AN ALTERNATIVE MINIATURE COTTON SPINNING SYSTEM

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Abstract

Australian cotton is well known for its high and consistent quality, although agronomy, physiology and breeding research continues to ensure Australian cotton stays competitive from a quality standpoint. The testing of fiber in yarn and fabric form means the selection of new cultivars and field treatments is based on outcomes important to the end user. Such field experimentation inevitably produces large numbers of small (< 1kg) lint samples that need to be processed through to yarn and fabric. To meet this need, an alternative miniature spinning system which is actually a hybrid spinning system was created utilizing a combination of the 'Shirley' miniature spinning plant and industrial-scale spinning machinery. This process uses the miniature system for carding and a single drawing passage, while industrial-scale machinery are employed for a second draw passage, the creation of twisted roving and ring spinning. The experimental sample required for this protocol is small, being only 170 g. This study showed that there was no significant difference between industrial-scale and the new hybrid miniature spinning system for yarn strength for both Upland and Pima cotton, although the miniature spinning protocol produced yarns that were less even. We conclude that this miniature spinning system is adequate for assessing the strength of medium count, carded ring spun yarns manufactured from small amounts of lint.

Introduction

Australian cotton has a good reputation for quality and consistency and is usually purchased to produce high quality medium to fine count, combed ring spun yarns. Because a premium is paid for Australian cotton, it is expected to enhance the quality of a mill's base lay-down and to perform in the spinning mill without difficulty.

The premium that is paid for Australian cotton is the result of the industry's adoption of CSIRO bred cultivars, the embracement of new production technologies and the implementation of best management practices. These have led to the creation of one of the most efficient and environmentally sound cotton production industries in the world. However, production efficiency alone does not support a commodity in today's markets. The Australian industry has thus initiated a new research program that aims to strengthen links between breeding, agronomic management and post-harvest fiber quality research.

Central to this program is linking research in breeding and farm systems to textile quality. The linkage allows evaluation of genetic, agronomic and physiological variables in terms of textile quality. This approach means that new cultivars and new production inputs and systems are assessed fully in terms of cotton's final end-use, rather than predicted via measurements on high volume instrumentation (HVI), the data of which can be limited in its ability to predict yarn and fabric quality. Indeed, using yarn and fabric quality to assess differences in cultivars and production practices allows all input variables to be accounted for in determining the best cultivar and production practice to adopt.

In order to determine textile performance on large multiples of cotton samples from field trials without the need or expense of running industrial scale machinery, CSIRO re-furbished a 'Shirley' miniature spinning plant manufactured by the Platt Company of the UK. This equipment was first manufactured in the mid 1950s and was designed to enable commercial mills and research organizations to process small batches (< 1 kg) of fiber to determine spinning ability. With the application of HVI systems to describe cotton fiber quality in the 1970s and 80s, utilization of small-scale spinning apparatus diminished. The current interest by CSIRO in spin testing is associated with the Australian industry's objective of linking research in breeding and farm systems to textile quality. In particular, interest lies in understanding the variation in yarn quality outside that attributable to the standard HVI fiber properties of length, strength and micronaire. Whilst these properties predict a large proportion of yarn quality variation, there remains a reasonable proportion of unattributed variation, due to fiber properties that are not typically measured (i.e. maturity, fineness, neps etc.). Being able to spin small samples of fiber into fine-medium count ring spun yarn enables unattributed variation to be captured and utilized in decisions about new cotton cultivars or cropping systems.

The Shirley miniature spinning plant (Figure 1) consists of a small card, draw frame and ring spinning frame. [1] Since no opening or pre-card cleaning is possible on the miniature system, the manufacturer's recommendations are to card the material twice. Following carding, three miniature draw passages are recommended to draw out the sliver until it is light enough to be spun directly on the miniature spinner. Un-like full-scale spinning, this miniature system does not include the intermediate step of producing a twisted roving between drawing and ring-spinning.

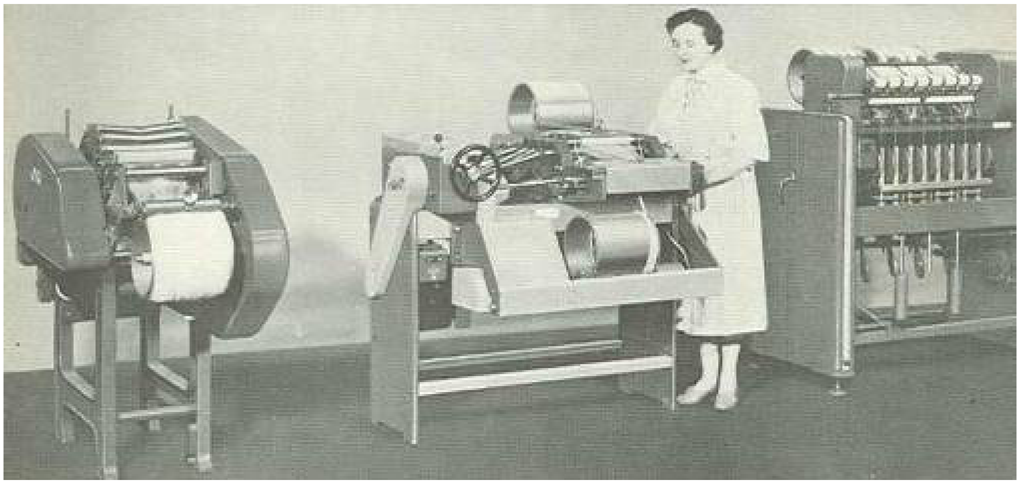

Figure 1 The 'Shirley' miniature spinning plant. (Extracted from Shirley operation manual)

CSIRO found that inferior and practically un-processable yarns were produced when the miniature system was used as recommended; numerous breaks occurred during spinning, and yarns with a large number of slubbings (thick places) and thin places were produced. This occurred because of the large draft ratio that had to be applied to the short length of uneven sliver on the spinning frame; a consequence of a drawing system with little or no blending capacity, and thus no capacity to make the sliver even before spinning.

The aim of this work was to:

1. Devise a hybrid miniature spinning protocol using a combination of both miniature and full-scale equipment, while still maintaining a small (< 1 kg) sample size.
2. Test the performance of the new miniature system against the standard full-scale system by manufacturing a medium count 20 tex (30 Ne) carded ring spun yarn with a twist factor (αe) of 4.0, for an industry standard Upland cultivar and Pima cultivar.

Materials and Methods

Upland and Pima cotton cultivars were grown together during the 2007 harvest season at the Australian Cotton Research Institute in Narrabri, New South Wales, Australia. The Upland cotton was saw-ginned, while the Pima cotton was roller ginned. No lint cleaning was applied in either case.

Bale samples were conditioned under standard conditions of 20°C +/-2°C and 65% +/-3% relative humidity for 24 hours and tested on an Uster Technologies 900 High Volume Instrument (HVI). Micronaire, staple length, length uniformity, staple strength and elongation were measured (Table I).

Fiber fineness (linear density) was determined using the CSIRO Cottonscan™ instrument, while fibre maturity ratio was determined using the CSIRO SiroMat™ instrument (Table II). Cotton neps were tested using an Uster AFIS PRO (Table III).

Table I– Fibre results by the HVI 900[1*]

Cultivar	Tenacity cN/tex	Elongation %	Length mm	Uniformity Index %	Micronaire (µg/inch)
Upland	30.4	7.6	28.2	82.8	4.9
Pima	51.5	4.6	36.6	88.8	3.8

[1]Calibrated using HVI ICC Upland and Pima Calibration Cottons [*] Average of 10 tests

Table II – Fineness[2] and maturity ratio results by the Cottonscan™ and SiroMat™

Cultivar	Fineness (mtex)	Maturity Ratio
Upland	210	0.9
Pima	143	0.8

[2]Average of 3-5 tests

Table III – Nep, Seed-Coat Nep and SFC results by the AFIS PRO[3]

	Ginned lint			Miniature route 1st draw passage			Full-scale route 1st draw passage		
Cultivar	Neps/ gram	SCN/ gram	SFC(w) %	Neps/ gram	SCN/ gram	SFC(w) %	Neps/ gram	SCN/ gram	SFC(w) %
Upland	184	23	4.3	79	15	4.1	75	7	8.0
Pima	284	19	3.2	157	5	2.8	402	12	4.7

[3]Average of 5 tests

Full-scale spinning

Fifty kilograms of each fiber was processed into yarn using machines set to industry standard settings. Production speeds were kept constant throughout the trial but machine settings e.g. draft distances, were optimised as per accepted practice in high-quality spinning mills. Figure 2 summarises the processing steps, equipment and throughput speeds used to convert the cotton into yarn.

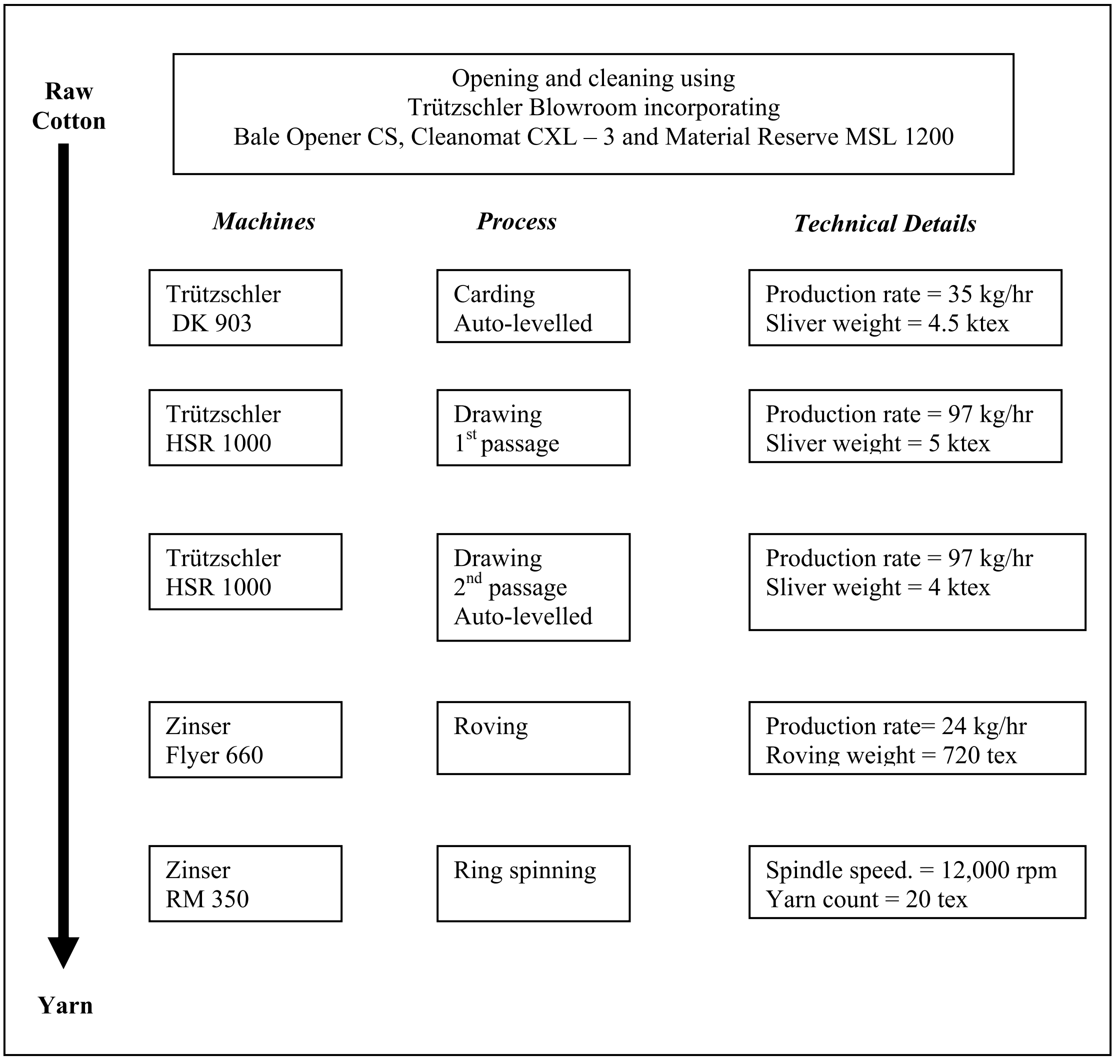

Figure 2 – Yarn processing route and settings for full-scale commercial spun yarn

Miniature spinning

Based on the knowledge that a major source of the inferiority of the Shirley miniature systems relates to the irregularity of the sliver and the large draft ratio at the spinning frame, a hybrid system was developed. This consists of using the miniature card and draw frame to produce slivers, which are then transferred to the full-scale spinning system for further processing through a further draw frame passage and the production of roving prior to spinning.

One hundred and seventy grams of fiber was processed using the miniature card and draw frame. Thereafter the fiber was processed into yarn using machines set to the same industry standard settings as the full-scale spinning process. Figures 3 and 4 summarise the miniature spinning protocol.

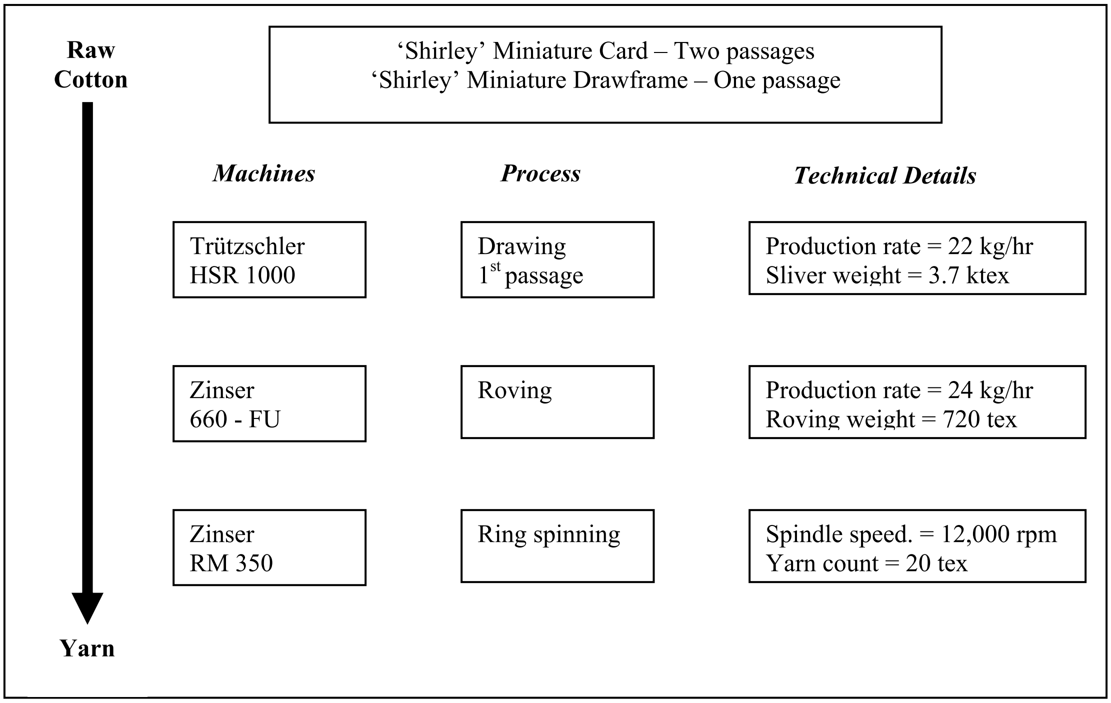

Figure 3– Yarn processing route and settings for miniature spun yarns

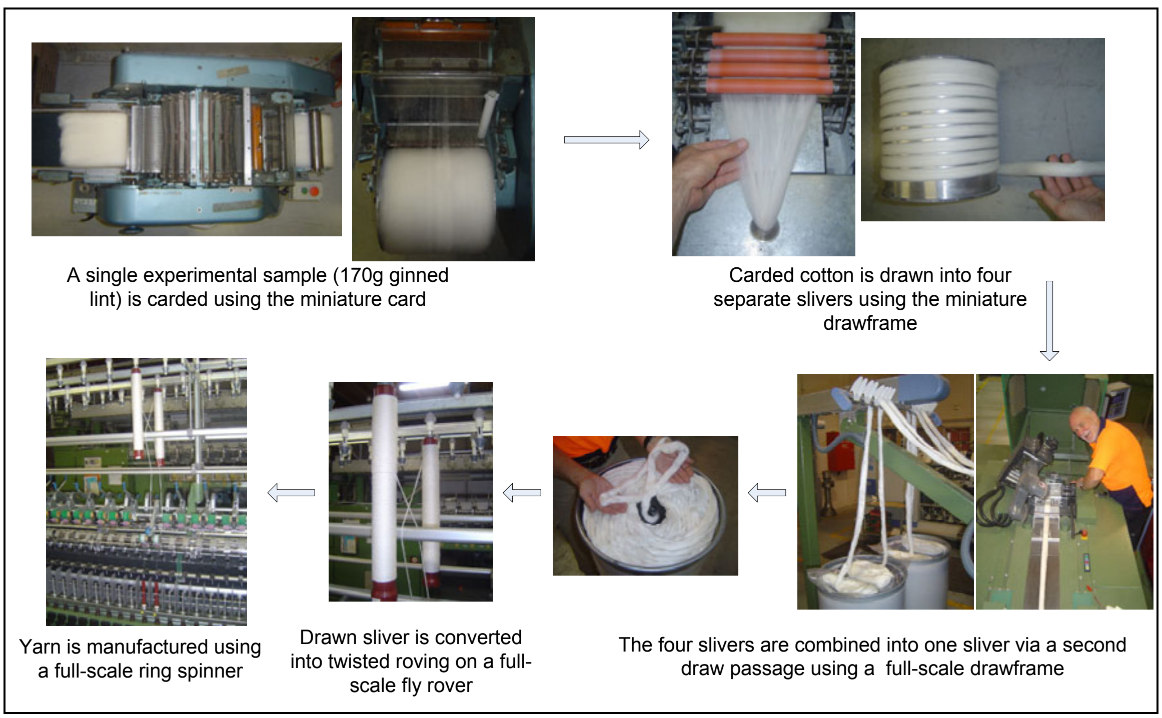

Figure 4 – Yarn processing route for miniature spun yarns

Yarn testing and data analysis

Spun yarns were conditioned under standard conditions of 20°C +/-2°C and 65% +/-3% RH for 24 hours and tested for linear density (count) as per Australian Standard (AS) 2001.2.23, twist as per AS 2001.2.14, and evenness, hairiness and imperfections using an Uster Technologies 4-SX evenness tester as per American Society for Testing and Materials Standard (ASTM) D1425. Tensile properties were determined using the Uster Technologies Tensorapid 3 as per ISO 2062.

Yarn property averages for each cultivar were compared using a one-way between subjects analysis of variance. Least significant differences for the interaction between the spinning systems and cultivars were calculated.

Results and Discussion

The yarn performance (Table IV) of cultivars reflected their respective fiber quality parameters, with the longer, finer and stronger Pima cultivar spinning significantly stronger and more even yarns than the Upland cultivar.

For yarn strength, there was no significant difference between the full-scale and the new miniature spinning system for both the Upland and Pima cultivars, although for both cultivars the miniature spinning system produced yarns that were less even than the full-scale system. As expected the full-scale processing route produced a much more even sliver due to the auto-leveling systems of the card and draw frame, which ensure production of an even and good quality sliver. The card of the simpler miniature system produces a wide dense bat, the evenness of which is determined primarily by the preparation given to the fiber by the operator, i.e. the degree to which fiber is evenly distributed on the card feed. The twice carded bat is then drawn and condensed without any leveling into sliver using the miniature draw frame (see Figure 4).

There was significant interaction between spinning system and cultivar for yarn thick places, thin places and neps (Table IV). The miniature system appeared to introduce neps and thick and thin yarn imperfections for the Upland cultivar only. Conversely for Pima, yarn neps were not significantly different between the two spinning systems; although perhaps surprisingly the full scale spinning system did produce yarns with more thick places possibly due to a machine setting problem as highlighted by the results for the first passage drawframe in Table III. This will need to be further investigated.

Table IV Yarn results for 20 tex (30 Ne) yarns

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

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

Conclusion

This study showed that there was no significant difference between commercial full-scale and the new hybrid miniature spinning system for yarn strength for both Upland and Pima, although the miniature spinning protocol produced yarns that were less even. For yarn neps, there was significant interaction between the type of cotton and spinning system, with the miniature system significantly generating more neps for the Upland cultivar only. We conclude that this miniature spinning system is adequate for assessing the strength of medium count carded ring spun yarns manufactured from small amounts of material. This system is being used to manufacture yarns from agronomy and physiology experiments consisting of substantial numbers of small samples, which otherwise could not be practically assessed via full-scale spinning.

References

1) Platt Brothers (1964),' Shirley Miniature Spinning Plant – Operation Maintenance Details', Platt Brothers (Sales) Ltd P.R. and Publicity Department. Oldham, England.

Acknowledgements

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