

REPORTS

Part 1 - Summary Details

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

CRDC Project Number: CWT6C
Annual Report: Due 30-September
Progress Report: Due 31-January
Final Report: Due 30-September
(or within 3 months of completion of project)

Project Title: Measuring cotton fibre maturity using polarised light microscopy

Project Commencement Date: 1/7/00 **Project Completion Date:** 30/6/03
Research Program: 6 Value Chain

Part 2 – Contact Details

Administrator: Mr Hayden Smith
Organisation: CSIRO Division of Textile & Fibre
Postal Address: P O Box 21, BELMONT VIC 3216
Ph: 03-5246 4013 **Fax:** 03-5246 4054 **E-mail:** Hayden.Smith@csiro.au

Principal Researcher: Dr Stuart Gordon
Organisation: CSIRO Division of Wool Technology
Postal Address: P O Box 21, BELMONT VIC 3216
Ph: 03-5246 4000 **Fax:** 03-5246 4057 **E-mail:** stuart.gordon@csiro.au

Supervisor: As above

Organisation:

Postal Address:

Ph: **Fax:** **E-mail:**

Researcher 2 (Name & position of additional researcher or supervisor).

Organisation:

Postal Address:

Ph: **Fax:** **E-mail:**

Signature of Research Provider Representative: _____

Part 3.3 – Final Reports

(The points below are to be used as a guideline when completing your final report. Postgraduates please note the instructions outlined at the end of this Section.)

1. Outline the background to the project.

Cotton fibre maturity is an extremely important property to spinners and fabric manufacturers because it determines how well fibres will process both from a chemical and a physical perspective. 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. While knowledge of cotton fibre maturity has always been important with regard to avoiding these problems, there is an increasing need for faster and more accurate measurements. The reasons for this are:

- Faster automated processing machinery which to be profitable needs to operate efficiently.
- Increasing demand for higher quality yarns and fabrics.
- Smaller mill blending lines means that bales of immature cotton cannot be blended out.
- Increasing competition from synthetic fibres whose properties are better specified and more consistent.

There are a number of methods for measuring fibre maturity though no one method is able to do so both accurately and with the speed for classing purposes. The methods currently used range from direct measurement of fibre wall thickness from magnified cross-sections to indirect methods that indicate maturity relative to some other fibre parameter.

Direct or reference values of fibre maturity used to calibrate faster indirect methods have been obtained by various methods over the last fifty years. Although theoretically more accurate, direct values suffer from significant experimental error due to the fine detail involved in preparing fibres for direct measurement and the limited numbers of fibres that can be practically measured. Furthermore, these tests often require the operator to make subjective assessments on the form of the fibre. Indirect methods are favoured by cotton marketers and processors because they provide fast results. However, effects of other fibre features tend to bias the results they give. For example, the Micronaire is the most widely used indirect method for measuring fibre maturity even though it actually measures a composite of fibre fineness and fibre maturity. This means that a fine, mature cotton, which is premium cotton, might give the same reading as coarse, immature cotton. Hindering the development of a fast and accurate indirect method is the absence of an accurate and precise reference method.

In this project CSIRO Division of Textile and Fibre Technology (TFT) is proposing to automate and make objective the polarised light microscopy method for assessing fibre maturity. This method determines fibre maturity based on the colours fibres assume when viewed under a polarised light microscope. The relationship between polarised light colour and fibre maturity is based upon a fibre's wall thickness and its cellulose chain orientation. The method has previously been overlooked because classing the fibres on the basis of colour was subjective and the manual counting of fibres was too slow. However, with the advent of colour digital cameras and associated analysis software, TFT believes that the method's status can be elevated to a position where it becomes the preferred reference

method for measuring maturity. Furthermore, TFT believes that the method can be made faster than current indirect methods such as the 'Shirley' Fineness and Maturity Tester and the Advanced Fibre Information Systems instrument. As well as reference and laboratory measurements, it is envisaged that the test will be portable enough for use in the field as another tool to assess crop maturity.

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

First year -

- (1) Establish simple fibre presentation procedure for test.
- (2) Establish basic relationship between fibre colour under polarised light and maturity on range of cottons.
- (3) Validate polarised light maturity results against current measurements for fibre maturity.
- (4) Develop image and colour analysis software for routine measurement of samples.

Second year -

- (1) Develop fibre colour and maturity algorithm for routine measurement of samples.
- (2) Synchronise microscope stage movement with image and colour analysis.
- (3) Report on development of test to fibre testing industry.

Third year -

1. Automate polarised light measurement.
2. Construct prototype instrument.
3. Investigate interest in development of commercial fibre maturity instrument.

All of the above objectives have been completed.

3. Detail the methodology and justify the methodology used.

The approach in this project has been first to validate the use of PLM as a direct measure of fibre maturity. This was done by undertaking a comprehensive and detailed survey of the interference colour emitted from cotton fibres when viewed under crossed polar lens using the set-up as specified in the ASTM Standard 1422. The survey involved examining the interference colours of cotton of different species, varieties and growths. Colours were measured using a digital Hue Saturation Intensity (HSI) colour model. Cross-sections cut at three places along the lengths of fibres were examined after colour profiles from the exact same fibres were collected. Matching the colour profiles with cross-sectional calculation of fibre maturity allowed colour to be directly compared with maturity. The results revealed a clear delineation between immature and mature fibres on this basis. Furthermore, the application of a uniform colour thresholds across fibres from different species and genetic backgrounds, presented as longitudinal sections, showed that the colours representing 'maturity' and 'immaturity' did not change on the basis of cross-sectional area or perimeter suggesting that the path length differences between cottons of different cross-sectional area are negligible. This

suggests that the crystalline structure of the fibre governs the optical path length rather than the more generally interpreted cross-sectional diameter.

The project, having determined the validity of the test, turned to automating the ASTM Standard 1422. This entailed automating microscope stage movement and integrating it with an image analysis program. Captured images of snippets are digitised before being processed using a pre-determined sequence of standard (Boolean) functions to define and calculate the areas of each snippet and the area of specific colours in each snippet, snippet length and the number of intersection points along a snippet. Snippet boundaries and areas are defined on the basis of a set of intensity values that separate pixels of interest from the rest of the image. Pixels of certain intensities are highlighted and segregated for measurement using a range of threshold functions each one of which relates to a particular colour (area) of interest. Figure 1 is a picture of the prototype instrument that measures the fibre maturity colours defined in ASTM 1422 automatically.

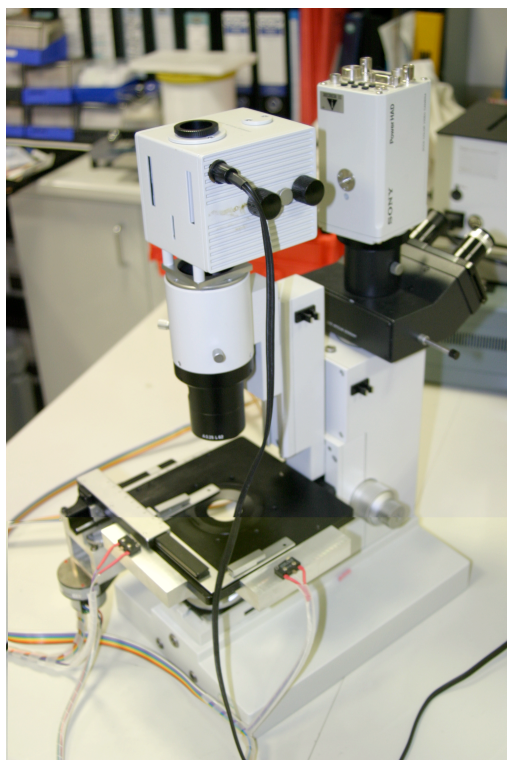


Figure 1 – A view of the automated polarized light microscopy method for measuring cotton fibre maturity showing digital camera and motorized XY stage.

A set of 35 cottons were then measured on the automated system and their percent yellow, blue, green and red colour plus snippet length and number of fibre ends and fibre crosses recorded. The colour data were then correlated with FMT data measured on the same cottons at the SRRC USDA laboratory in New Orleans. The FMT data at SRRC is recognised internationally as being the most precise data from this method. The relationships between FMT maturity and the percent yellow and blue colours were highly significant and the prediction algorithm at this stage seems

unlikely to require more than two terms (variables) making the application of percent blue or yellow colour a robust measurement of maturity.

The reference set of cottons was increased recently to include 25 low micronaire cottons from the 2002/03 growing season. The addition of these cottons makes the calibration set more uniform across a wider range of fibre maturities and improves prediction of immature samples using algorithms based on the yellow and blue colours. The new expanded set of cottons; 35 measured at SRRC plus the 25 low micronaire cottons, was remeasured on the ACRI FMT to provide the same reference values for the entire set.

Further improvement of the above relationship between percent yellow and blue and FMT maturity has been investigated with regards to sample preparation and presentation including sample size (0.5 mg, 1 mg & 2 mg), snippet cutting technique, snippet length (0.5 mm, 1 mm & 2 mm), number of replicates (1 → 6 replicates), different mounting media, light intensity and magnification including objective type.

At this point in time, we have achieved all objectives set out in CDWT6C and have started building two new prototypes for inter-laboratory trials later this year.

The test time in the present prototype is currently 5 minutes. This will be reduced to 2 minutes in the new prototypes. This test time will be the same test time for the stand alone MicroMat (new FMT) and faster than the AFIS Fineness and Maturity Module. Sample preparation time is similar or faster than these methods and unlike these methods samples can be tested without conditioning.

4. Detail and discuss the results including the statistical analysis of results.

See above.

Correlations between FMT maturity, which has been selected as a reference more on the basis of its availability than its accuracy, and percent colour (blue and yellow) area are significant but vary according to the range of maturity values represented in the set and the number of replicates performed. For selected sets where fibre maturities are uniform across a wide range, e.g., the range of maturity ratio values extends between 0.60 and 1.10 more than 74% of the correlation (R^2) is explained by the percent blue or percent yellow colour area as measured by the automated polarised light microscopy method. This percentage increases when replicates are measured. The recommended number of replicates will be determined for the new prototypes once instrument and inter-laboratory variation have been accounted for.

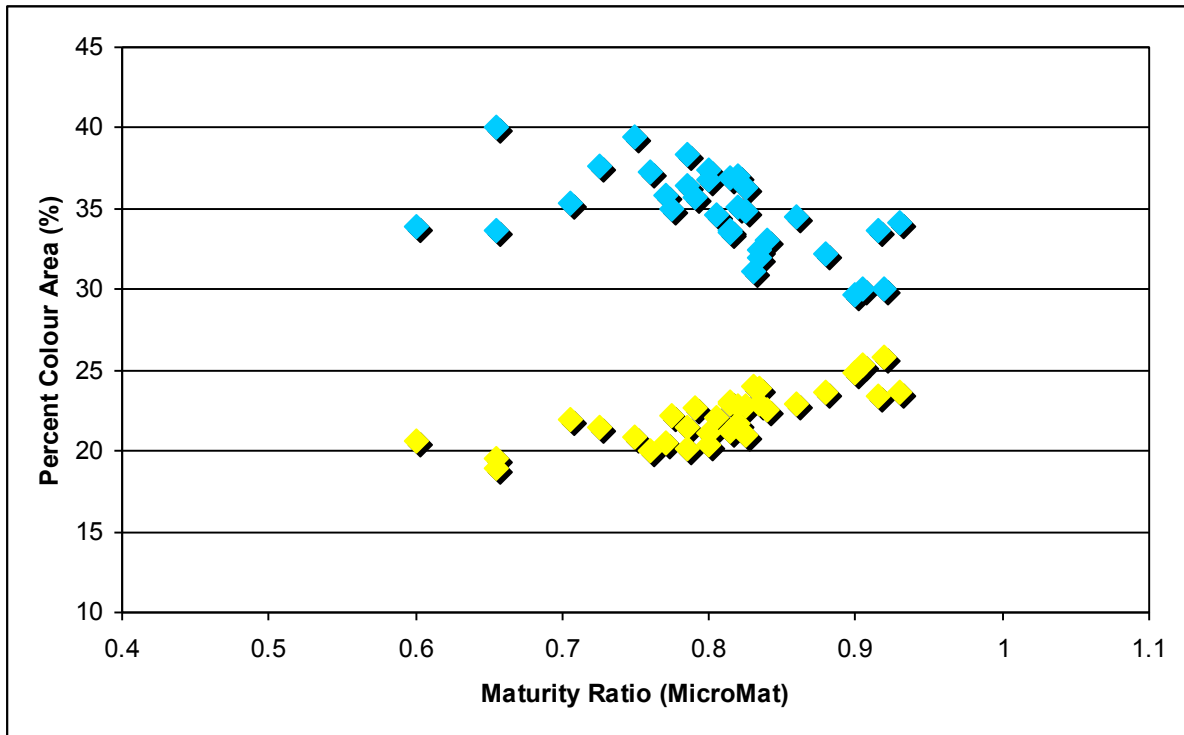


Figure 2 – Maturity Ratio as measured by the ‘Shirley’ FMT at the USDA SRRC laboratories against the percent yellow and blue colours measured on the original 35 reference cottons by the polarised light microscopy method.

5. Provide a conclusion as to research outcomes compared with objectives. What are the “take home messages”?

The polarized light microscopy method developed in this project provides a fast, accurate and direct measure of fibre maturity and the distribution of fibre maturity in a fibre sample. The instrument will be useful reference and quality assurance tool in mill and merchant test laboratories as well as being a valuable research tool in the effort to further understand the links between environment, plant genetics and fibre maturity.

6. Detail how your research has addressed the Corporation’s three Outputs - Economic, Environmental and Social?

The research in this project directly impacts upon the profitability and competitiveness (economic) objective of the Corporation. The instrument being developed will help identify opportunities for enhancing the quality of Australian cotton from a mill perspective and, as such, lead to an enhancement in terms of its quality image thus increasing the demand for Australian cotton in the global cotton market.

7. Provide a summary of the project ensuring the following areas are addressed:

- a) technical advances achieved (eg commercially significant developments, patents applied for or granted licenses, etc.)**

An extensive patent search has been conducted by Intellectual Property Management Pty. Ltd. on behalf of CTFT. The search has revealed no similar

inventions. A provisional patent will be submitted prior to discussion of results at the 2004 ITMF Cotton test Meeting in Bremen.

b) other information developed from research (eg discoveries in methodology, equipment design, etc.)

The information revealed in the survey of cotton fibre interference colours is the subject of a peer review paper currently being drafted.

c) are changes to the Intellectual Property register required?

Subject to successful application/defence of provisional patent.

8. Detail a plan for the activities or other steps that may be taken:

(a) to further develop or to exploit the project technology.

See new project proposal

(b) for the future presentation and dissemination of the project outcomes.

See new project proposal

(c) for future research.

See new project proposal

9. List the publications arising from the research project and/or a publication plan.

Papers

- New Developments in Cotton Quality Assessment: The Australian Direction, S. Gordon, paper in preparation for the Bremen International Cotton Conference, March 2004.
- A Survey of Interference Colours Observed in Mature and Immature Cotton, S. Gordon and N. Phair, paper in preparation for the Textile Research Journal November 2003.
- Polarised Light Microscopy Method for Measuring Cotton Fibre Maturity, S. Gordon and S. Lucas – provisional patent application in preparation October 2003.
- Internal Structure of Mature and Immature Cotton Fibers Revealed by Scanning Probe Microscopy, J. Maxwell, S. Gordon and M. Huson, paper accepted for publication by the Textile Research Journal September 2002.

Presentations

- CRDC Fibre to Fabric (F2F) Workshop Narrabri NSW – February 2000
- CRDC F2F Workshop Narrabri NSW – March 2000
- CRDC F2F Workshop Geelong VIC – August 2001
- Bremen Cotton Test Method Meetings Bremen Germany – March 2002
- CRDC/ITMF F2F Workshop Narrabri NSW – April 2003
- ACSA Conference Royal Pines QLD – September 2003

10. Provide an assessment of the likely impact of the results and conclusions of the research project for the cotton industry. Where possible include a statement of the costs and potential benefits to the Australian cotton industry or the Australian community.

See new project proposal and the CRDC led International Field to Fabric Initiative (IFFI) and International Cotton Classification Initiatives (ICCI).

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.

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Hindering the development of a fast and accurate indirect method is the absence of an accurate and precise reference method.

In this project CSIRO Textile and Fibre Technology has developed a technology that measures fibre maturity directly and automatically. The advantages over current reference methods are the method's accuracy, speed and objectivity. Furthermore, the method has a test time equivalent to that of some indirect test methods. The test time for the method at the moment is in the order of 2 minutes, which is similar to test times for other laboratory based fibre maturity tests such as the Uster AFIS PRO and the SDL-Shirley Micromat Cotton Fineness Maturity Tester.