January, August & Final Reports

REPORTS

Part 1 - Summary Details

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

CRDC Project Number: **CWT4C**

January Report: ☐ Due 29-Jan-01

August Report: ☐ Due 03-Aug-01

Final Report: ☒ Due within 3 months of project completion

Project Title: Measuring Cotton FIbre Fineness and Maturity using the Sirolan-Laserscan

Project Commencement Date: 1 July 1999 **Project Completion Date:** 31 December 2001

Research Program: Processing and Market

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Measuring Cotton Fibre Fineness and Maturity using the Sirolan-Laserscan.

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Final Report for the Australian Cotton Research and Development Corporation.

CRDC Ref. No: CSWT 4C

September 2002

Plain English Summary

The commonly used Micronaire value for cotton is related to both fibre fineness and maturity. There is a need for a new measurement technique to separate these. This is of particular importance to the Australian industry where varieties of fine mature cotton have the potential to be wrongfully discounted commercially by misinterpreting a low Micronaire value as indicating immaturity in a coarser fibre.

A preliminary study (CRDC Project CSWT 1C) indicated that the Sirolan-Laserscan, an instrument developed by CSIRO for measuring wool fibre diameter, had potential, in this new mode of operation, to be applied to cotton.

The current project has extended and expanded the preliminary work. Largely using sets of carefully grown samples harvested at different times, the work has been able to demonstrate that the approach can indeed deliver reliable fibre maturity and average fineness data.

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1. Background

The commonly used Micronaire value for cotton is related to both fibre fineness and maturity. There is a need for a new measurement technique to separate these. This is of particular importance to the Australian industry where varieties of fine, mature cotton have the potential to be wrongfully discounted commercially by misinterpreting a low Micronaire value as indicating immaturity in a coarser fibre.

A preliminary CRDC funded project (CRDC Project CSWT 1C), demonstrated that the Sirolan-Laserscan, in a novel mode of operation, is able to measure the fineness of cotton fibres independent of fibre maturity.

Following this, a paper on the preliminary results of the technique was presented to the US Beltwide meeting in January 1999 and also Dr Geoff Naylor visited and had in-depth discussions with the other key researchers in this area at the USDA in New Orleans (CRDC Project CSWT 2C). The main outcome was that there is general agreement that the new Sirolan-Laserscan approach has significant potential as a viable technique for measuring cotton fibre fineness. Further, it is thought that it might easily be possible to extend the approach to yield fibre maturity information by combining the results from this approach with the current micronaire measurement.

2.0 Objectives and Progress

2.1 Original Project Objectives

The original project objectives were:

Year 1:

(a) In collaboration with researchers at the USDA extensive testing of the Sirolan-Laserscan as a tool for measuring fibre fineness independently of maturity will be conducted. This testing will cover a range of cotton samples supplied by the USDA that have been well characterised and cover as wide a range as possible of micronaire, fibre fineness and maturity values.

(b) A mathematical analysis will be undertaken to determine if it is theoretically feasible to derive fibre maturity information from a combination of fibre fineness and micronaire data. If this analysis is positive, a preliminary/feasibility experimental program will be conducted.

Year 2:

(a) Complete evaluation of the Sirolan-Laserscan approach to measuring fibre fineness will be completed including an examination of means to simplify/re-engineer aspects of the instrument to improve the measurement and make it faster and more suitable (user friendly) as a test method.

(b) An experimental evaluation of the determination of fibre maturity from a combination of fibre fineness and micronaire will be completed.

2.2 Modification of objectives

As highlighted in the progress report in August 2000, as samples from the USDA were not available as originally planned Objective A in Year 1 was refocussed to testing a series of cotton samples specially obtained via Greg Constable at ACRI. These samples had been harvested at different times to form a controlled set where fibre fineness should increase with growing time.

2.3 Achievement of objectives

The modified set of objectives have all been achieved.

3. Relevance to CRDC Outputs

This project is part of the CRDC Output 'Profitability and Competitiveness'. The project is aimed at developing a new quality control tool for measuring fibre quality. This will further enhance Australia's ability to position itself as a supplier of high quality cotton to world markets.

Further, accurate fibre maturity and fineness information leads to improved efficiency during cotton textile processing and higher final product quality, thus improving the competiveness of cotton versus other fibre types.

3.0 Methodology

In the Sirolan-Laserscan, developed for wool metrology, fibre snippets are individualised and suspended in a carrier fluid. Single snippets are then counted and measured as they interact with a laser beam. Thus in principle the Laserscan gives two independent pieces of information namely (a) the number of snippets observed and (b) fibre thickness. Applying this technology to cotton, CRDC funded project CSWT 1C demonstrated that, in a novel mode of operation, the Sirolan-Laserscan is able to measure the fineness of cotton fibres independent of fibre maturity.

The principle is indeed quite straight forward. First a quanitiy of fibre snippets of know length is prepared using suitable guillotine. After weighing, fibres were fed into the Sirolan-Laserscan which is used to count the number of snippets N. The average fineness (linear density) F was then calculated by the formula:

$$F = \alpha W/(NL)$$

where W is the total weight of the snippets, L is the snippet length, and , α is predetermined instrument correction factor which arises as the instrument 'misses' a constant fraction of the snippets.

The purpose of the project is to build on the progress reported in the earlier preliminary study and indeed demonstrate the validity and viability of this methodology.

One of the challenges with this project is that as there is no established accurate method for measuring fibre fineness and maturity, it is not possible to simply check the result obtained with the Laserscan with another approach. Rather the approach taken in this project is carefully assemble samples with a known growing history so it is possible to predict the expected trends in the results. Further as detailed below a theoretical analysis was developed to check the self consistency of the results.

3. Results

3.1 The Effect of Different Harvesting Times on Fibre Fineness (Year 1 Modified Objective A)

A set of samples harvested at different times were analysed. This demonstrated that as expected the fibre fineness increased as the cotton was allowed more time to grow before harvesting ie the techniques is giving sensible results. These results are described in detail in a paper presented to the Beltwide conference in January 2001 and reproduced here as Appendix 1.

In the second year of the study, with the cooperation of Greg Constable and his team at ACRI, this experiment was repeated with two different varieties. Again this gave an encouraging set of results as detailed in Appendix 2.

3.2 Derivation of Fibre Maturity Data (Year 1 Objective B and Year 2 Objective B)

A detailed literature search revealed that this modelling work was undertaken and successfully completed in the 1960s by English scientists at the Shirley Institute. Using a large data set of 100 different cotton samples a simple empirical mathematical formula was derived to relate fibre fineness, fibre maturity and micronaire. In other words, when two of these three quantities are known, it is a straightforward to calculate the third. Advice from the USDA researchers and others indicate that there is good reason to expect a simple relationship and they believe the established empirical relationship to be still valid for modern cotton varieties.

This relationship was applied to the data sets for cottons picked at different times (see Appendices 1 and 2) and this gave acceptable maturity values with predicted trends.

3.3 Development of a Further Qunatitative Test of the Measured Fibre Fineness and Maturity Values. (Year 2 Objective B)

Using the know fact that fibre perimeter is largely constant as the fibre matures, then it would be expected that the fibre perimeter would be constant over the set of samples picked at different times. This assumption leads to the simple relationship that for these samples fibre maturity should be linearly proportional to fibre fineness. As demonstrated in Appendix 1 is a good quantitative check on the fibre fineness and maturity values obtained in our experiments and values do indeed confirm to this relationship.

3.4 Estimating the size of the Instrument Correction Factor

As noted in the Background above, it is necessary to apply an instrument correction factor in the calculation of fibre fineness. This arises as in the measurement zone the cell is somewhat wider than the laser beam that is used to detect snippets. As snippets as basically randomly flowing through the cell suspended in liquid, some of the snippets which inevitably flow close to sides of the cell and totally miss the laser beam will not be counted. The exact size of this correction with thus depend on the specific details of the fluid flow which are hard to estimate with certainty (eg the fluid flow near the edges of the cell could be different to the middle and equally the position of snippets might not be random).

The practical solution to this problem is to 'back calculate' this correction factor after measuring fibre of known fineness values.

As an independent check, this was investigated further. High speed video analysis was undertaken which revealed that to a large extent snippets seems to behave randomly. Using this information same simple modelling was undertaken to estimate expected values for the correction factor. Some of the results as listed in Appendix 3. The estimated values are similar to the measured values given further confidence about the instrument.

As not every snippet is counted, in statistical terms the total number of snippets N in the weighed sample is estimated rather than being an exact value. The error in this estimate can be evaluated statistically and simple experiments have demonstrated that simple known statistics apply. This error is reduced to lees than 1% by counting a large number of snippets, typically greater than 20,000.

3.5 Increasing the Speed of Measurement (Year 2 Objective A)

As the concentration of snippets in the instrument is increased, the chance of two snippets being in the measurement zone of the instrument at the same time increases. When this occurs it is possible for the instrument to count them as one snippet leading to potential error in the number of snippets. In its commercial operation in the wool industry, the Laserscan is limited to a maximum count rate of 100 snippets per minute to control ie minimise the occurrence of this potential problem. For the current application this is quite a severe limitation on the speed of measurement. In this mode of operation a typical measurement time is 45 minutes, clearly not commercially acceptable. This issue was tackled in two ways.

Firstly, instead of simply dropping the snippets into the instrument reservoir, approaches to premixing them in a quantity of carrier liquid were investigated. A variety of different techniques were investigated and it was found that a premix using a laboratory test tube shaker was satisfactory.

Secondly, the software of the instrument was modified to enable it to function at higher concentrations. This enabled a larger quantity of snippets to be put into the machine thus reducing the measurement time. Results are illustrated in Appendix 4. Note that in this graph the previous 'normal' operation is only 5 mg. As the quantity of snippets is increased at first the number of fibres measured increases linearly but at larger quantities a deviation from linearity is observed arising as expected from the instrument under counting as explained above. However, this effect was found to be quite reproducible and predicable. This it is possible to work at the increased rather by a simple small adjustment of the instrument factor α. This enabled a ten fold increase in the speed of operation to be implemented.

It is believed that another factor of 5 needs to be implemented to meet a commercial speed. Other ideas for this will be investigated in the continuing work (Project CTFT2C)

3.6 Carrier Liquid in the Instrument (Year 2 Objective A)

In its normal usage in the wool industry, the liquid in the Sirolan-Lasersan is a water-propanol mixture. This provides both good wetting of the snippets (so they readily enter the instrument rather than floating on the liquid surface) and also simulates a environment of 65% relative humidity. In the case of wool the humidity is important as the fibre diameter being measured varies with relative humidity. For the current application the relative humidity in the instrument is unimportant as it is simply counting snippets.

Experiments were undertaken to identify a simpler (cheaper) carrier liquid. Simple water-surfactant/detergent mixes were examined. It has proved more difficult than expected to find a suitable surfactant however this has now been achieved.

3.7 Market Information

As part of the project an analysis has been undertaken of the requirements of different market segments for the technology. From this a simple business model has been developed. It is believed that it would be prudent to first aim to produce a stand alone instrument for use by spinners in their quality control laboratories. If this leads to positive feedback then this would act as a driver to enter the HVI market, which of course is dominated by Zelweger Uster and the USDA.

It is noted that the business/marketing strategy will have to be further jointly developed and approved by CRDC and CSIRO as the work progresses.

3.7 ITMF Working Group on Fibre Fineness and Maturity

As a result of the presentation to the US Beltwide conference in January 2001 of work from this project, Geoff Naylor and Stuart Gordon were invited to join the ITMF working group on fibre fineness and maturity. As a result both attended and presented at their workshop in Bremen in March 2002. This has been reported separately to CRDC.

As the current project has progressed and appears to becoming closer to a real commercial outcome, it was decided for commercial reasons, not to give an update on our technical progress. It should however be noted that the general feedback and contacts made at the workshop and the main Bremen conference are proving to be most valuable to the ongoing progress of this project and other CRDC funded work at CSIRO Textile and Fibre Technology.

5. Research Conclusions

Based on the results to date, the approach of using the Sirolan-Laserscan in this new mode of operation looks promising as the basis of a technique for measuring cotton fibre fineness and maturity.

6. Intellectual Property

Whilst the current application of the Sirolan-Laserscan is novel, it is based on a well established principle, namely the gravimetric determination of fibre fineness. At this stage it is envisaged that the final instrument would not infringe the patents associated with the Laserscan technology.

7. Impact on Cotton Industry

A commercially viable technique for accurately measuring both fibre fineness and maturity would undoubtable be of significant value to the Australian cotton industry. It would enable growers to confidently identify and market fine mature cottons without the current ambiguity caused by the micronaire measurement.

8. Recommendations for Future Work

The work has indicated that there is potential for the approach to technically measure fibre fineness and maturity. The work in this area is continuing in CRDC funded project CTFT2C.

9. Acknowledgments

Financial support for this project was provided by the Cotton Research and Development Corporation and also CSIRO. The help of Greg Constable and his team at ACRI in providing cotton samples is gratefully acknowledged.

10. Publication from Project

Naylor, G.R.S. Cotton Maturity and Fineness Measurement using the Sirolan-Laserscan.. Proc. 2001 Beltwide Cotton Conference.

Appendix 1. Beltwide Paper January 2001

Cotton Maturity and Fineness Measurement Using the Sirolan-Laserscan.

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Abstract

Using a set of cotton samples representing differing growing times, the present paper assesses the potential of the Sirolan-Laserscan to measure average fibre fineness. The measured results accurately reflect the expected variations in fibre fineness values for these samples. Combining these measured fibre fineness values with HVI micronaire data the paper illustrates that average maturity ratio values can also be obtained. Again for the set of samples measured the average maturity ratio values follow the expected trends. Further an independent simple test is developed to examine the internal consistency of the fineness and maturity ratio values for this set of samples. The Sirolan-Laserscan results pass this test unlike those obtained from the FMT.

Introduction

Commercially the presence of immature fibres in a blend can lead to significant textile problems including the formation of neps during processing and 'white spec' imperfections during dyeing. Fibre maturity can be measured directly from fibre cross-sections and Thibodeaux and Rajasekaran (1999) have used this approach in the development of reference standards for cotton fibre maturity. Unfortunately, this approach is inherently slow and hence not suitable as a commercial test. Despite considerable research effect no satisfactory commercial method is available for assessing fibre maturity. For example the Micronaire measurement is a mixture of both fibre fineness (mass per unit length) and maturity and for many cotton varieties the micronaire value may not be a good indicator of either property (Williams and Yankey, 1996).

Naylor and Sambell (1999) described the results of a preliminary study using a new approach to measure the fibre fineness of cotton samples independently of fibre immaturity. This approach utilised the Sirolan-Laserscan, a commercial instrument developed for the wool industry. This instrument developed at CSIRO is in commercial use for the rapid measurement of the full fibre diameter distribution of wool samples (IWTO, 1993). The technique suspends fibre snippets in an isopropanol-water mixture that transports them such that they cross the path of a laser beam. The fibre diameter of each fibre snippet is determined from its interaction with the laser light. Naylor and Sambell (1999) illustrated that the instrument in a novel mode of operation can indeed be used to determine fibre fineness accurately.

The current paper extends the earlier preliminary work

Methodology

Samples from a plot of Sicala 40 cotton were hand picked at different times over the growing season to provide a range of fibre maturities. Unopen bolls were oven dried, opened by hand, and ginned in a 20-saw laboratory gin. The lint was characterised using HVI and FMT standard procedures.

Average fibre fineness was determined following the technique described previously (Naylor and Sambell, 1999). Samples were conditioned at 20 C and 65% relative humidity for at least 24 hours before taking measurements. Fibre snippets were then cut using a standard Sirolan-Laserscan guillotine from aligned 'beards' of fibres produced using the SpinLab Fibroliner. After weighing, the fibre snippets were fed into the Sirolan-Laserscan which was set such that it continued to count until all the sample was exhausted. This yielded the total number of fibres N 'seen' by the instrument. (As the actual laser beam is smaller in size than the measurement cell, statistically only a proportion of the input snippets are registered by the Sirolan-Laserscan.) A predetermined instrument correction factor, α, is then applied to yield the total fibre snippets in the sample. The average fibre fineness (linear density) FF was then calculated by the formula:

$$FF = \alpha W/(NL) \qquad (1)$$

where W is the total weight of the snippets and L is the snippet length.

Results

Table 1 lists the details for the set of cottons examined together with their associated HVI and FMT results (Constable, private communication). Qualitatively these data follow the expected trend. For the first five samples the measured micronaire (both HVI and FMT values) and FMT fibre fineness and maturity ratio values all follow an increasing trend with an increase in growing period/fibre development. Similarly the reversal in this trend for the last sample is to be expected for the late developing bolls.

The FMT data can however be analysed a little more quantitatively. By definition, the maturity ratio M measures the portion of immature or 'dead' fibres and is related to the degree of wall thickening by

$$M = (4\pi * 0.577)A/P^2 \qquad (2)$$

where A and P are the cross-sectional area and perimeter of the fibre respectively (Thibodeaux, 1998). For a given cotton variety it is known that perimeter P is approximately constant. From Equation 2 it then follows that if P is constant, then fibre maturity M, is directly proportional to fibre cross-sectional area A ie fibre fineness. Using these relationships, Thibodeaux (1998) illustrated the linear relationship between fibre fineness FF and maturity ratio M for fixed fibre perimeter values. Interpolating from Figure 2 in Thibodeaux's paper

$$FF \approx 0.069*P^2*M \qquad (3)$$

where fibre fineness is measured in millitex and fibre perimeter in micrometres.

Equation 3 can be used as an independent test of the self consistency of the measured fibre fineness and maturity values for the current set of samples as they would be expected to have a constant value of the fibre cross-sectional perimeter P. Figure 1 shows a plot of the measured fibre fineness versus maturity ratio using the FMT indicating that the FMT results do not conform to Equation 3. It appears as though the FMT is overestimating the maturity ratio for the first few samples ie the very immature samples. This is not altogether surprising as Lord (1955) observed that in the Airflow approach, the simple linear relationship between the rate of airflow and specific surface area begins to break down for dense plugs of cotton (immature samples).

Table 2 and Figure 2 summarise the results for average fibre fineness values obtained using the Sirolan-Laserscan. Lord (1956) demonstrated that over a wide range of samples measured fibre fineness (FF), maturity ratio (M) and micronaire (Mic) are related by the equation

$$M*(FF) = 3.86*Mic^2 + 18.16*Mic +13.0 \qquad (4)$$

Using this equation, the Sirolan–Laserscan average fibre fineness values combined with the HVI micronaire values determine maturity ratio values M. These derived maturity values are also listed in Table 2 and plotted in Figure 2.

Qualitatively the trend in the measured average fibre fineness values and maturity ratio values are as expected, as explained above. Comparing these average fibre fineness and maturity ratio values obtained with the Sirolan-Laserscan with those obtained from the FMT, the Sirolan-Laserscan average fibre fineness values are somewhat larger and the derived maturity ratio values cover a wider range.

Following a similar quantitative analysis to that applied to the FMT data, Figure 1 also plots the Sirolan-Laserscan average fibre fineness values against the derived maturity ratio values. Also shown is the fit of this data set to Equation 3, ie a linear relationship passing through the origin. The Sirolan-Laserscan results are in much better agreement with Equation 3 than those obtained with the FMT. This independent test is added evidence of the validity of the measurement approach.

In summary, the Sirolan-Laserscan approach to measuring average fibre fineness correctly determines the trends of expected fibre fineness values as a function of growing time over the samples tested. When combined with HVI micronaire values the Sirolan-Laserscan fibre fineness values can be used to determine average fibre maturity ratio values which also follow the expected trends. Further, unlike the FMT values, the Sirolan-Laserscan values of average fibre fineness and fibre maturity ratio forms a self-consistent set for samples of fixed fibre cross-sectional perimeter.

Conclusion

The results presented add further positive evidence that the new approach of using the Sirolan-Laserscan to measure cotton fibre fineness and maturity ratio looks promising.

Acknowledgments

Financial assistance from the Australian Government and also a research grant from the Australian Cotton Research and Development Corporation is gratefully acknowledged. The author would also like to thank Dr. G. Constable and Mr C. Tyson for providing the cotton samples and corresponding HVI and FMT values used in this work. Thanks also to Miss. L. O'Brien for her technical assistance.

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Table 1. Summary of Cotton Samples and Corresponding HVI and FMT Characterisation.

Harvest Date	**Comment**	**HVI Data**		**FMT Data**	
		Mic.	**Mic**	**Maturity**	**Fineness**
11/02/2000	**Small Bolls -closed**	2.1	1.7	0.63	76
11/02/2000	**Large Bolls- closed**	2.2	2	0.62	99
21/02/2000	**Closed**	2.5	2.4	0.61	127
2/03/3000	**Large Bolls - closed**	3.1	3.2	0.65	170
2/03/2000	**Large Bolls - open mature**	4.7	4.2	0.79	199
10/04/2000	**Late Bolls - open**	3.2	3.3	0.73	157

Table 2. Sirolan-Laserscan determined Average Fibre Fineness and Inferred Average Fibre Maturity Ratio Values.

Harvest Date	**Comment**	**Fibre Fineness (mtex)**		**Estimated**
		Mean	**SD**	**Maturity Ratio**
11/02/2000	**Small Bolls - closed**	102	6	0.54
11/02/2000	**Large Bolls - closed**	134	7	0.48
21/02/2000	**Closed**	147	9	0.54
2/03/3000	**Large Bolls -closed**	165	3	0.67
2/03/2000	**Large Bolls - open mature**	199	5	0.79
10/04/2000	**Late Bolls - open**	167	6	0.69

Figure 1 The relationship between fibre fineness and maturity ratio for two different measurement techniques.

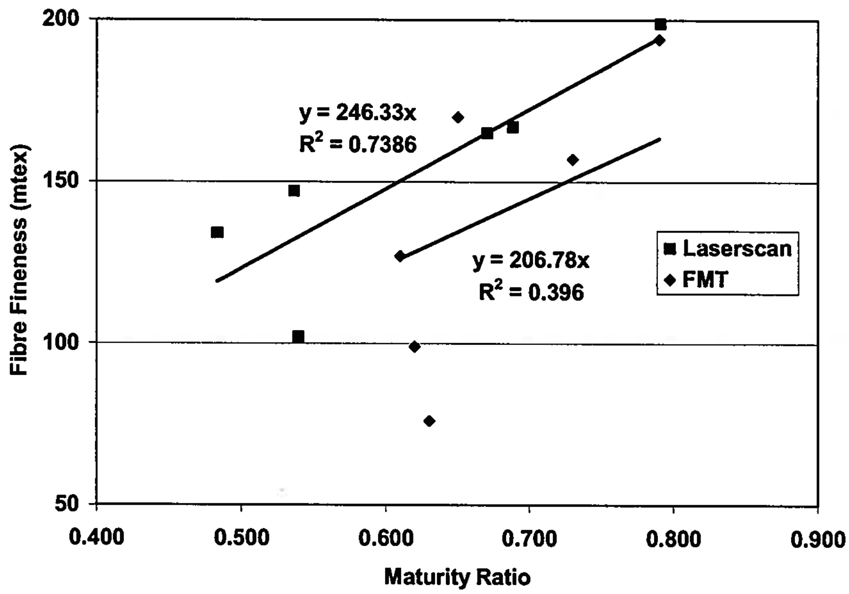
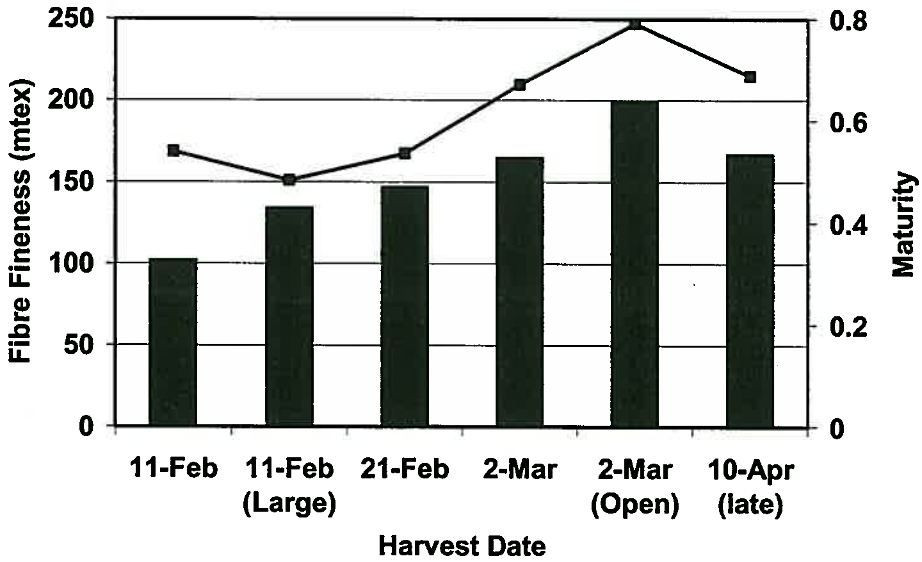


Figure 2 Summary of Average fibre fineness (bars) and inferred maturity ratio



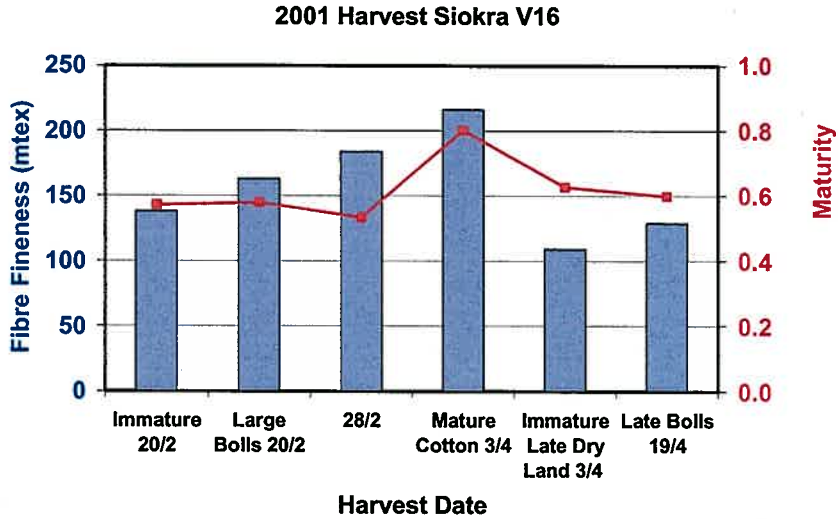
(squares) values obtained from the Sirolan-Laserscan.

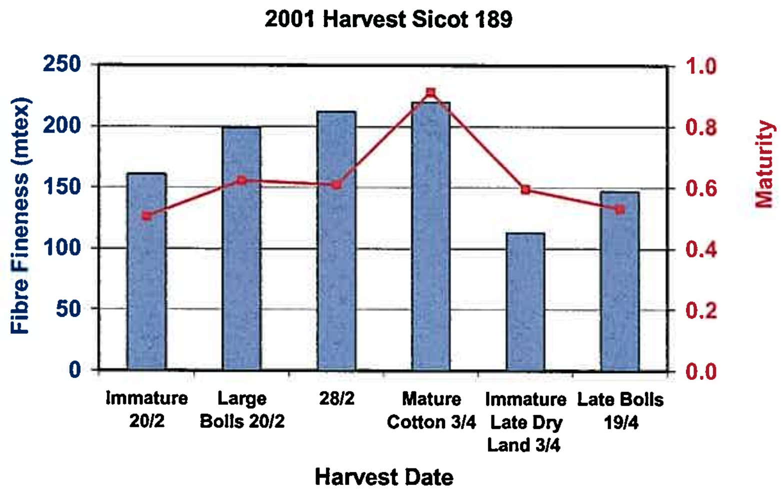
Appendix 2. Results from Year 2 Time of Harvesting trials.

In the second year of the trials ACRI provide samples of Sicot 189 and Siokra V16 as follows:

1. Harvested 20 Feb. Smaller and less mature bolls from about half way up the plant.
2. Harvested 20 Feb. Larger but still unopened bolls from near the bottom of the plant.
3. Harvested 28 Feb. Still unopend bolls from the same position as 2.
4. Havested 3 April. Mature opened bolls.
5. Harvested 19 April. Immature unopend bolls from the top of the plant.
6. Harvested 3 April. Immature unopened bolls from the top of the plant at a dryland site.

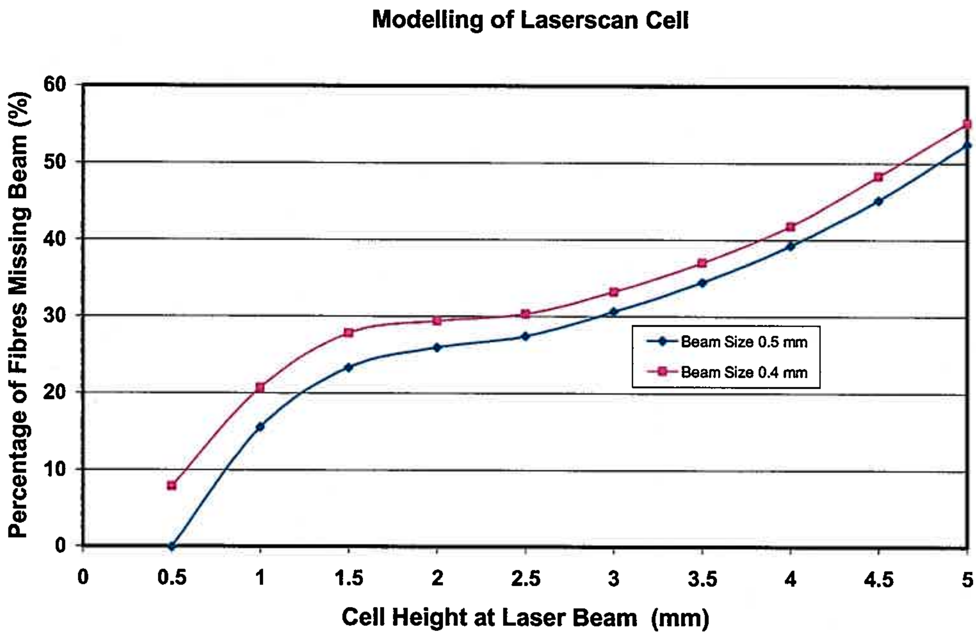
The measured results are as follows:





Appendix 3. Modelling of the Instrument Correction Factor.

Modelling of the percentage of fibres missing the beam in the instrument was undertaken for a range of parameters and typical results are as illustrated . This modelling assumes a purely random orientation and distribution of snippets in the fluid. The inverse of the missing percentage is the expected instrument correction factor.



Appendix 4. Effect of Increasing Speed of Measurement by Increasing Mass Measured on the Accuracy of the Measurement.

Results from trials where the quantity of premixed cotton snippets entering the instrument was varied. Note that the previous 'normal' amount is the smallest amount on this graph. As the quantity of snippets is increased there is a small but predictable deviation from linearity in the number of snippets measured by the instrument. This deviation arises from the the increased occurance of two or more snippetes simultaneoussly passing the measurement cell and being counted as only one.