figure 1 illustrates a typical fibre maturity distribution and the long immature tail of ‘mature’ cotton, as measured by SiroMat. Figures 2 and 3 illustrate the relationship between reflectance measurements and average maturity and the skew of a fibre maturity distribution. Relationships between fibre properties and actual colour (hue) values, a^* (red-green) and b^* (yellow-blue) were subdued because the hue components of the CIELAB colour system are not significantly affected by the achromatic changes measured by L^* .

The extent of the differences in dye uptake between cotton samples in this set as a result of their different maturity properties is demonstrated by calculating the ΔE values between pairs of the samples. Table V lists the ΔE values. Noted is that sample F, which has the lowest maturity ratio value (0.90) records ΔE values close or in excess of one for 4 out of the five more mature samples, i.e. A, B, C and H in the set.

Conclusion

In this study we have demonstrated the value of SiroMat maturity, maturity distribution and calculated fineness values to predict primary quality in yarn, fabric and dyed fabric. Calculated fibre fineness from HVI Micronaire and SiroMat maturity ratio values was very strong in predicting yarn evenness and imperfections, whilst SiroMat skewness of the maturity distribution and average maturity ratio were strong in predicting dye shade variation. Interestingly, significant shade variation between samples occurred even though the range of maturity ratio values was between 0.90 and 0.98, which by convention would classify all samples examined as being ‘mature’ or ‘above average’ in maturity. The results show that mixing (yarn) samples that differ in terms of their maturity ratio scale by > 0.04 maturity ratio units will create dye shade problems, i.e. $\Delta E > 1.00$, irrespective of the fibre being ‘immature’.

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Table I – HVI Test Results

Sample	LEN (inches)	SFC (%)	STR (g/tex)	MIC ($\mu\text{g}/\text{inch}$)
A	1.18	9.1	30.6	4.8
B	1.20	10	31.4	4.8
C	1.21	8.9	31.7	4.9
D	1.21	8.3	33.4	4.7
E	1.24	9.8	31.8	4.4
F	1.26	8.7	32.9	4.4
G	1.27	9.9	32.6	4.4
H	1.31	8.2	35.3	4.4

Table II – SiroMat Test Results

Sample	SiroMat MR	SiroMat MR SD	SiroMat MR SK	SiroMat FIN
A	0.97	0.44	-2.37	194
B	0.95	0.47	-2.43	199
C	0.94	0.46	-2.28	207
D	0.93	0.48	-2.29	198
E	0.93	0.48	-2.21	180
F	0.90	0.50	-2.12	185
G	0.96	0.45	-2.41	174
H	0.98	0.44	-2.49	171

Table III – Yarn Test Results

Sample	Evenness CVm (%)	Thin -50%	Thick +50%	Neps +200%	Tenacity (cN/tex)	Elongation (%)
A	17.5	35	368	234	14.7	6.1
B	18.1	45	463	242	14.9	6.2
C	18.1	30	587	658	16.3	5.9
D	16.5	18	318	274	18.9	5.4
E	16.0	9	282	298	17.1	6.1
F	15.7	14	230	266	16.5	5.6
G	15.7	2	266	233	18.5	5.2
H	15.1	3	255	274	19.7	5.4

Table IV – Dye Uptake in Fabric Results

Sample	L	a	b
A	42.98	-2.06	-28.36
B	42.59	-1.95	-28.42
C	42.91	-2.12	-28.07
D	43.27	-2.25	-28.03
E	43.51	-2.14	-28.31
F	43.89	-2.21	-28.03
G	43.30	-2.18	-28.19
H	42.48	-2.08	-28.26

Table V – Differences in Colour (? E) between Dyed Fabric Samples

Sample	?E A vs.	?E B vs.	?E C vs.	?E D vs.	?E E vs.	?E F vs.	?E G vs.
B	0.411	-	-	-	-	-	-
C	0.301	0.497	-	-	-	-	-
D	0.471	0.834	0.387	-	-	-	-
E	0.529	0.937	0.647	0.386	-	-	-
F	0.969	1.374	0.985	0.619	0.477	-	-
G	0.374	0.775	0.412	0.175	0.247	0.609	-
H	0.515	0.235	0.470	0.840	1.031	1.432	0.828

Table VI – Differences in Pilling (Grade & Weight Loss) between Selected Dyed Fabric Samples

Sample	Pilling Grade				Weight in (g)	Weight out (g)	Fibre loss (%)
	10 min	20 min	30 min	60 min			
A	3	2.5	2	1.5	3.403	3.364	1.14
D	3.3	3	3	1.8	3.495	3.456	1.11
F	4	4	3.6	3	3.577	3.536	1.13
H	4	3.2	3.2	3	3.352	3.309	1.28

Table VII – Correlation Coefficients between Selected Fibre and Yarn and Fabric Properties

	CVm	Thin	Neps	Ten	L*	a*	b*
LEN	-0.870 <i>0.005</i>	-0.848 <i>0.008</i>	-0.181 <i>0.667</i>	0.746 <i>0.033</i>	0.051 <i>0.905</i>	-0.260 <i>0.533</i>	0.185 <i>0.661</i>
STR	-0.748 <i>0.033</i>	-0.690 <i>0.058</i>	-0.145 <i>0.733</i>	0.880 <i>0.004</i>	-0.123 <i>0.772</i>	-0.348 <i>0.399</i>	0.367 <i>0.372</i>
MIC	0.943 <i>0.000</i>	0.876 <i>0.004</i>	0.481 <i>0.227</i>	-0.587 <i>0.126</i>	-0.443 <i>0.272</i>	0.403 <i>0.322</i>	-0.093 <i>0.826</i>
SM MR	0.036 <i>0.933</i>	0.018 <i>0.967</i>	-0.145 <i>0.733</i>	0.137 <i>0.747</i>	-0.799 <i>0.017</i>	0.538 <i>0.169</i>	-0.592 <i>0.122</i>
SM FIN	0.898 <i>0.002</i>	0.833 <i>0.010</i>	0.539 <i>0.168</i>	-0.588 <i>0.126</i>	-0.146 <i>0.731</i>	0.179 <i>0.672</i>	0.150 <i>0.724</i>
SM SDMR	-0.077 <i>0.856</i>	-0.004 <i>0.992</i>	-0.018 <i>0.966</i>	-0.098 <i>0.817</i>	0.713 <i>0.047</i>	-0.433 <i>0.284</i>	0.456 <i>0.256</i>
SM SKMR	-0.063 <i>0.882</i>	-0.080 <i>0.851</i>	0.220 <i>0.600</i>	0.193 <i>0.647</i>	0.864 <i>0.006</i>	-0.579 <i>0.132</i>	0.557 <i>0.152</i>

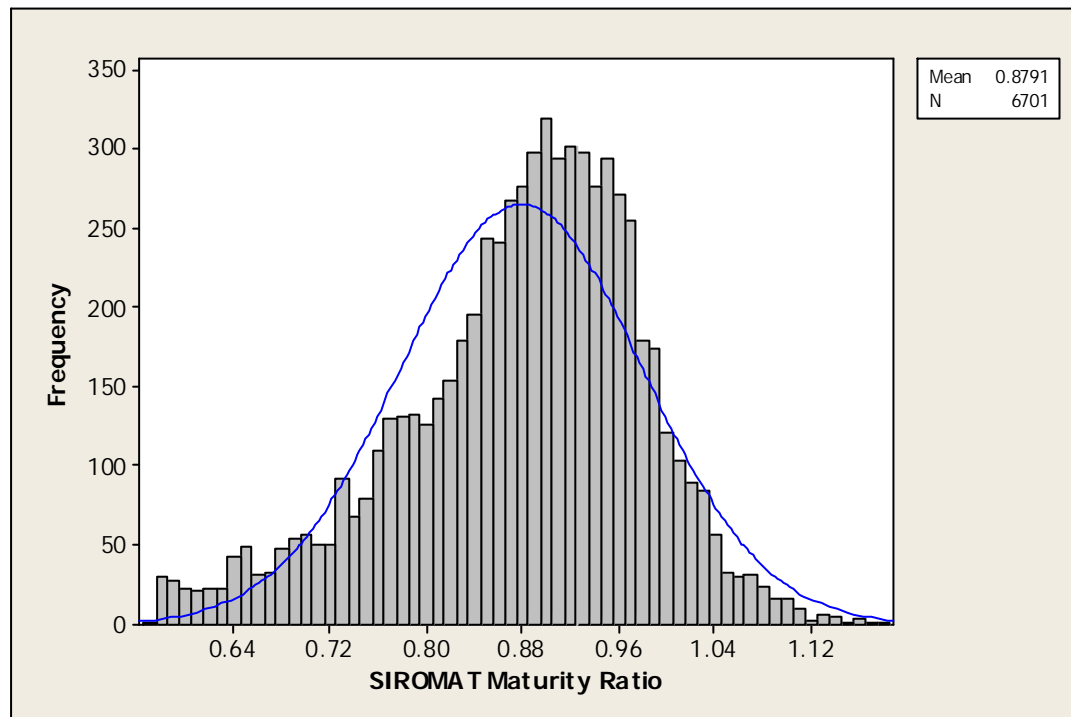


Figure 1 – Typical SiroMat MR distribution obtained for ‘mature’ cotton. Note negative skew with long immature tail for the average MR value of 0.88

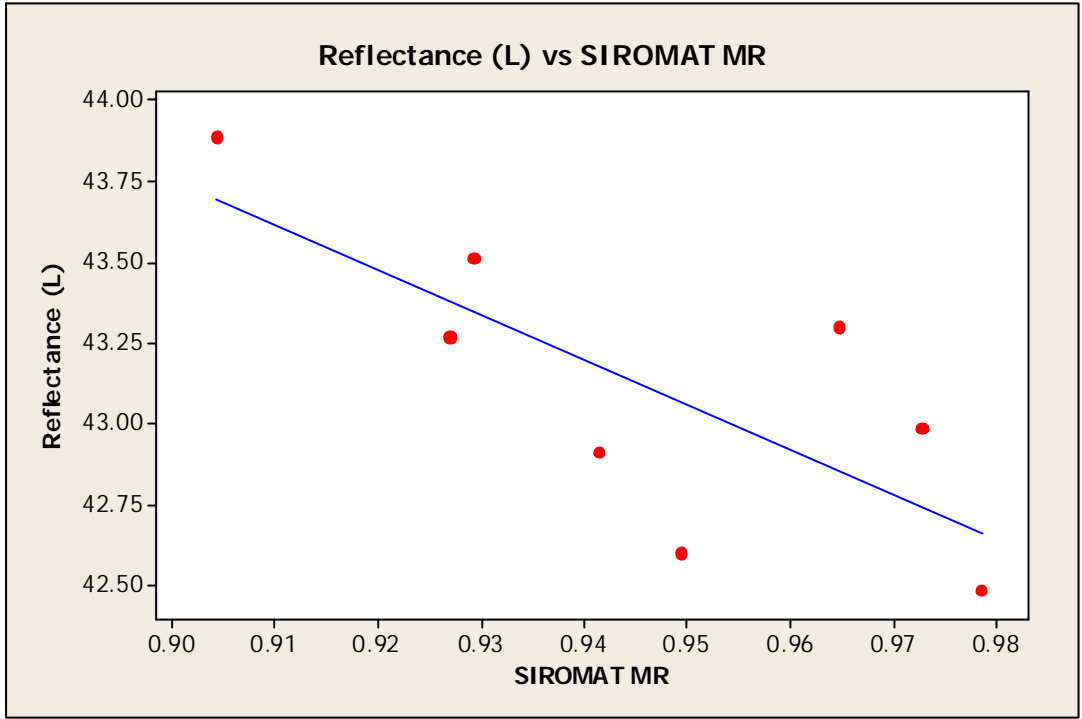


Figure 2 – Relationship between SiroMat MR and bulk dye uptake as measured by the reflectance off blue dyed knit fabric

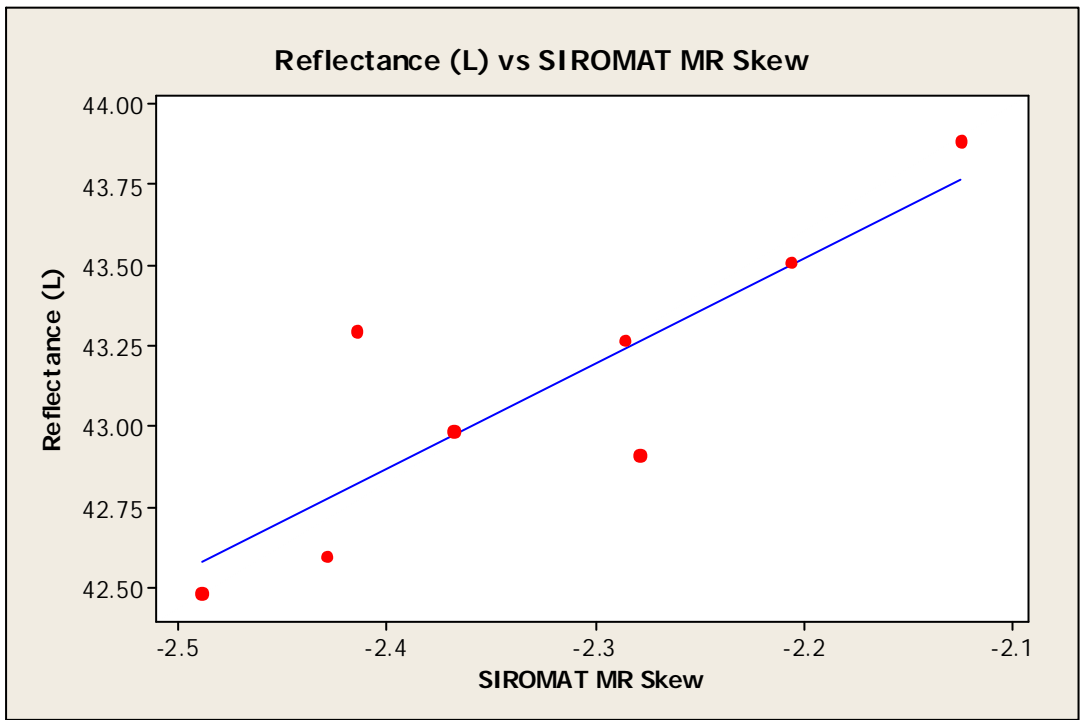


Figure 3 – Relationship between the skewness of the SiroMat MR distribution for each sample and bulk dye uptake as measured by the reflectance off blue dyed knit fabric

Assessing the Impact of Harvest Aid Timing on Fibre Quality and Textile Performance

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Abstract

Currently there are concerns relating to high micronaire, short fibre content and neps in Australian cotton. This study investigates crop management practices that aim to minimise these problems. Harvest aid treatments were systematically applied at different times from 29% to 100% open bolls for field grown *Gossypium hirsutum* plants. Yield was significantly less for treatments applied up to 56% bolls open, yet remained constant for later harvest aid treatments. The range of fibre maturity across treatments was small (maturity ratio 0.88 for the earliest cf. 0.91 for late treatment application), while micronaire and linear density were significantly less for treatments applied up to 42% open bolls, yet similar for later treatments. Nep content was high for all treatments (>250 counts/g with no lint cleaning) with later treatments trending to have less nep. The addition of lint cleaning passages was significant in generating neps. Approximately 100 neps per gram were added for each additional lint cleaner passage. No significant differences between timing of harvest aid treatments were noted for yarn performance attributes (yarn irregularities and strength for carded 20 tex ring spun yarns). There was however, a significant relationship between fabric colour intensity (b*) and time of harvest aid treatment with the earlier treatments taking up less dye. This study is part of an ongoing and larger initiative, linking crop management practices with textile performance to enhance quality at all levels of the production chain.

Introduction

In recent years there have been concerns relating to high micronaire, short fibre content and the small fibre entanglements called neps in Australian cotton (Gordon et al., 2004). In the case of the high-micronaire, it has been suggested that improvements in agronomic practices (e.g. soil and plant nutrition), which encourage better growth and yields, along with the adoption of integrated pest management strategies and the introduction of Bollgard II® (Monsanto) that improves fruit retention, coupled with years with warmer than average seasons, have all contributed to this issue. Growers in Australia are discounted when micronaire is too high or too low (optimum G5 range is 3.8 to 4.9). While there is currently no discount to growers when there is a high incidence of neps, it can affect overall industry reputation when cotton arrives at the mill.

The micronaire value represents a combination of fibre maturity, linear density and diameter. Maturity relates to the degree of thickening of the cell wall during fibre development. Immature fibres with little cell wall thickening (and which give a low micronaire value) will be more prone to nep formation during mechanical manipulation such as lint cleaning (Mangialardi and Lalor, 1990). Neps are undesirable as they decrease mill processing efficiency and typically absorb less dye and reflect light differently and may appear as 'flecks' on finished fabrics (Goynes et al., 1997; Anthony et al., 1988). Fibre immaturity has also been associated with yarn irregularities, non-uniform dyeing of fabrics and decreased processing efficiency (Gordon et al., 2004; Smith, 1991).

There are concerns that management practices that force open immature bolls to include in the harvest to increase yield or to reduce micronaire may increase the incidence of the textile issues described above. The chances of higher levels of immature fibres are also exaggerated when crops are still actively growing at the end of a season and experience an abrupt end caused by a cold finish.

Premature application of harvest aids will also cause the same effect (Anthony et al., 1988; Snipes and Baskin, 1994; Bednarz et al., 2002). The generally recommended practice for harvest aid application is to apply harvest aids around 60% or more of the bolls on a plant are open (Faircloth et al., 2004).

Recently studies by Bednarz et al. (2002) have explicitly shown that management practices such as the timing of harvest aids can increase the incidence of immature fibre. However, no studies have attempted to vary the amount of immature fibre present in the crop, quantify this, and relate this to fibre quality (including neps) and textile performance. A field experiment was conducted to systematically vary the timing of harvest aids, with the intention of generating different amounts of immature fibre at harvest and assess fibre quality and textile performance. This information will form part of a larger study that aims to develop crop management guidelines that optimise both crop yield and fibre quality that aim to meet textile production standards.

Materials and Methods

Cultural details

An experiment that systematically imposed different timings of harvest aids was conducted at the Australian Cotton Research Institute (ACRI), Narrabri (30° S 150° E). This is a semi-arid environment with a uniform grey cracking clay (USDA Soil Taxonomy: Typic Haplustert).

The Experiment was sown on 15 October 2005 with a commercial row crop planter using the Bollgard II® Roundup Ready® (Monsanto) *Gossypium hirsutum* cultivar Sicot 71BR (CSIRO, Australia). The experiment was established and grown with full irrigation using non-limiting nitrogen and thorough insect control as previously described (Hearn and Fitt 1992). Nitrogen was applied as anhydrous ammonia, injected below and to the side of the plant line, implemented 4 weeks before sowing at a rate of 200 kg ha⁻¹.

Treatment plots (9 m by 4 m), contained four rows spaced at 1 m. In the centre two rows of each plot harvest aid (Defoliant and a boll opener) were applied at approximately five day intervals from 143 days after sowing resulting in 8 harvest aid treatments (Table 1). The experiment was a randomised complete block design (RCBD) replicated four times. Harvest aids were sprayed with a calibrated CO₂ pressurised 2.0 m hand boom using a flat fan nozzles (110-01) at 200 k Pa delivering 100 L ha⁻¹ of spray solution. The chemical and rates were: 0.2 L ha⁻¹ Dropp Liquid® (Bayer CropScience, active constituent 500g L⁻¹Thidiazuron); 3 L ha⁻¹ Prep 720® (Bayer CropScience, active constituent 720g L⁻¹ Ethephon); and 2 L ha⁻¹ D-C Tron® (Caltex, active constituent 991ml L⁻¹ Petroleum Oil).

Crop Measurements

To establish crop status when harvest aid treatments were applied a fixed area of 1m of row in each control plot was monitored to determine the percentage of bolls open. To determine lint yield the third row (9 m) of each plot was harvested with a spindle picker and the seed cotton was weighed. A sub-sample of approximately 400 g of seed cotton was taken from each plot and ginned to determine gin turnout (% lint) used to calculate lint yield. Samples were saw ginned using a 20 saw gin located at the ACRI.

Lint cleaning

Sub-samples of ginned lint were subjected to one and two passes of lint cleaning. Lint cleaning was conducted with an experimental lint cleaner having a sample feed loading ratio of 100g m², a saw speed of 855 rpm and a combing ratio of 23. The lint cleaner had four grid bars each located at a distance of 0.5mm from the saw.

Fibre quality measurements

Sub-samples of ginned lint (not lint cleaned) were subjected to high volume instrument (HVI) testing (ACRI, Narrabri).

Recovered HVI material was blended through one passage of a 'Shirley' Analyser, and then tested for maturity ratio via the CSIRO SiroMat maturity tester (Gordon et al., 2005) and for linear density via the CSIRO CottonScan (Naylor and Purnalis, 2005).

Preparation of SiroMat specimens involved guillotining a fibre beard prepared using a ‘Fibrosampler’ to obtain between 2 to 3 mg of 1 mm snippets from two cuts near the aligned end of the beard. The snippets were collected and then spread in an annular pattern on a 5 cm x 7 cm glass slide using an OFDA™ fibre spreader. A clean 5 cm x 7 cm slide was used to cover the specimen. Castor oil (refractive index = 1.477 – 1.481) was used as the mounting medium to enhance the contrast of the fibre snippets to their background. Preparing the SiroMat instrument involved adjusting the digital camera settings (U balance, V balance and shutter speed) and the microscope lamp intensity to match a prescribed background (magenta) colour in terms of red, green and blue ratios. Background colours were also checked at regular intervals during testing to minimize drift in instrument readings. Three replicates were tested per experimental sample.

For linear density determination, samples were passively conditioned for at least 48 hours under standard conditions (20°C +/- 2°C and 65% relative humidity +/- 3%). Fifteen grams of cotton lint was pressed in a corer to produce approximately 100mg of 2mm snippets which was weighed and then analysed by the CottonScan instrument. Five replicates were tested per experimental sample.

Samples from lint cleaning treatments (including a control sample with no lint cleaning) were subjected to Uster AFIS PRO fibre quality analysis. Samples for the AFIS PRO were passively conditioned for at least 48 hours under standard conditions and tested according to the manufacturer’s instructions. Five replicates were tested per experimental sample.

Yarn Manufacture - Spinning

One hundred and sixty eight grams (4 x 42 g lots) of machine harvested ginned lint (not lint cleaned) was sub-sampled from each experimental sample. Each 42 g lot was separately carded twice and drawn once using a ‘Shirley’ miniature spinning plant card and draw frame (Platt brothers, England); machine settings (e.g. roller distances and draft ratio) were constant for all samples. The four miniature drawn slivers were then drawn together once using a Trutzschler HSR 1000 draw frame. The resulting single sliver was converted into twisted roving using a Zinser 660 roving frame which was spun into yarn using a Zinser 350 ring spinning frame. For full-scale processing, draft and twist was optimised for each sample to deliver a 20 tex yarn with a twist factor (ae) of 4.0 (798 turns per metre). One yarn bobbin per sample was tested for count, twist, evenness and imperfections (Uster tester 4-SX), and tensile properties (Uster Tensorapid 3). Yarn was waxed and wound but not cleared using a Schlafhorst Autoconer AC238 winding machine.

Fabric Production - Knitting and dyeing

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, e.g. $L_1a_1b_1$ and $L_2a_2b_2$, where 1 in this case was the control harvest aid treatment (100% open bolls) (Equation 1).

$$\Delta E = \text{SQRT} (L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2 \quad (1)$$

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.

Data analysis

ANOVA of data was conducted using Minitab 15.1. Data were analysed as a randomised complete block design. Least significant difference (LSD) values (5% level of significance) were reported for significant ANOVA (P<0.05), with the level of significance being reported as: *0.01<P<0.05, **0.001<P<0.01, ***P<0.001. NS denotes non significant ANOVA (P>0.05).

Results and Discussion

Fibre yield and quality

Yield of cotton lint from harvest aid treatments applied up to 42% open bolls, were significantly less than later treatments, with yield being similar for treatments applied from 68% open bolls (Table 1).

HVI fibre length was between 1.14 and 1.19 inch. Length was significantly less by an average of 0.03 (1/32nd) inches for treatments applied up to 68% open bolls and short fibre trended less for harvest aid treatments applied from 77% open bolls. There was no significant difference in bundle strength across treatments (Table 2).

Fibre micronaire and linear density were significantly less for harvest aid treatments applied up to 42% open bolls, yet no significant differences were noted between treatments from 56% open bolls (Table 3). The range of fibre maturity ratio across treatments was small, although the earliest treatments (29 and 42% open bolls) had maturity ratios less than 0.9 (Table 3).

Lint cleaning and neps

Neps were higher than expected across treatments (>250 counts per gram), and although not strongly significant, there was a slight trend for higher neps for earlier treatments, but no significant interaction was noted between harvest aid treatment application and the amount of lint cleaning. As expected lint cleaning had a strong influence on nep generation, with each lint cleaner passage generating approximately 100 neps per gram (Table 4). Each lint cleaner passage significantly removed trash from lint, and significantly impacted short fibre content (Table 4). This result suggested that changes in harvest aid management had little impact on nep generation in this study, and rather the mechanical process of lint cleaning had the greater affect.

Textile performance

No significant differences were noted across treatments for important yarn performance parameters such as yarn irregularities, imperfections and tenacity (Table 5). 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^* values than later treatments (Table 6). This change in the intensity of b^* (blue to yellow) is corroborated by a reasonable linear relationship between the timing of harvest aid application and b^* ($R^2 = 0.69$) (Fig. 1). 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 1 – Time of harvest aid implementation, and corresponding percent open bolls and lint yield. Yield values are the average of 4 replicates.

Harvest aid treatment (days after sowing)	% open bolls	Lint Yield (kg/ ha)
143	29.2	2424a
147	41.9	2444a
152	56.0	2620a
157	68.4	2745b
161	76.9	2814b
166	85.9	2739b
171	93.0	2632b
183 (Control)	100.0	2781b
LSD	-	213**

Table 2 – High volume instrument fibre length and tensile properties for machine harvested ginned (not lint cleaned) lint for cotton subjected to different harvest aid treatments. Values are the average of 4 replicates.

Harvest aid treatment (% open bolls)	Length (decimal inches)	Length uniformity (%)	Short fibre index (% <0.5 Inch)	Strength (cN/tex)	Elongation (%)
29.2	1.14a	81.9	10.2	31.1	4.2
41.9	1.17a	82.1	10.0	31.4	4.2
56.0	1.15a	81.9	10.1	30.3	4.1
68.4	1.14a	82.4	10.1	29.6	4.6
76.9	1.19b	82.6	9.6	31.7	3.9
85.9	1.18b	82.2	9.2	30.8	3.7
93.0	1.17b	83.6	8.8	30.7	4.1
100.0	1.18b	83.5	8.9	31.4	4.3
LSD	0.03*	NS	NS	NS	0.3***

Table 3 – High volume instrument micronaire, CottonScan fibre linear density and SiroMat maturity ratio for cotton subjected to different harvest aid treatments. Values are the average of 4 replicates.

Harvest aid treatment (% open bolls)	HVI Micronaire	CottonScan linear density (mtex)	SiroMat maturity ratio
29.2	4.08a	172a	0.89
41.9	4.15a	181a	0.88
56.0	4.55b	194b	0.92
68.4	4.55b	191b	0.93
76.9	4.33b	183b	0.92
85.9	4.68b	195b	0.90
93.0	4.58b	196b	0.90
100.0	4.58b	193b	0.91
LSD	0.36*	12**	NS

Table 4 – Uster AFIS PRO Neps, Short fibre content and Trash, for machine harvested ginned lint subjected to 0, 1 or 2 lint cleaner (LC) passages, for cotton subjected to different harvest aid treatments. Values are the average of 4 replicates.

Harvest aid treatment (% open bolls)	Neps (Count/ g)			Short fibre content – weight (% <0.5 inch)			Trash (Count/ g)		
	0 LC	1 LC	2 LC	0 LC	1 LC	2 LC	0 LC	1 LC	2 LC
29.2	403	490	643	13.2	12.5	14.3	143	71	47
41.9	337	450	576	12.7	13.3	14.8	162	55	37
56.0	272	341	471	10.1	10.9	13.3	130	72	58
68.4	308	317	440	13.2	11.1	13.7	133	65	44
76.9	344	419	570	13.0	12.0	14.1	113	48	32
85.9	369	495	637	13.1	13.8	15.7	113	47	38
93.0	333	368	520	11.7	11.6	13.2	106	44	39
100.0	309	410	528	11.4	12.1	13.5	103	51	37
LSD	NS	112*	NS	NS	1.9*	NS	NS	NS	NS
Mean	314	411	503	11.5	12.2	12.8	118	53	39
LSD		52***			1.2**			13***	

Table 5 – 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 ringspun 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 6 – 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)	L*	a*	b*	? E from 100% open bolls
29.2	44.303	-2.207	-27.910a	1.10
41.9	44.532	-2.258	-28.015a	1.29
56.0	42.619	-1.998	-28.370	0.68
68.4	43.028	-2.015	-28.344	0.28
76.9	43.486	-2.124	-28.262	0.21
85.9	42.384	-1.921	-28.577	0.96
93.0	42.571	-1.958	-28.562	0.77
100.0	43.292	-2.110	-28.340	0
LSD	NS	NS	0.322**	-

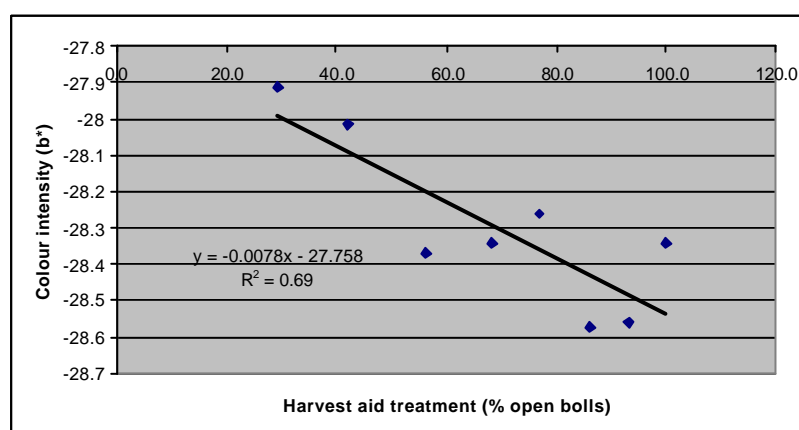


Figure 1 - Colour space result (b*) for reflectance colorimetric analysis of fabric dyed with Cibacron blue LS3R (1%), for different harvest aid timing treatments (% open bolls).

Conclusion

Harvest aids were systematically applied at different times from 143 DAS (29% open bolls) to 183 DAS (100% bolls open). Yield was significantly less for treatments applied up to 56% open bolls, yet remained constant for later harvest aid treatments. The range of fibre maturity across treatments was small (maturity ratio 0.88 for the earliest cf. 0.91 for late treatment application), although micronaire and linear density were significantly less for treatments applied up to 42% open bolls. Lint cleaning significantly generated neps at 100 neps per gram for each additional lint cleaner passage but there was no strong evidence that the changes in fibre quality measured in the early treatments exaggerated the effect of lint cleaners on the level of neps and short fibre. No significant differences were noted for yarn performance attributes for 20 tex ring spun yarns manufactured from lint across all harvest aid treatments. This was not expected and it is hypothesised that a finer count yarn may accentuate greater differences in yarn performance (particularly tensile properties) between early and late treatments. Dye uptake in knitted fabric was significantly less for treatments applied up to 42% open bolls, which is due to less mature (lower linear density and micronaire) fibre in these treatments. Indeed the current industry standard practice of applying harvest aids at or more than approximately 60% open bolls should ensure maximum yield, fibre quality and textile performance for this commonly grown Australian *G. hirsutum* variety.

Acknowledgments

The authors acknowledge the Cotton Catchments Communities Co-operative Research Centre, the Australian Cotton Research and Development Corporation and the CSIRO for financial support, and we greatly thank Jane Caton, Darin Hodgson, Rebecca Giles, Fred Horne, Mark Freijah, Susan Miller, Geni Kozdra, Susan Horne and Colin Brackley for technical assistance.

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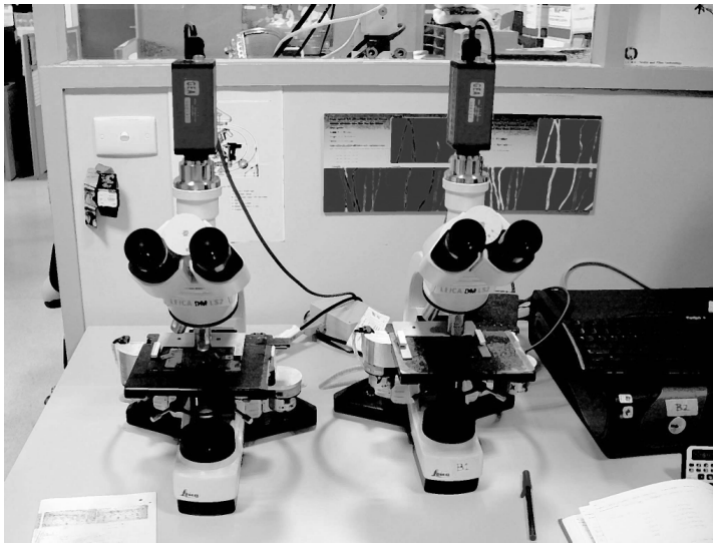
SiroMat: Progress Report

Stuart Gordon, Nicole Phair and Stuart Lucas
CSIRO Textile and Fibre Technology

Bremen ITMF Meetings 2006

SiroMat

An instrument to measure the average & distribution of fibre maturity values in a cotton sample directly & quickly



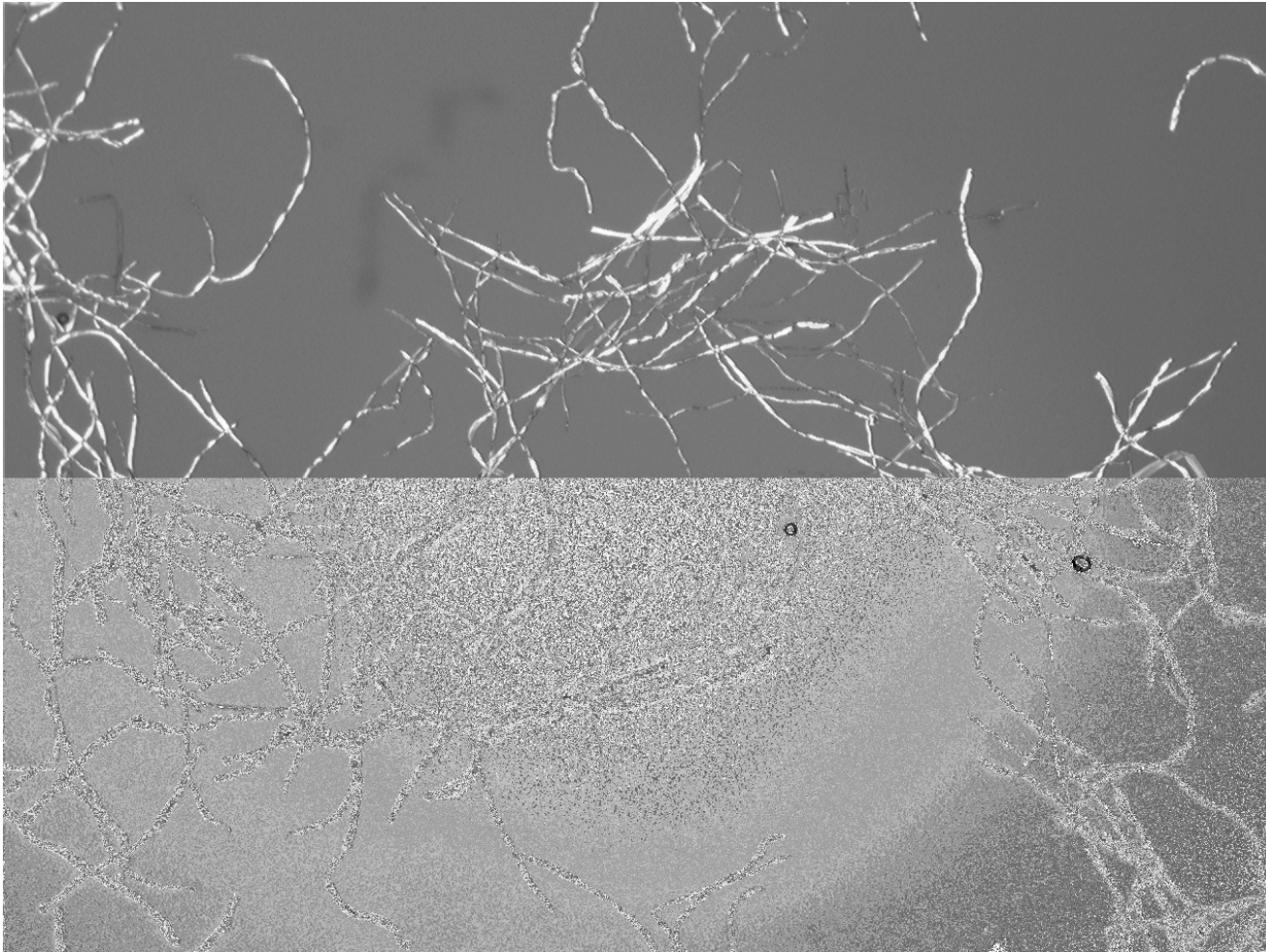
Automation of the Polarized Light Method (from ASTM 1442)

- Direct measure of relative fibre maturity
- More of the fibre (section) measured
- Measure distribution of maturity in sample
- Easy preparation
- Additional info on fibre geometry

Progress

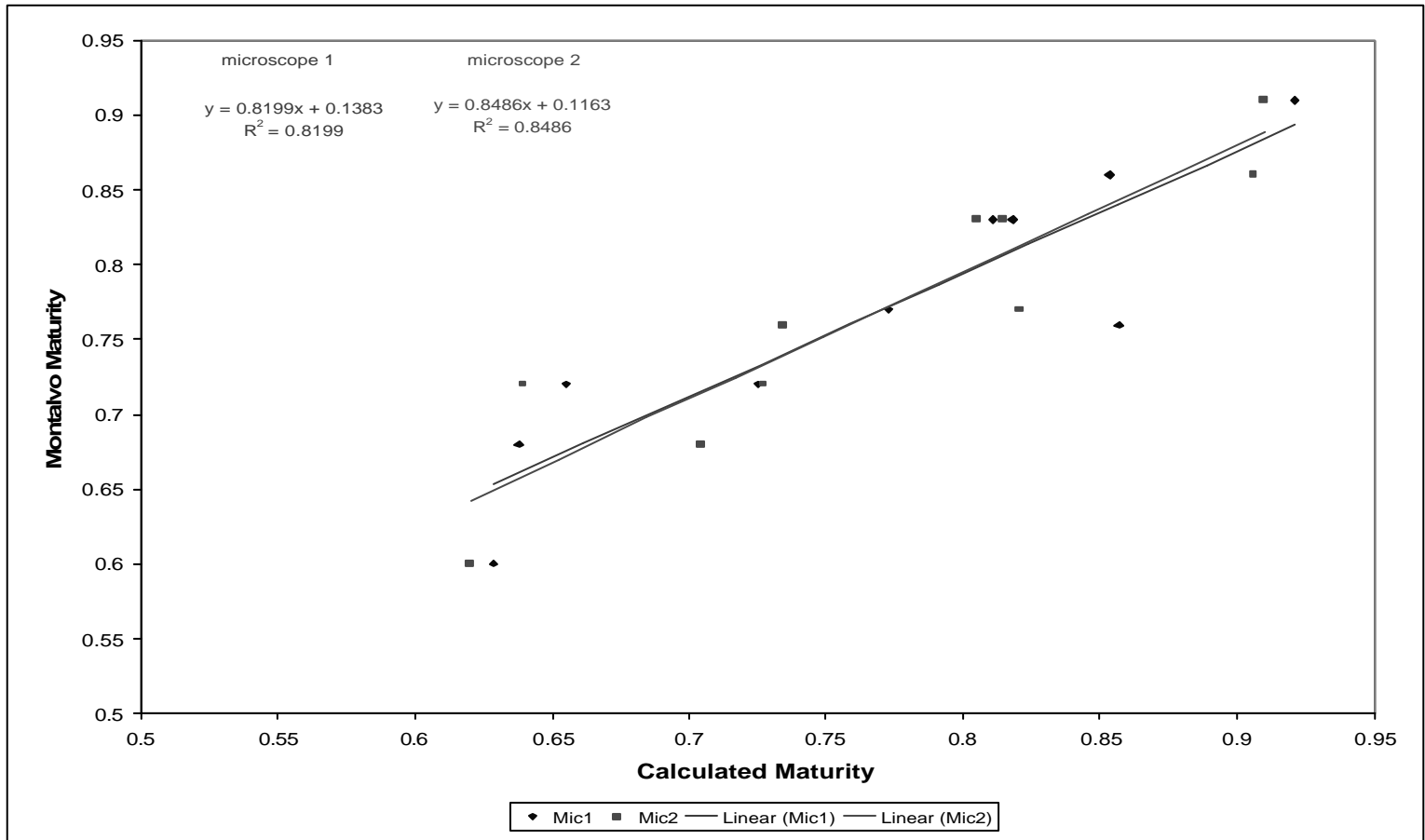
1. Develop prototype instrument – 2001-2003
 - Relationship b/n cross-section geometry and transmission of interference colors
 - Prediction of maturity from interference colors
2. Build replicate test instruments – 2003-2005
 - Components; light source, filters & cameras
 - Test agreement b/n instruments
3. Develop instruments for routine laboratory tests – 2005-2007

Instrument FoV in 2004



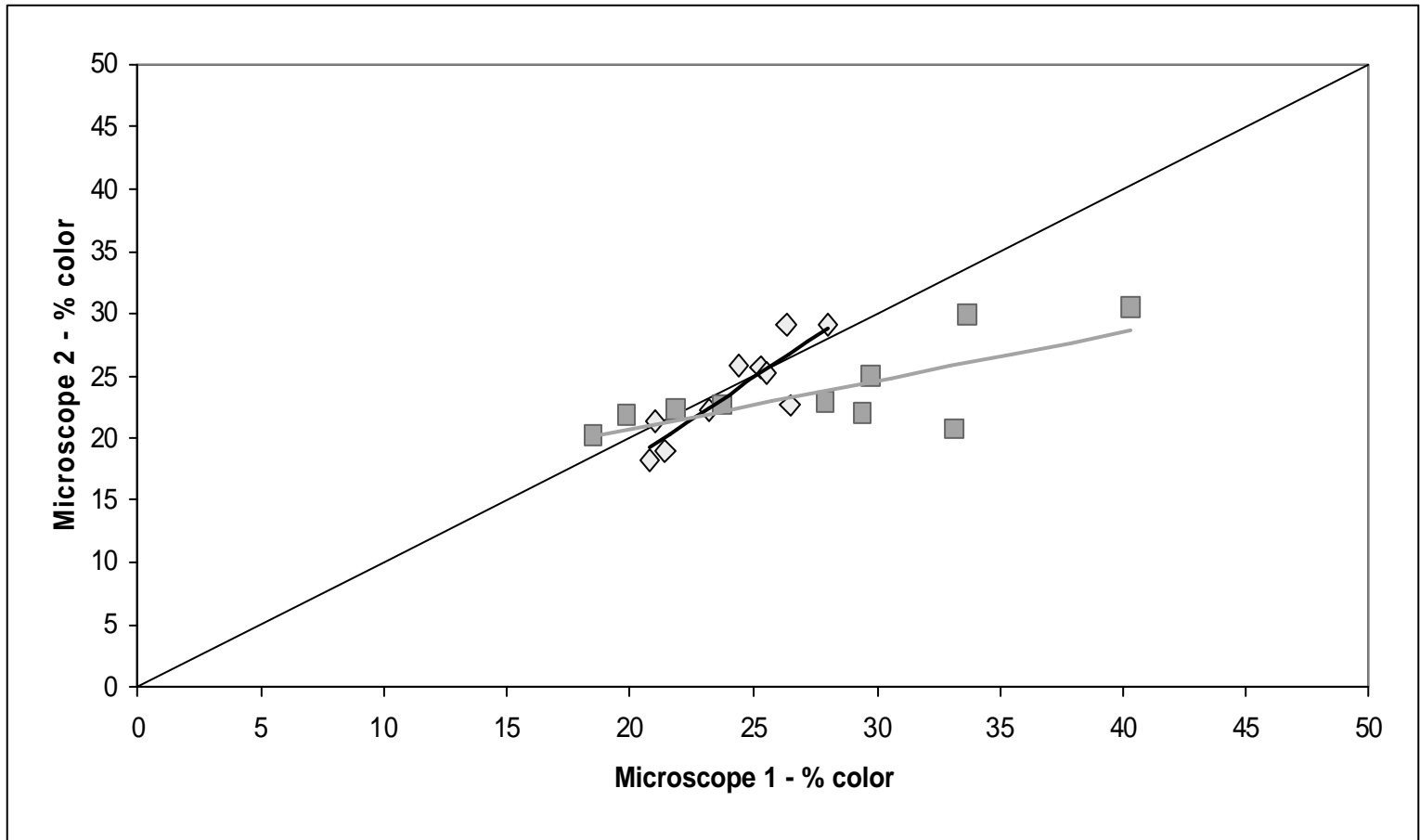


2004 results - instrument variation





2004 results - instrument variation



Progress since 2004

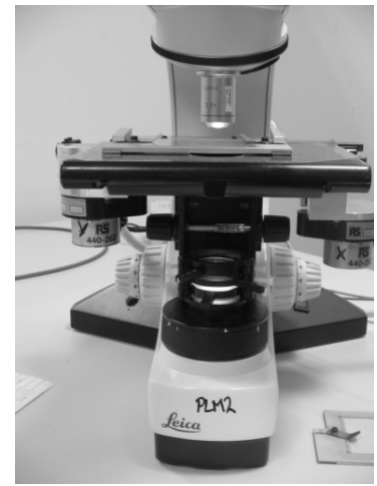
Constant light source – control

Uniform optical retardation

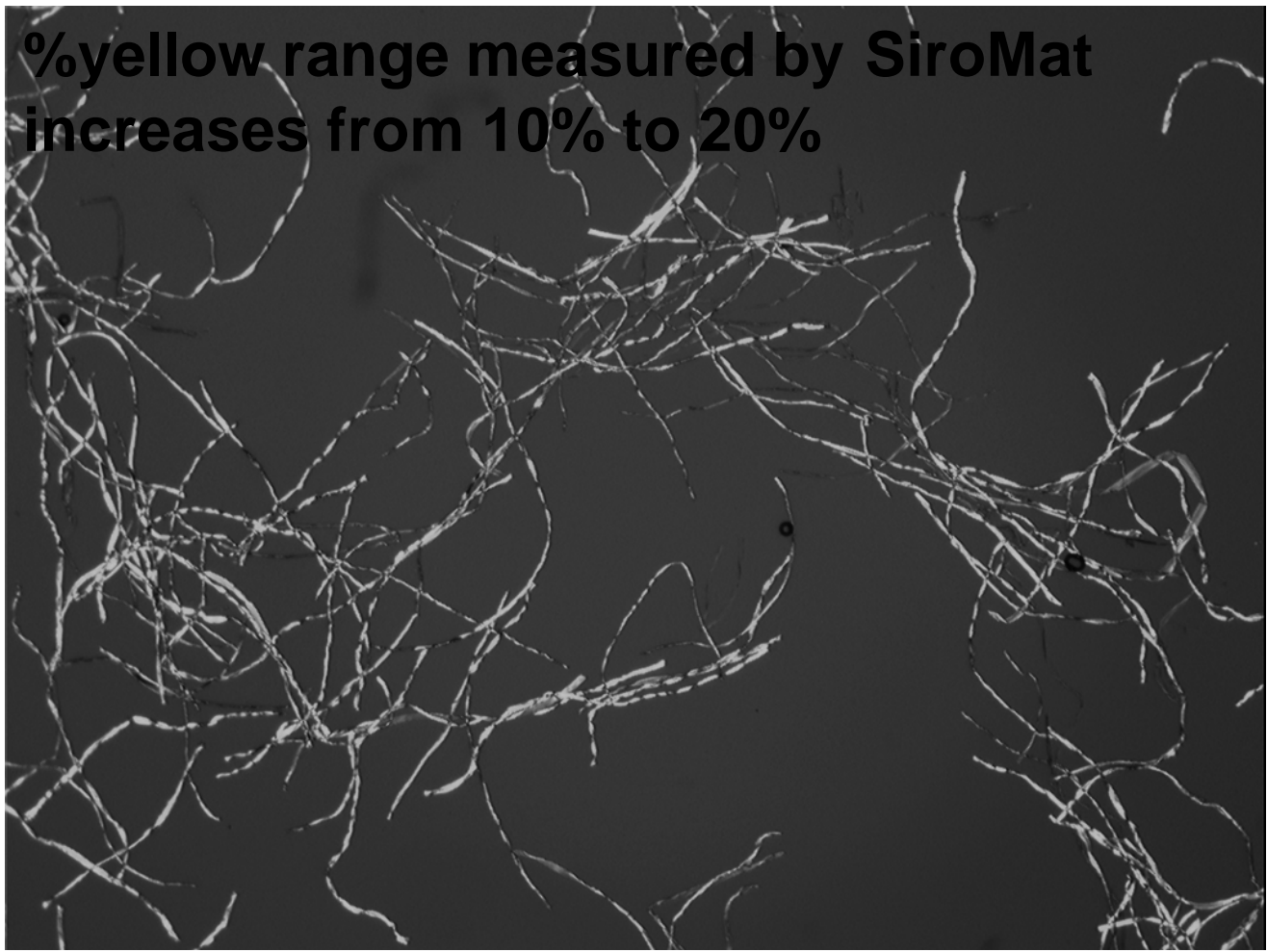
Two term equation (%yellow & %green)

Two instruments x 3 reference (USDA) cottons
x 10 replicates – nested ANOVA

Demonstration of SiroMat value



Instrument FoV in 2006





Progress since 2004

Two instruments x 3 reference (USDA) cottons
x 10 replicates – nested ANOVA

USDA Samples – Ma. 2

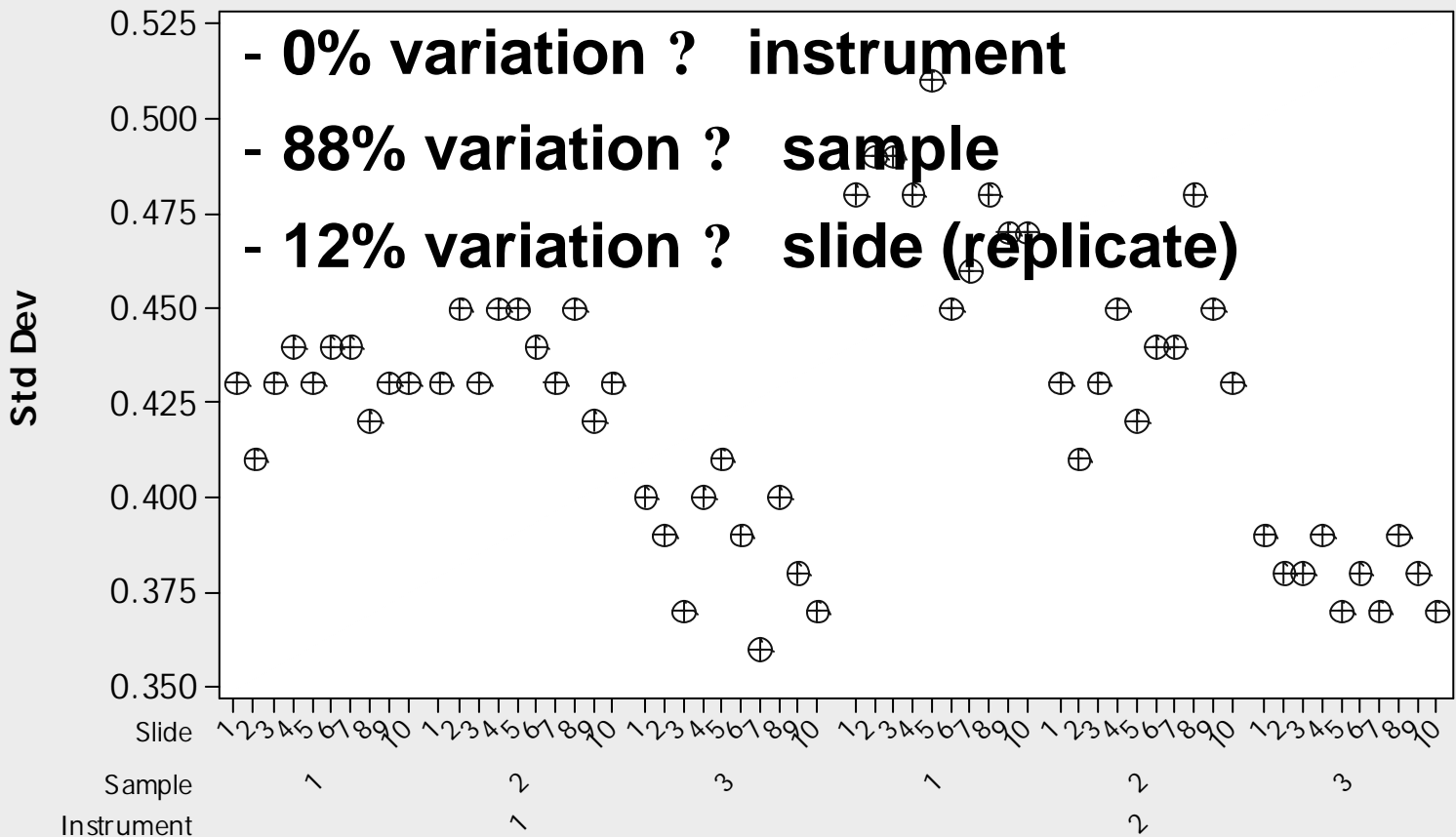
Sample ID	USDA MIC	Average Maturity	Std Dev Replicates	Std Dev Maturity	Skew Maturity
5740	3.27	0.763	0.039	0.480	-0.303
5741	4.04	0.860	0.034	0.438	-0.473
5742	4.97	0.902	0.019	0.386	-0.634



Textile and Fibre Technology

Interval Plot of Std Dev vs Instrument, Sample, Slide

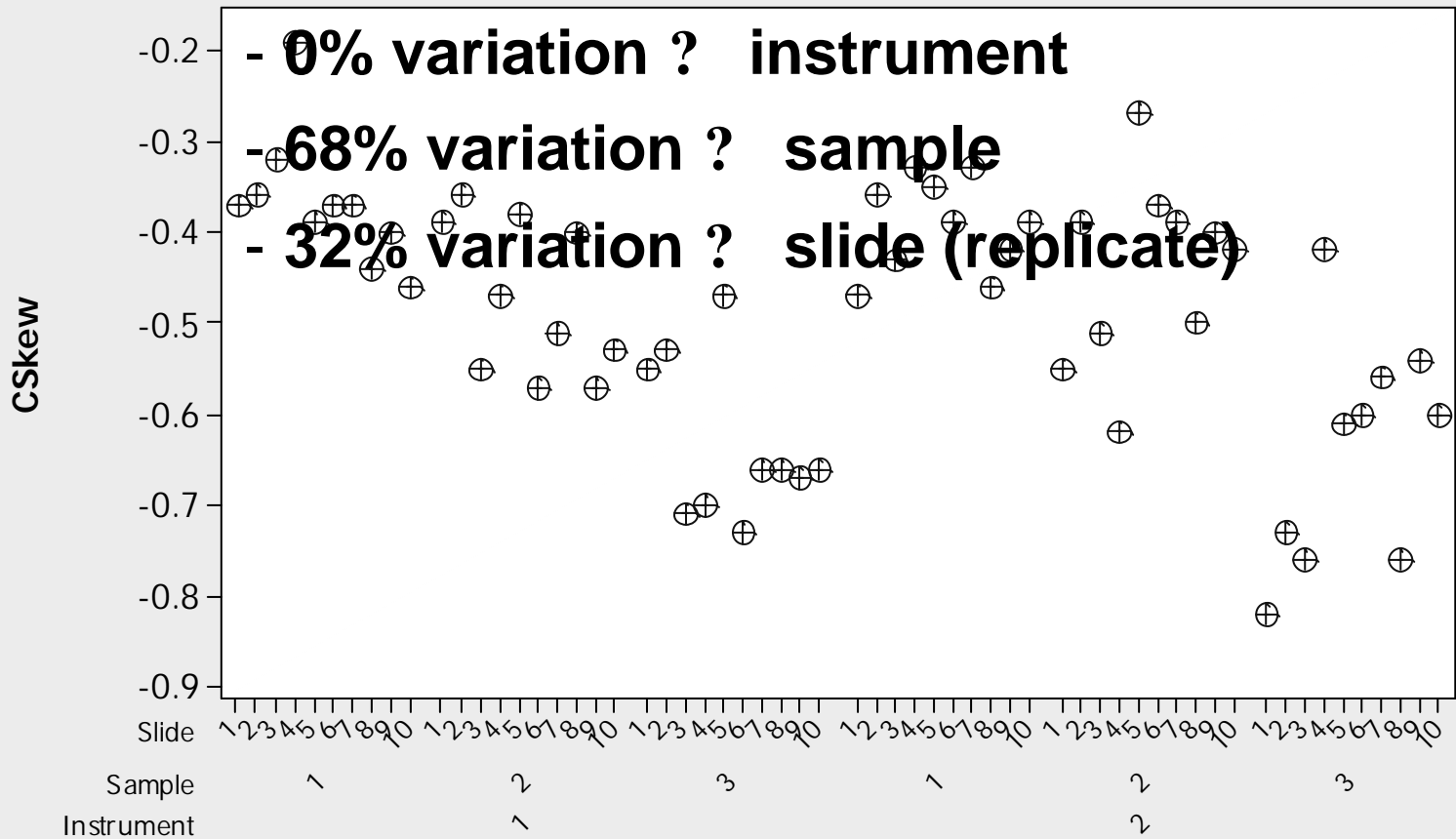
95% CI for the Mean





Textile and Fibre Technology

Interval Plot of CSkew vs Instrument, Sample, Slide
95% CI for the Mean



Demonstration of SiroMat value

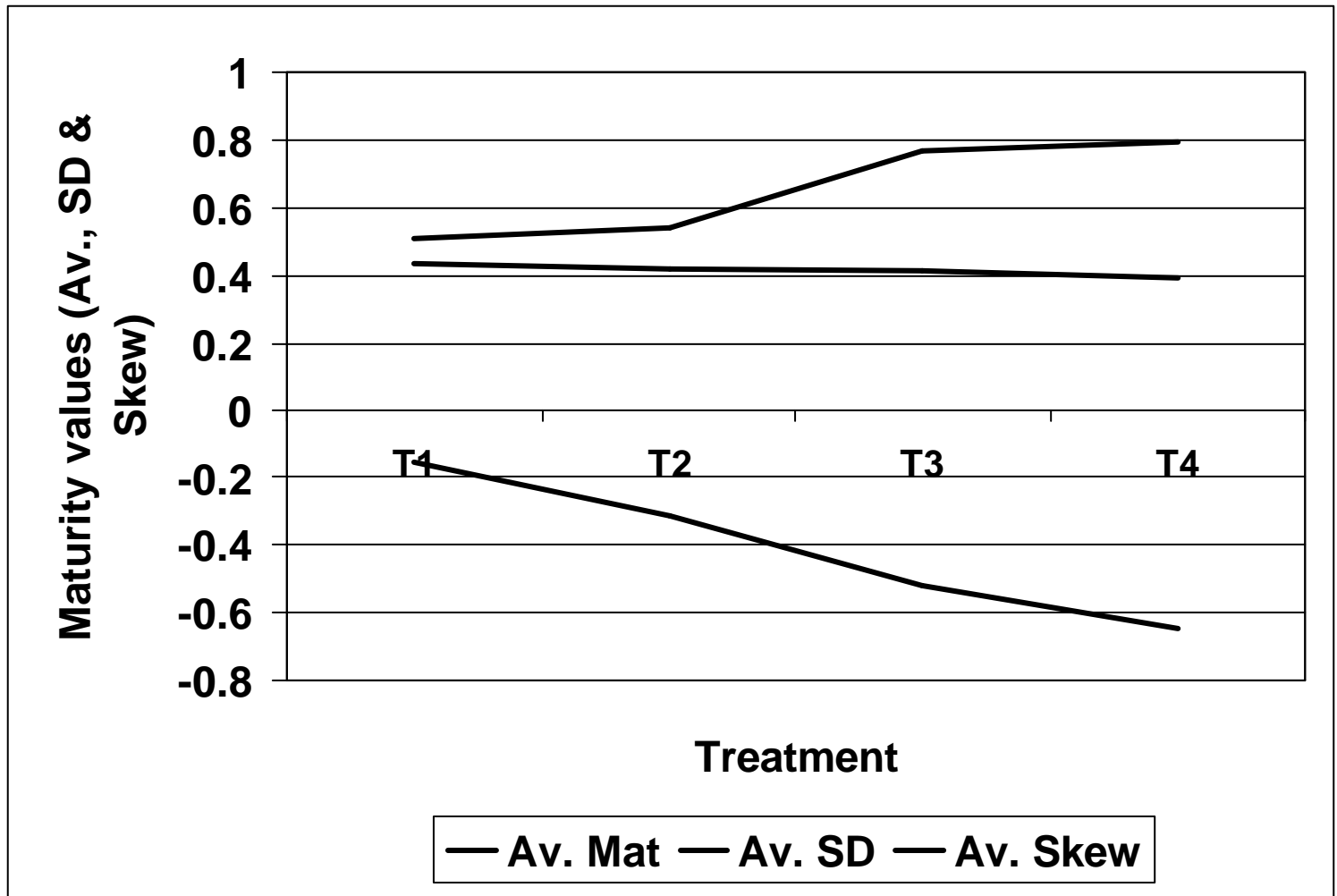
An experiment examining night temperature on duration of boll period

- Four conditions (time & temperature)
 1. 30°C day & 6°C night for duration of boll period
 2. 30°C day & 6°C night for 26 days post-anthesis
 3. 30°C day & 6°C night for 27 to 35 days post-anthesis
 4. 30°C day & 6°C night for 42 to 56 days post-anthesis

Harvest bolls from same plant position (node 7), lab gin, weigh lint, blend and test on SiroMat (2 x replicates)



Demonstration of SiroMat value





Work remaining

Employ uniform optical retardation

Further improve representation in two term equation (%yellow & %green)

Increase test speed to 2.5 minutes/specimen

Further demonstration of SiroMat value



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- Don Ramsey & Graham Higgerson – advice on calibration and optical components



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Cotton
Advisory
Committee

Technical
Information Section

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Update on Cotton
Production Research



to increase the supply of sucrose available for sustained fiber and vegetative plant growth.

To achieve this, researchers must produce a transgenic plant by regenerating a whole plant from a plant cell that has been transfected with DNA sequences comprising a gene capable of suppressing the biosynthesis of oil in the developing seed. Plants made according to these specifications exhibit increased production of fiber.

There is an application available on line (see reference below) that explains a method for obtaining a non-genetically modified cotton plant with reduced seed-oil content by selecting native alleles, or alleles produced through mutagenesis, reduce oil content with the resulting increase in fiber yield. The modified genotype can be used to develop commercially acceptable cultivars that contain the cottonseed-oil suppression trait.

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New Research and Development Work from Australia in Cotton Fineness and Maturity Assessment

Stuart Gordon and Geoff Naylor, The Cotton Textile Research Unit,
CSIRO Textile and Fibre Technology, Australia

The Australian Cotton Industry

The Australian cotton industry is one of the most modern and technically advanced agricultural industries in the world. Nearly all of Australia's cotton is exported to mills in Asia, with Indonesia, Thailand, South Korea, China, and Japan being the main destinations (<http://www.austcottonshippers.com.au/>). Whilst Australia produces only around 6% of the world's traded cotton, most of it is used by spinning mills for high quality fine count combed yarns and from this perspective Australia is a significant producer of world high-medium and fine cotton.

The cotton that Australia has grown over the last decade has earned a very good reputation amongst spinners for producing high quality yarns. The Commonwealth Scientific and Industrial Research Organization (CSIRO), the Australian Government research and development organization, recently

conducted a survey of mills that use Australian cotton to obtain more accurate information on its quality. Results from the survey confirmed that further improvements in nep levels, short fiber content, and a move to micronaire values within the 'premium' range of 3.8 to 4.2 would be beneficial.

The Importance of Fiber Maturity and Fineness and Current Test Methods

The three fiber quality characteristics identified above relate directly or indirectly to a cotton variety's fiber maturity and fineness. From the spinners' perspective, both fiber maturity and fineness are key parameters with sometimes opposing effects on mill productivity and yarn quality. For example, yarn is specified in terms of its weight per unit length, and fiber fineness determines the number of fibers in a given yarn cross

Table I – Micronaire Values for Upland Cotton

Micronaire ($\mu\text{g}/\text{inch}$)	Comments	Discounts Applied, Points* per Pound (Adam 2005 and Australian Cotton Industry 2004-2005)
< 3.2	Significantly immature	400 to 1400 pts off
3.3 – 3.7	Immature	200 to 500 pts off
3.8 – 4.5	Fine and mature fiber for fine to medium count yarn	50 pts on for 3.8 to 4.2 range
4.6 – 4.9	Coarse fiber for coarse count yarn	
> 5.0	Significantly coarse	250 to 700 pts off

* 100 points = 1US cent

section. The use of finer fibers increases the number of fibers in the cross section of a given yarn, which improves spinning efficiency and yarn evenness. Equally, cotton fiber maturity is an important property to spinners and fabric manufacturers because it determines how well fibers will process, both from a chemical and a physical perspective. Immature fiber, that is fibers with little or no fiber wall thickening, is associated with the formation of small entanglements called neps, irregularities in processed fiber assemblies including finished yarns, non-uniform dyeing of fabrics, and decreased processing efficiency. A central problem in managing fiber fineness and maturity is the absence of convenient and accurate test methods to assess these properties.

A limitation of the test methods currently available is slow test times making large numbers of measurements impractical. Another problem is that the test methods measure fiber parameters not solely related to each property e.g., micronaire measures specific surface area by the air pressure differential across a weighed plug of randomly distributed fibers. The micronaire scale is marked in micrograms per inch, and was based on an observed linear relationship between air permeability and linear density for a range of cotton samples of similar maturity. Subsequent testing of immature cotton produced results that varied significantly from actual weight per unit inch determinations. These results were determined on the basis as previously-established theoretical relationships between the measured airflow resistance and the surface area per unit volume of solid fibers with regular cross sectional shapes. However, because cotton fibers are hollow and have irregular cross sectional shapes, this relationship is compromised. A study by Lord (1956) showed that the relationship between micronaire and fiber weight was curvilinear and that changes in fiber maturity produced concomitant variations in micronaire readings. The equation below shows the relationship, determined by Lord, between micronaire (X) and the linear density (H) and maturity (M), of a fiber expressed as a maturity ratio:

$$MH = 3.86X^2 + 18.16X + 13$$

Lord's (1956) equation indicates that the micronaire value is actually related to the product of fiber fineness and maturity and its interpretation is ambiguous i.e., a coarse, immature sample and a finer more mature sample can both have the same micronaire value. Despite these shortcomings, the micronaire test is still the most widely accepted test for fiber fineness, and by assumption fiber maturity, on the basis of its simplicity and speed. Moreover, the usefulness of other test methods, e.g., double compression airflow methods, is also currently hindered by inter-relationships that exist between fiber properties and/or reproducibility. Table I lists the typical range of, micronaire values found in Upland cotton, together with comments on the type of cotton they represent from a market viewpoint and the range of premiums and discounts applied to particular values. The need to separate micronaire into its fineness and maturity components is of particular importance to producers of fine, mature cotton, which can be wrongfully discounted because low micronaire values are taken as indicating immaturity. For example, there is cotton grown in the 3.3 to 3.7 range in Table I that is actually fine and mature and therefore should receive a premium rather than a discount.

A further limitation of the micronaire test is that it only gives an indication of the average fiber quality and it does not give any information on the range of fiber fineness or maturity within a sample. For example, two cottons could have the same micronaire value and average fiber maturity but one sample could have a greater proportion of immature fibers than the other. The cotton with the greater proportion of immature fibers will have different processing properties, and the yarn and fabric produced from the two cottons will be of different quality. For example, shiny or dye resist neps are associated with very immature fibers within a sample that are not highlighted by the micronaire or other measurement methods that only provide average values.

Survey of Current Fiber Maturity and Fineness Measurement Techniques

CSIRO conducted a survey in 2004, in conjunction with the Fiber Institute in Bremen (Faserinstitut Bremen), to identify current practices regarding fiber maturity and fineness measurement. In July 2004 this survey was sent to 152 laboratories as part of the well-known Bremen Cotton Round tests. Figure 1 provides a breakdown of the 56 businesses that responded to the survey. The largest segment (31) were laboratories in spinning mills, 9 respondents were test center for merchants, 15 tested for research purposes, probably laboratories in universities and private and public research institutes, and one laboratory in a non-woven mill.

Figure 1
Respondents in the 2004 CSIRO Survey

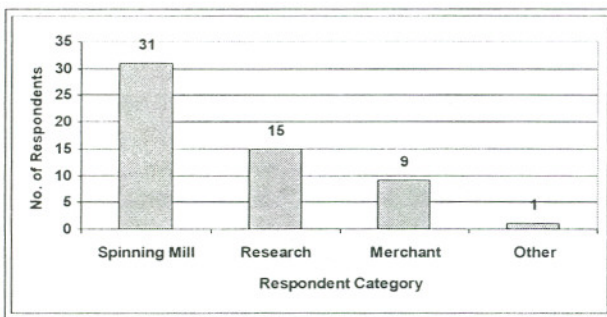


Figure 2
Survey Response to the Question
"Is this an Important Fiber Property of Cotton?"

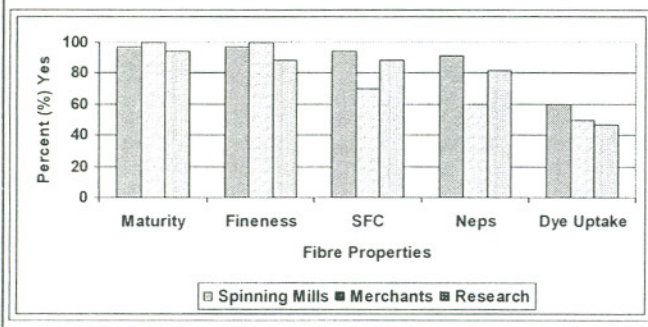
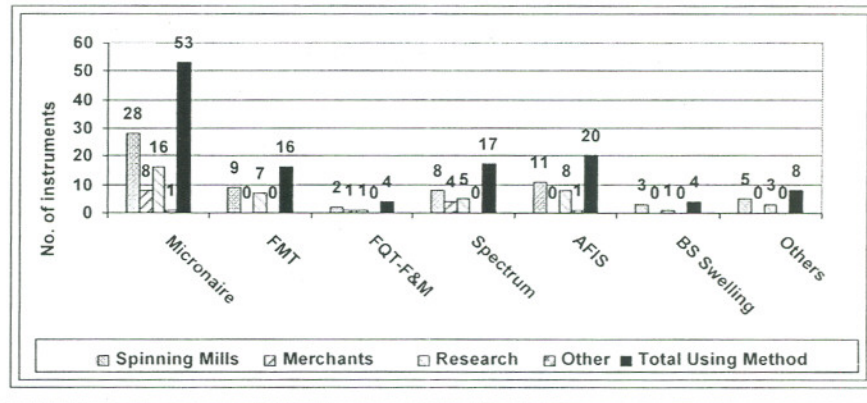


Figure 3
Techniques Currently Used to Measure Fiber Maturity by Industry Segment



As shown in Figure 2, the spinning mill and merchant categories rated fiber maturity and fineness as being of equal and high importance, while short fiber content, neps, and dye uptake were of lesser importance. However, spinning mills, rated the latter properties as being more important than the Merchant category did. An inference drawn from these ratings could be that problems associated with the later properties are predicted, and thus mitigated, by measuring fiber maturity and/or fineness.

More than 80% of the spinners-test centers and 60% of the merchants-test centers claimed to measure maturity and fineness routinely. Figure 3 shows the range of techniques employed. Fifty-three of the 56 laboratories used micronaire, either using a stand alone instrument or integrated within an HVI, to assess fiber maturity and/or fineness. Most laboratories, particularly those from the Spinning Mill and Research categories, also used other instruments to provide additional information on fiber maturity and fineness. The most popular were the Uster AFIS (20 instruments), the Uster Spectrum (17) and the 'Shirley' FMT (16).

The survey also highlighted what appears to be an information gap with respect to the best way of measuring (and using) these properties. There was a significant difference in the response by the spinning mill and merchant categories, and the Research category, which tended to be less satisfied with current technology.

Most laboratories used micronaire as the main indicator of fiber fineness and maturity. However, most Spinning Mills and Merchants also desired further information on these properties. Hence, laboratories also used other test instruments to gain information.

Test speed is an issue for laboratories in the Merchant category and the survey results suggest that the reason fiber fineness

and maturity may not be measured by laboratories in this category is because test methods for these properties are not fast enough. Test speed was less of an issue for the Spinning Mill and Research categories.

New Instrumentation for Measuring Cotton Fiber Maturity and Fineness

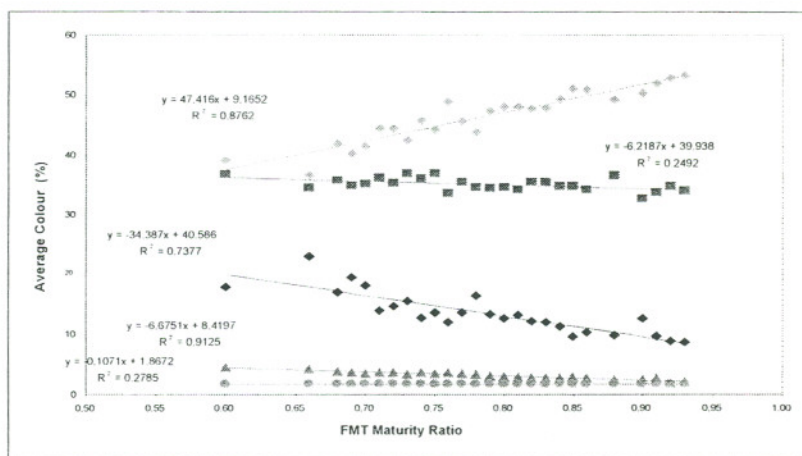
As part of a broader R&D initiative around the post-harvest quality of Australian cotton, CSIRO, in conjunction with the Australian Cotton Industry, is developing two patent pending technologies for measuring fiber maturity (SiroMat) and fineness (Cottonscan) quickly, directly and accurately. Each technology is based on an existing standard technique.

In the case of SiroMat the standard method for determining maturity by polarized light microscopy (ASTM D1442) is automated, and in the case of Cottonscan the standard method for determining fineness or linear density by the cut and weigh method (ASTM D1769) is automated too.

SiroMat

The SiroMat method determines fiber maturity based on the colors that fibers assume when viewed under a polarized light microscope. The relationship between the interference colors assumed by fibers under crossed polars and fiber maturity is based upon the orientation of cellulose chains in the fiber wall, which affect the path length of light through the wall. The method has previously been overlooked because classing the fibers on the basis of color was subjective and the manual counting of fibers was too slow. The Standard Method (ASTM

Figure 5
SiroMat 'Percent' Maturity Results (2 x 2 mg replicates)
Versus Maturity Ratio as Measured by the "Shirley" FMT



D1442) in fact warns against using the method for acceptance testing because "laboratory precision can be poor." However, the advent of color digital cameras and the increased power of today's personal computers have made this approach viable.

In addition, it has been thought that the method was biased by fiber fineness (Lord and Heap, 1988) or, by implication, the path length of light through the fiber. A recent survey of the interference colors assumed by different cottons by Gordon and Phair (2005) showed that there was no difference in color on the basis of genetic origin or intrinsic fineness. Three different cotton species were included in the survey, and thus a wide range of cross-sectional parameters (cross-sectional wall area and perimeter) were represented. The survey demonstrated that the interference colors transmitted by a fiber related directly to a prescribed range of values for fiber maturity, and were not co-dependent upon fiber perimeter or cross-sectional area as previously thought.

Color digital cameras, color image analysis software, and higher powered computers have made automation of the polarized microscopy test viable and allow test times of less than two minutes per sample to be achieved. Moreover, the sample does not require conditioning before testing. Thus, the SiroMat method determines fiber maturity based on the colors fibers assume when viewed under a polarized light microscope set up according to the ASTM standard. Cotton fibers are automatically scanned and analyzed so that selection of fibers or fiber sections and interpretation of their color is no longer subject to operator interpretation. As well as measuring average fiber maturity, the method is able to measure the distribution of mature and immature fibers in a sample. Figure 4 shows an image of cotton fiber segments analyzed by the SiroMat test and Figure 5 shows the relationship between SiroMat results and maturity ratio as measured by the 'Shirley' FMT.

Figure 4
Field of View Analyzed by the SiroMat Instrument



Cottonscan

The Cottonscan instrument is illustrated in Figure 6 (Naylor, 2001 and Naylor and Purmalis, 2005). The approach of this technology is to prepare a known mass of snippets from a sample of test cotton and then measure the total length of the fibers in the sample so that the fiber fineness (mass per unit length) can be directly calculated. The total length is determined by forming a uniform suspension of the snippets in a liquid, which is passed through an optical cell where the snippets are photographed and examined using image analysis techniques. Figure 7 shows a typical image captured by the instrument. Combining this measurement with an independently measured micronaire value (from a HVI) the average fiber maturity can be calculated using Lord's well established empirical relationship between Micronaire, maturity ratio and fineness (Lord, 1956). Further details of the first prototype Cottonscan instrument are described by Gordon and Naylor (2004) and include some preliminary results. As an example, Figure 8, reproduced from Gordon and Naylor, shows the good correlation between fiber fineness and maturity values obtained on the Cottonscan instrument and FMT measurements from six well blended cotton samples.

The primary differences between the two new instruments are that SiroMat measures maturity of individual fibers directly and so can give information about the population and distribution of maturity values in a sample, whereas Cottonscan measures average fiber fineness and then infers an average maturity value from an existing empirical relationship. In terms of operational capabilities, the SiroMat approach is slower than Cottonscan and is focused on being a tool in quality assurance and research laboratories. On the other hand, the Cottonscan measurement time is within HVI analysis times.

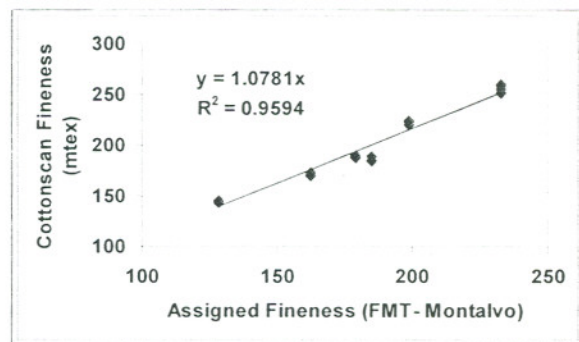
Figure 6. The Cottonscan instrument



**Figure 7
Typical Unprocessed Image Captured by the Cottonscan Instrument**



**Figure 8
Cottonscan Average Fibre Fineness Values Versus Results Obtained With the 'Shirley' FMT (n=5)**



More detailed technical progress with the development of these two technologies was presented to the recent ITMF International Committee on Cotton Testing Methods meeting held in Bremen in March 2006.

Conclusion

The Australian cotton industry currently produces high quality, contaminant free cotton very efficiently. The industry is seeking to improve its fiber quality further and is currently undertaking a targeted research and development program. One aspect that has been identified is the need for new technology to accurately measure fiber maturity and fineness independently and thereby improve on the current micronaire value. To this end, two new instrument technologies that automate and provide more precise direct measurements of fiber maturity (SiroMat) and fineness (Cottonscan) are being developed. The primary differences between the instruments are that SiroMat measures maturity of individual fibers directly and so gives information about the population and distribution of maturity values in a sample, whereas Cottonscan measures average fiber fineness more quickly (at speeds compatible

with HVI testing) and then infers an average maturity value from an existing empirical relationship.

These two technologies are still in the prototype stage and further R&D is being undertaken in Australia to demonstrate the robustness of the technologies for commercial use. It is an objective of this R&D program that the technologies, once fully developed, will become widely accepted as routine tools for determining cotton fiber maturity and fineness. This will provide efficient and accurate tools to enhance the viability of the world's cotton industry.

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Short Notes

• Thermal Defoliation and its Effects on Fiber Quality

Defoliation is a prerequisite for machine picking of cotton, and it is estimated that almost 30% of world cotton is machine picked. All cotton is machine picked only in Australia, Israel and the USA. Most cotton is machine picked in Argentina, Brazil, Greece, Spain, and many Central Asian countries. It is usually recommended that leaves could be forced to drop when almost 2/3 of bolls on the plant have already opened. Defoliation also helps to reduce trash in cotton and minimize gumming of spindles during picking. The advantages of machine picking include lower cost, earlier picking to avoid unfavorable weather conditions and eliminate the need for a second picking. Chemical defoliation is the most popular way to get rid of green leaves for avoiding chlorophyll-staining of cotton fibers. Showler *et al.* (2006) studied thermal defoliation and compared it with chemical defoliation with respect to defoliation efficiency and effects on fiber quality. They used hot air from the propane burner, where the air was heated to 193°C and directed at cotton plants. The number of leaves on treated and un-treated plots were counted before the plants were hit with hot air. The number of leaves that survived the treatment was counted to estimate the defoliation efficiency (survival

was estimated by counting leaves that retained 5% green area or more).

Results showed that thermal defoliation caused the death of 80-98% of leaves after one day of the treatment in all the three experiments. Mortality did not improve much in the following days. The chemically treated plots did not show 30-40% leaf mortality until five days after the treatment. The number of dead leaves increased to 84-87% on the 7th day after chemical treatment. Mortality continued to increase and reached 91-98% 13 days after treatment. Thermal defoliation is quick and dried more leaves compared to chemical defoliation, which has a gradual effect. No statistical differences were detected after seven days when mortality rates exceeded 80%. The experiments showed that although thermal desiccation was quick in action, the dried leaves tend to stay attached to the plant. It seems that sudden exposure of green leaves to hot air disrupted the physiological or chemical processes for the formation of an abscission layer at the point of its attachment to stem and leaves.

The below fiber quality data are the average of three locations. One of the locations had lower trash contents compared to other two. The data by location showed no significant differences for any fiber quality characteristic measured in the studies. However, the thermal defoliation