THE INFLUENCE OF DRUM ARRANGEMENT OF SPINDLE HARVESTERS ON FIBER QUALITY AND YIELD

Marinus H.J. van der Sluijs
Textile Technical Services
Geelong, Victoria
Australia

Abstract

It has been stated that mechanical harvesting has had the greatest impact on cotton production since the invention of the cotton gin and plays an important role in determining fiber and seed quality, as the quality of ginned cotton is directly related to the quality of seed cotton prior to ginning. Irrespective of which mechanical harvesting method is used, the set-up and adjustment, training and skill of the operators, as well as the timing of defoliation and harvesting play a major role in the amount of trash and moisture present in the seed cotton. The efficiency of harvesting and the resultant fiber quality can be influenced by many factors and many studies have been conducted to investigate the consequence of seed cotton moisture and set up in terms of spindle type and size as well as speed.

Spindles are attached to bars which are arranged on rotating drums. Conventional units have two opposed rotating drums, one on each side of the row whereas in-line drum arrangement, have both drums on the right side of the row. This study focused on drum arrangement as there has been no recent published research conducted in which the two different drum arrangements have been compared in terms of harvesting efficiency, using high yielding commercial varieties, and fiber quality.

Introduction

Traditionally, seed cotton was harvested (picked or removed from opened bolls on the cotton plant) by hand, with mechanical harvesters developed and implemented in the early 1940s. Although only 30% of the cotton produced worldwide is harvested mechanically, some of the largest producers and exporters of cotton lint, such as the US, Australia and Brazil, harvest 100% of their seed cotton mechanically (Anon 2011). The adoption of mechanical cotton harvesters was mainly due to an increase in cotton acreage and yield, which resulted in dramatic increases in production, as well as due to the shortage, unsuitability, inefficiency and cost of labor (Abernathy and Williams 1961, Doraiswamy, Chellamani et al. 1993, Anon 2004, Anon 2011). Although it has been stated (Holley 2000, Hughs, Valco et al. 2008) that mechanical harvesting has had the greatest impact on cotton since the invention of the cotton gin, there is no doubt that the quality of cotton harvested by hand is superior to that of mechanically harvested cotton. The introduction of mechanical harvesting, and the resultant practice of once over harvesting with the aid of chemical boll openers and defoliants, has led to trashier, more variable and sometimes with higher moisture content cotton being delivered to the gins (Williamson and Riley 1961, Doraiswamy, Chellamani et al. 1993, van der Sluijs and Long 2015, van der Sluijs and Holt 2017). Therefore, harvesting plays an important role in determining fiber and seed quality, as the quality of ginned cotton is directly related to the quality of seed cotton prior to ginning (Anon 2001). Irrespective of which mechanical harvesting method is used, the setup and adjustment, training and skill of the operators, as well as the timing of defoliation and harvesting play a major role in the amount of trash and moisture present in the seed cotton (Williamson and Riley 1961, Anon 2004, Mygdakos 2009).

Spindle harvesters accounts for the bulk of all the cotton harvested mechanically world-wide and the efficiency of harvesting and the resultant fiber quality can be influenced by many factors, including spindle speed, spindle size and shape as well as row unit factors, such as drum arrangement, compressor plate pressure, spindle tip clearance as well as scrapping plates.

The spindle harvester is a selective type harvester that uses rotating tapered, barbed spindles (Figure 1), to pull seed cotton from opened bolls into the machine. Initially, these machines were only able to harvest seed cotton from one row at a time, but, with developments over the years, these machines can now harvest up to six rows with one pass, with ever greater speed. Spindle harvesters are large and complex machines, which are expensive to purchase, costly to maintain and require precise setup and adjustment, as well as trained and skilful operators to obtain the maximum yield and value per hectare. Compared to the stripper harvester, spindle harvesters are generally more expensive to operate and maintain, can handle higher yielding crops more efficiently, have higher harvesting efficiencies and higher lint turnout, since the seed cotton, so harvested, contains less trash.

Figure 1. Spindle type harvester

Spindles are attached to bars which are arranged on rotating drums. Conventional units have two opposed rotating drums, one on each side of the row. The advantage of this configuration is that the cotton plant is harvested from both sides, which should result in higher harvesting efficiency (Willcutt, Buschermohle et al. 2010). The in-line drum arrangement, which has both drums on the right side of the row, result in the cotton plant being harvested only from one side, was introduced by John Deere (JD) in 1989, with the release of the JD 9960 (Deutsch and Junge 1989, Deutsch and Junge 1990). The advantage of this drum arrangement is that there are substantially fewer parts required, making it easier to understand and the grower and dealer need to carry fewer parts. It also results in a reduction in the weight of the unit (Deutsch and Junge 1989, Deutsch and Junge 1990, Willcutt, Buschermohle et al. 2010). Trials, conducted in 1986 showed that the harvesting efficiency for the in-line units was slightly better than that of the conventional units at various yields (Deutsch and Junge 1989, Deutsch and Junge 1990). Figure 2 shows a diagram of the two different drum arrangements, namely the opposed (A) and in-line (B) drum arrangements.

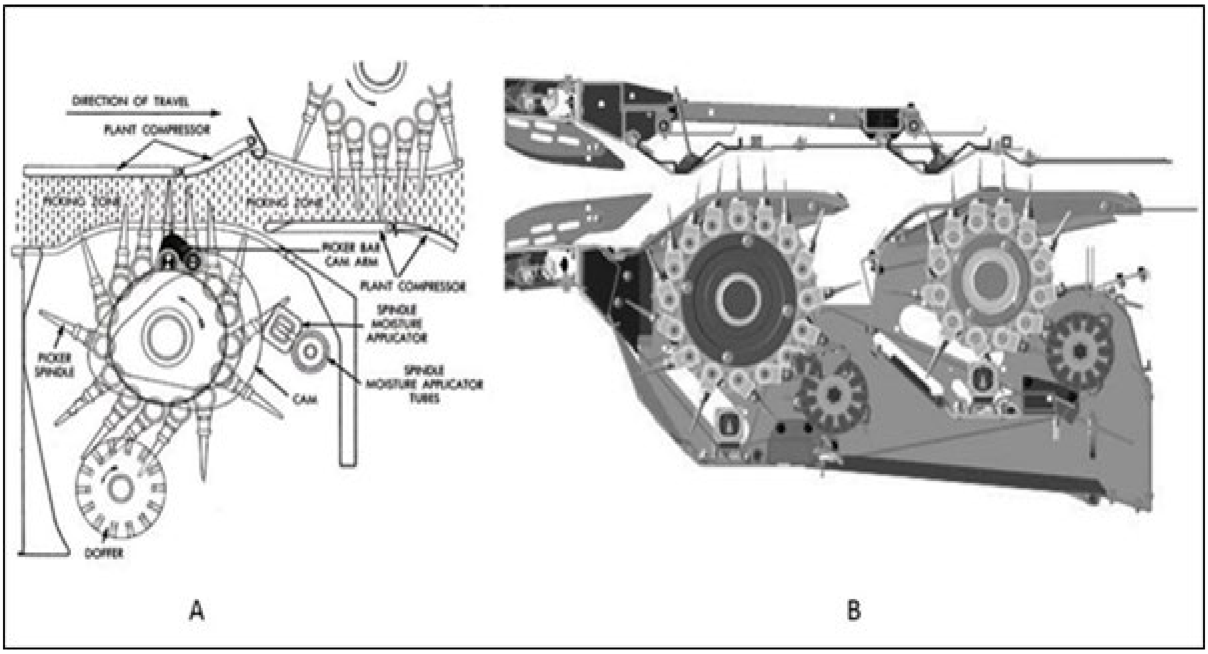

Figure 2. A. Opposed drum arrangement. B. In-line drum arrangement (Willcutt**,** Buschermohle et al. 2010, Anon 2015)

This study was undertaken as no recent research has been published in which the two different drum arrangements have been compared in terms of harvesting efficiency, using high yielding (>2000 kg ha^{-1} fiber) commercial varieties and fiber quality.

Materials and Methods

For this study, seed cotton was obtained from one field at the Australian Cotton Research Institute (ACRI) at Narrabri (30°19'S 149°47'E) in the Namoi Valley (central region) of NSW. The cotton was produced during the 2013/2014 growing season (planted in 2013; defoliated, harvested and ginned in 2014), with an average fiber yield of 2800 kg ha^{-1}. A summary of the field operations employed is presented in Table 1.

Table 1. Field size, planting, harvest aid application, harvest and gin date

Field size (ha)	Planting date	1st Harvest Aid date	2nd Harvest Aid date	Harvest date	Gin date
76	15 October	12 April	26 April	16 May	10 July

The cotton variety used for the trial was Sicot 71 BRF, a widely adopted, high yielding variety with good disease resistance and fiber quality (Stiller 2008). The field was subjected to standard management practices for irrigated Upland cotton in Australia. The field was first subjected to harvest aids by air with a mixture of leaf defoliant (0.1 L ha^{-1} Dropp® liquid from Bayer Crop Science), boll opener (0.2 L ha^{-1} Prep™ from Bayer Crop Science) and defoliant aid spray (l L ha^{-1} D-C-Tron® from Caltex). The field was sprayed by air for a second time with a mixture of leaf defoliant (0.15 L ha^{-1} Dropp®), boll opener (2 L ha^{-1} of Prep™) and defoliant aid spray (l L ha^{-1} D-C-Tron®).

Only part of the field was utilized for this trial, the trial being conducted using a randomized complete block design, with four replications. Seed cotton from the plots (8 by 10 meter), containing eight rows spaced at 1 meter, was harvested by a JD 9986 spindle harvester, with PRO-16 heads, in an in-line drum arrangement and a Case IH 2555 spindle harvester, with an opposed drum arrangement. Both harvesters were two row units which were maintained and operated via normal industry practice and manufactures recommendations. Harvesting took place during the early afternoon (13:00 to 14:00), with the ambient air conditions of the field (average temperature of 24.4 °C and relative humidity of 32.1%) continually monitored via the weather station situated at ACRI to ensure that harvested seed cotton did not have a surface moisture level greater than the recommended level of 12% (van der Sluijs and Long 2015).

A 0.5 kg seed cotton sample was collected from each replicate produced and was ginned using a 20-saw gin with a pre-cleaner (Continental Eagle, Prattville, AL) located at ACRI. Lint was then sub-sampled and subjected to two lint cleaning passages using a purpose built laboratory-scale lint cleaner, designed and built by CSIRO Manufacturing, which is based on the operating principals of the controlled batt saw lint cleaner, recognized as the standard type of cleaner used in the ginning industry (Gordon, Bagshaw et al. 2010, Gordon, Bagshaw et al. 2011). The lint cleaner is fitted with a 25.4 cm saw and four grid bars, with the saw operated at a speed of 855 rpm, with a combing ratio of 23:1. Fiber samples were fed into the lint cleaner, with a prepared batt of 100 gm^2 - see Figure 3 for images of the gin and lint cleaner. Samples were taken from these treatments for fiber quality analysis.

Figure 3. Image of sample gin and lint cleaner

The seed cotton harvested from each plot was weighed to calculate the weight of usable fiber as a percentage of the weight of un-ginned seed cotton (lint turn out). To determine the harvest efficiency, the seed cotton left on the plants in the field were removed and weighed with the ground loss not included in determining harvest efficiency.

Fiber samples were subjected to testing by an HVI™ model 1000 (Uster® Technologies Inc, Knoxville, TN) located at Auscott Limited Classing (Sydney, NSW), to determine color (reflectance Rd, and yellowness +b), trash count, % trash area, leaf grade, UHML (inch), length uniformity index % (UI%), short fiber index % (fibers shorter than 0.5 inch) (SFI%), bundle strength (g/tex) and micronaire. Fiber samples were also subjected to analysis by AFIS PRO (Uster® Technologies Inc, Knoxville, TN) located at CSIRO Manufacturing (Geelong, VIC) to determine total, fiber and seed-coat nep content and size, total, trash and dust content and size, as well as visible foreign matter % (VFM%). The maturity ratio (MR) and fiber fineness (FN) were determined by the Cottonscope instrument (BSC Electronics, Perth, WA) also located at CSIRO Manufacturing.

To test for statistical differences between the two harvesting treatments, ANOVA was conducted on the experimental data using Genstat 16.0 (Lawes Agricultural Trust, IACR Rothamsted, UK). The standard deviation, designated as sd, was also calculated to quantify the amount of variation. Where significant statistical differences at the 0.05 and lower level were identified, Fisher's least significant differences (LSD) were calculated from which the means differences were derived. For ease of interpretation non-significant results were designated as ns.

Results and Discussion

Harvesting Efficiency and Lint Turn Out

Table 2 summarizes the average amount of seed cotton harvested, the amount of seed cotton left on the plants and the lint turn out and the amount of cotton fiber produced after ginning. There was a statistically significant difference between the two drum arrangements (519 kg) in terms of the average amount of seed cotton harvested. There were also differences, although, insignificant, in the amount of seed cotton left on the cotton plant, the amount of cotton fiber produced after ginning and lint turn out.

Table 2. Seed cotton harvested, left on plant and lint turn out

Drum Arrangement	Harvested seed cotton in kg	Seed cotton left on plant in kg	Cotton lint in kg	Lint Turn Out (%)
Opposed	2701	86	1045	38.7
In-line	2182	139	858	39.3
P value	<0.001	ns	ns	ns

On average, the harvester with the opposed drum arrangement harvested 23.8% more seed cotton than the harvester with the in-line drum arrangement. The plant loss was 3.2% and 6.4% respectively, for the opposed and in-line drum arrangement. This was contrary to an earlier trial, conducted in 1986, which showed that the harvesting efficiency for the in-line drum arrangement was slightly better than that of the opposed drum arrangement (Deutsch and Junge 1989, Deutsch and Junge 1990). Although it is noted that the results of this trial could have been influenced by the fact that very low yielding varieties (1682 to 842 kg ha^{-1}) were used. Although there was more cotton fiber produced after ginning from the harvester with the opposed drum arrangement, the lint turn out from the harvester with the in-line drum arrangement was 1.17% higher than that harvested with the opposed drum arrangement. This small difference in lint turn out was in all likelihood due to the fact, that although not significant, the seed cotton harvested with the opposed drum arrangement contained on average more trash (such as bark, leaf and sticks), as indicated by the AFIS PRO trash, dust and VFM% results after ginning prior to lint cleaning - see Table 3.

Table 3. AFIS PRO trash results after ginning prior to lint cleaning

Drum Arrangement	Total Trash/g	sd	Trash Cnt/g	sd	Total trash size µm	sd	Dust Cnt/g	sd	VFM %	sd
Opposed	1200	323	215	47	344	19	985	277	4.04	0.81
In-line	884	206	164	40	345	7	720	167	3.11	0.76
P value	ns		ns		ns		ns		ns	

Fiber Quality

Following two lint cleaner passages, there were small, but statistically insignificant, differences between the two harvester drum arrangements, in terms of fiber color (both Rd and +b), UHML, UI%, SFI%, strength and micronaire - see Table 4. In terms of fineness and maturity, as determined by the Cottonscope, there were also no significant differences between the two harvester drum arrangements - see Table 4.

Although the fiber produced from the opposed drum arrangement contained, on average, higher trash levels, in terms of HVI™ and AFIS PRO measurements, than the fiber produced by the in-line drum arrangement, the differences were small and statistically insignificant - see Table 5. This result was not unexpected as the trash results for the cotton fiber prior to lint cleaning showed that the trash levels of the opposed drum arrangement contained higher trash levels than the fiber produced by the in-line drum arrangement - see Table 5.

Table 4. HVI™ and Cottonscope fiber properties after lint cleaning

Drum Arrangement	HVI														Cottonscope			
	Rd	sd	+b	sd	UHML inch	sd	UI %	sd	SFI %	sd	Strength g/tex	sd	Micronaire	sd	FN (mtex)	sd	MR	sd
Opposed	79.2	1.4	7.8	0.2	1.16	0.01	81.2	0.4	10.1	0.6	30.0	1.0	4.50	0.19	201	8	0.88	0.01
In-line	79.1	1.6	7.8	0.1	1.15	0.01	81.4	0.7	10.3	0.9	29.3	1.0	4.56	0.06	200	7	0.88	0.01
P value	ns		ns		ns		ns		ns		ns		ns		ns		ns	

Table 5. HVI™ and AFIS PRO trash after lint cleaning

Drum Arrangement	HVI						AFIS PRO									
	Trash count	sd	% Area	sd	Leaf grade	sd	Total trash/g	sd	Total trash size µm	sd	Trash Cnt/g	sd	Dust Cnt/g	sd	VFM %	sd
Opposed	14	4	0.14	0	2.0	0	165	33	350	20	30	6	134	28	0.54	0.17
In-line	13	3	0.25	0.36	2.1	0.4	148	42	348	18	26	6	122	37	0.49	0.15
P value	ns		ns		ns		ns		ns		ns		ns		ns	

There was no significant difference between the two drum arrangements in terms of total, fibrous and seed-coat nep content and size - see Table 6.

Table 6. AFIS PRO fiber properties after lint cleaning

Drum Arrangement	Nep Cnt/g	sd	Fiber Cnt/g	sd	SCN Cnt/g	sd	Nep size µm	sd	SCN size µm	sd
Opposed	568	68	544	70	24	3	682	7	1012	64
In-line	567	22	542	21	25	3	682	8	1001	42
P value	ns		ns		ns		ns		ns	

Conclusion

It is generally accepted that harvesting plays an important role in determining harvesting efficiency, as well as fiber and seed quality. This study was conducted to determine the effect of drum arrangement on fiber quality and harvesting efficiency.

The study showed that the harvesting efficiency of the opposed drum arrangement was substantially better than the in-line units and resulted in a statistically significant 22% increase in yield. This increase in yield did not translate into higher lint turn out as the seed cotton harvested by the opposed drum arrangement contained more trash. Although there were small differences in terms of fiber color (both Rd and +b), length, length uniformity, short fiber index, strength and micronaire, after ginning and two passages of lint cleaning, they were statistically insignificant. Similarly, there were also no significant differences between the two drum arrangements in terms of fineness and maturity. Although, the fiber produced by the opposed drum arrangement contained, on average, higher trash levels, than the fiber produced by the in-line drum arrangement, the differences were small and statistically insignificant. There was also no significant difference between the two drum arrangements in terms of total, fibrous and seed-coat nep content and size.

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Disclaimer

Mention of trade name, propriety product or specific equipment does not constitute a guarantee or warranty and does not imply approval of the product to the exclusion of others that may be available.

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