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 the influence that harvest aid management practice has on fibre quality and textile performance, with the aim of minimising 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 significantly generated neps at approximately 100 counts/ g per 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 small entanglements or neps in Australian cotton (Gordon et al., 2004). In the case of micronaire it has been suggested that improvements in agronomic practices (e.g. soil and plant nutrition) that 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 currently there is no discount to growers when there is a high incidence of neps, it can affect overall industry reputation when cotton arrives at the mill.

Micronaire is an index 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 thus displaying lower micronaire) 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 when approximately 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 (30º S 150º 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 CO_2 pressurised 2.0 m hand boom using 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^{-1}Thidiazuron); 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 m^{-2}, 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 Purmalis, 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 42g lots) of machine harvested ginned lint (not lint cleaned) was sub-sampled from each experimental sample. Each 42g 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 of αe 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 238RM winding machine.

Fabric Production - Knitting and dyeing

Yarns were knitted with a cover factor of 1.32 (a tightness factor of 15.4 $tex^{1/2}$ 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).

$$\Delta E = SQRT\ (L_1 - L_2)^2 + (a_1 - a_2)^2 + (b_1 - b_2)^2 \qquad (1)$$

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 inch 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 counts 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 but 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 delta E 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 % open bolls, and lint yield. N=4.

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. N=4.

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. N=4.

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. N=4.

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 eveness and imperfections, and yarn strength attributes for carded 20 tex ringspun yarns. N=4.

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. N=4.

Harvest aid treatment (% open bolls)	L*	a*	b*	ΔE 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**	-

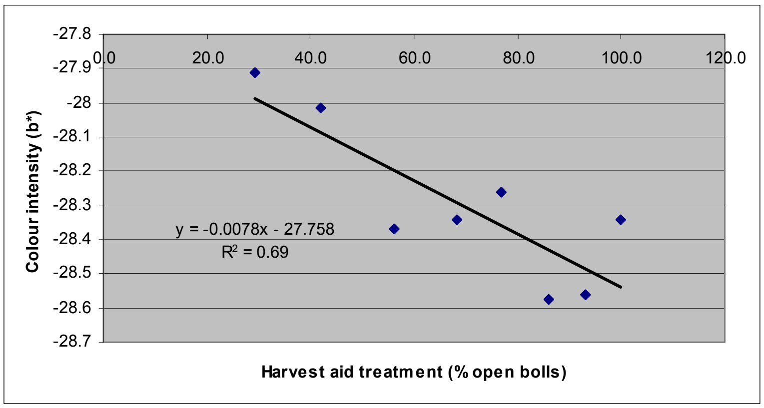

Figure 1 - Colour space result (b*) for reflectance colorimetric analysis of fabric dyed with Cibacron blue LS3R (1%), for different harvest aid timing treatments (% open bolls).

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 counts/ g per 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 will insure maximum yield, fibre quality and textile performance for this commonly grown Australian *G. hirsutum* variety.

Acknowledgments

The authors acknowledge input from CSIRO colleagues Geoffrey Naylor and Rene van der Sluijs. We thank 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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