COMPARING DRYLAND COTTON UPLAND FIBER QUALITY FROM ON-BOARD SPINDLE AND STRIPPER HARVESTING SYSTEMS

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Abstract

On-board spindle and brush type stripper round module harvest systems were evaluated on commercial field scale for dryland Upland cotton in Australia over three harvest seasons. Observations on harvester performance, including harvesting efficiency, harvest loss, seed cotton yield and lint turn out were conducted at three locations, with a single variety. Fiber quality was measured by High Volume Instrumentation (HVI™) and analysed to determine if there were any significant differences between the two harvesting systems. The stripper harvested more material with lower harvest loss than the spindle harvesters. The seed cotton harvested by the stripper systems contained plant material which resulted in a lower lint turn out than the spindle harvester although the yield in bales ha^{-1} was similar or slightly higher. There were no real significant differences in fiber quality as measured by the HVI, except for color and trash. Overall, the significant differences in color and trash did not affect the economic return to the grower as the visual color and trash grades were below, i.e., better than, the Australian base grade. It is hypothesised that the reasons for this was due to the appropriate timing and application of defoliation, harvesting when moisture content d 12%, reduced leaf allowing for gentler ginning and mature fiber.

Introduction

Cotton harvesting represents the largest single cost item in cotton production and is the largest capital investment other than land (Willcutt, Buschermohle et al. 2009). The cost of production is a critical issue for a cotton grower and, since harvesting in Australia, on average, contributes 6 to 9% to the total cost of production (ICAC 2016, ICAC 2019), it comes as no surprise that there is a focus in Australia on making efficiency and related gains in this area.

Australia produces predominately irrigated spindle harvested Upland cotton (*Gossypium hirsutum* L.), which is ginned with modern super high capacity saw gins that are capable of producing more than 1,000 bales per day and more than 100,000 bales per season (van der Sluijs and Holt 2017). Most of the spindle harvesters in Australia are John Deere (JD) 7760 and the newer CP690 models, which have been described as a hybrid of a cotton harvester and an oversized round hay baler. These harvesters produce round modules which are covered with an engineered polyethylene film that both protects the seed cotton and provides compressive force to maintain the module density. These harvesters have been embraced by the industry, with up to 95% of the Australian crop harvested with these machines, as they can harvest cotton continuously when conditions permit, which makes them very efficient, dispenses with the requirement of sourcing reliable seasonal workers to undertake laborious module building and result in a cost saving of up to 34% ha^{-1} (Martin and Valco 2008, Bennett, Woodhouse et al. 2015, Salassi, Deliberto et al. 2015, van der Sluijs, Long et al. 2015, van der Sluijs and Jenson 2019).

Trials were conducted with the aim to specifically investigate the quality of fiber harvested using the spindle harvester compared with fiber harvested via the newly introduced JD CS690 stripper harvester. The research was undertaken using a commercial variety commonly used for dryland cotton production in Australia. The results from these trials will help assess and quantify the impact of the two harvesting methods on fiber quality which is of growing importance as the Australian industry adopts increased areas of dryland (rain-fed) and semi-irrigated cotton production systems.

Materials and Methods

Paired comparisons of plots harvested with stripper and spindle harvesters were conducted at three locations in New South Wales during the 2017 (planted in 2017, harvested and ginned in 2018), 2018 (planted in 2018, harvested and ginned in 2019) and 2020 (planted in 2020, harvested and ginned in 2021) growing seasons. The cotton variety used was Sicot 748 B3F (Stiller 2017), a variety recommended for dryland and semi-irrigated cotton. Cotton was planted as single skip (every third row skipped resulting in 66% less planted area) row spacings. The fields were managed according to standard practices for dryland cotton production in Australia. A summary of the field and ginning operations employed are presented in Tables 1 and 2.

Table 1. Farms, planting, harvesting and gin dates

Year	Farm	Planting date	Harvest date	Gin date
2017	A	18 Oct.	18 Apr.	22 May
2018	B	31 Oct.	26 Apr.	7 May
2018	C	24 Nov.	8 May	3 July
2020	A	18 Nov.	19 & 21 May	6 Aug.

Following defoliation, the fields were harvested, using grower owned and operated JD 7760 and CP690 round module spindle harvesters, equipped with PRO-16 row units and JD CS690 round module brush strippers with on-board field cleaner. All harvesters were maintained and operated using normal industry practice and manufacturers recommendations. Only part of the fields were utilized for the experiments, using a randomized complete block design, with five replications of each of the two harvesting methods. For all locations, round modules were dropped in the field and picked up by a mast-type tractor mounted implement that holds the module with the axis parallel to the tractor rear axle and were then staged together in the sequence that they were harvested. The modules were placed to allow easy access for the equipment and trucks, on a smooth, even, and firm compact surface that allows water to drain away. Round modules were staged in a 'Sausage' (end to end) method with a gap between modules to facilitate water runoff. All the harvesters were equipped with moisture sensors, which were mounted on the round module builder which allowed the operators to ensure that the moisture content was d12%. This was to ensure that no excessive drying was needed during the ginning process, as previous studies showed that high seed cotton moisture can affect the processing performance of the gin as well the quality of the fiber and seed (van der Sluijs and Long 2015, van der Sluijs and Delhom 2016).

The modules produced from each field were marked and labelled prior to transportation and delivery to the commercial cotton gin used by each grower. All modules from the three farms were ginned in the sequence that they were produced within the same timeframe and under standard commercial conditions with standard processing stages required for dryland Upland cotton to achieve the Australian base grade. The four gins where the modules were ginned are all modern super high-capacity saw-type gins which are well maintained, operated according to manufacturer's recommendations and moisture levels monitored and maintained to achieve the required reduction in trash without damaging fiber quality.
Harvest loss is a crucial factor in evaluating harvester performance as it measures the amount of seed cotton left in the field which would otherwise have been harvested and ginned resulting in more fiber and increased income for the grower. Harvest loss was determined by collecting all the seed cotton left on the plant and found on the ground after harvesting. In every spindle and stripper harvested replicate, plants within a two-meter-long row was chosen at random and marked. All the seed cotton left on the plants in the designated area was removed by hand, with all the seed cotton on the ground within ten centimeters on either side of the plants also collected. The samples from the plant and ground were bagged separately to determine harvest loss. Prior to weighing all trash, sticks and burrs were removed by hand in order to obtain a more accurate indication of the loss of seed cotton. Once weighed the weight was extrapolated to a hectare by multiplying by 5000.

Classing samples, from opposite sides, of each bale were collected at the gin after bale formation. These bale samples were subjected to objective measurement, as per ASTM D5867 (ASTM 2012a), using Uster® Technologies AG, HVI 1000 instruments (Knoxville, TN) by certified classing facilities. Two sub samples of each sample were tested for color in terms of yellowness (+b), reflectance (Rd), upper half mean length (UHML in inch), length uniformity (UI%), short fiber index (fibers < 0.5 inch) (SFI %), bundle strength (g tex^{-1}), elongation (EL%) and micronaire (Mic). The above-mentioned quality attributes (excluding HVI color, SFI% and elongation) are used by merchants in Australia to value and trade cotton bales. Visual classing of the lint was assessed for color (color grade), visible trash (leaf grade) and preparation (degree of smoothness or roughness of the cotton sample), according to the 2018 & 2020 grades as established by USDA-AMS, as per ASTM D1684 (ASTM 2012b).

The percentage of the weight of usable fiber per the weight of un-ginned seed cotton (lint turn out) was calculated by the commercial ginning operators using module and ginned bale weights.

To test for statistical differences between treatment means, ANOVA was conducted on the experimental data using Genstat 16.0 (Lawes Agricultural Trust, IACR Rothamsted, UK). Means for each parameter followed by the same letter are not significantly different at *P* d 0.05.

Results and Discussion

The warm, humid, and sunny conditions experienced during the three growing seasons led to mature cotton being grown on the entire plant resulting in successful and relatively easy defoliation and good harvesting conditions. This allowed the gins to utilize the same cleaning and drying processes (i.e., two stages of seed cotton drying and cleaning, followed by the saw gin stand, and then by a flow through air lint cleaner and two stages of either the controlled-batt saw or batt-less saw lint cleaning) for both spindle and stripper harvested seed cotton.

Yield, Harvest Loss and Lint Turn Out

In all the trials the cotton strippers harvested significantly more material (seed cotton including trash) than the spindle harvesters - see Table 2. Differences in harvested material averaged 30.1% and 49.7% for 2017 and 2020 respectively at Farm A, 10.5% at Farm B and 12.9% at Farm C, with the average increase in harvested material approximately 26%. This difference is not unexpected (Hughs, Valco et al. 2008) and above the 10% required for harvesting by stripper rather than harvesting by spindle (Young and Martin 1966). These results are in line with previous studies that found that harvest efficiency for spindle harvesters was typically 85 to 90% and for stripper harvesters 99% (Williford, Brashears et al. 1994, Faircloth, Hutchinson et al. 2004, Faulkner, Wanjura et al. 2011). The average lint turn out for the spindle harvested cotton was significantly greater than for the stripper harvested cotton - averaging 14.9% and 27.4% at Farm A in 2017 and 2020 respectively, 17.6% at Farm B and 10% at Farm C. Similar results (Faulkner, Wanjura et al. 2007, Faulkner, Shaw et al. 2008, Wanjura, Faulkner et al. 2010) were found in previous studies and not unexpected, despite improvements in cleanliness due to the action of the on-board field cleaner (Baker and Brashears 2000), the stripper harvested cotton also contained plant material in the form of leaf, sticks, stalk, burrs and pin trash as well as immature fiber. Although the lint turn out was less for the stripper harvested cotton the yield in bales ha^{-1}, with the exception of Field A in 2020, was higher than the spindle harvested cotton - see Table 2.

Unfortunately, harvest loss was not measured for Farm A in 2017. There were statistically significant differences in harvest losses between the stripper and spindle harvested areas for all the other trials - see Table 2. On average the total amount of seed cotton lost on the ground at Farm B was 143 and 53 kg ha^{-1} respectively for the spindle and stripper harvesters and left on the plants was 79 kg ha^{-1} for the spindle harvester. In total the average loss for the spindle harvester was 222 kg ha^{-1}, which was almost four times the amount of material left in the field when using the stripper harvester. Taking the lint turn out into account, this equates to 95 and 19 kg ha^{-1} of fiber respectively, for spindle and stripper harvesting. The average ground loss at Farm C was 84 and 37 kg ha^{-1} of seed cotton respectively for the spindle and stripper harvesters and the plant loss was 96 kg ha^{-1} for the spindle harvester. In total the average loss for the spindle harvester was 180 kg ha^{-1} of seed cotton, which was almost five times the amount of material left in the field when using the stripper harvester. When considering the lint turn out, this loss in seed cotton equates to 78 and 15 kg ha^{-1} of fiber respectively, for spindle and stripper harvesting. On average the total amount of seed cotton lost on the ground at Farm A in 2020 was 74 and 20 kg ha^{-1} respectively for the spindle and stripper harvesters and left on the plants was 98 kg ha^{-1} and 4 kg ha^{-1} of seed cotton and stripper harvesting. In total the average loss for the spindle harvester was 172 kg ha^{-1} of seed cotton, which was almost seven times the amount of material left in the field when using the stripper harvester. When considering the lint turn out, this loss in seed cotton equates to 75 and 8 kg ha^{-1} of fiber respectively, for spindle and stripper harvesting.

Table 2. Number and weight of modules, number of bales and lint turn out

Harvesting Method	Hectares harvested	Total weight of modules (kg)	Harvest loss (kg ha^{-1})			Total Bale weight (kg)	Lint Turn Out %	Bales ha^{-1}
			Plant	Ground	Total			
Farm A (2017)								
Stripper	13.7	20,080	*	*	*	7,449	37.1	2.40
Spindle	13.7	15,432	*	*	*	6,578	42.6	2.11
Farm B (2018)								
Stripper	14.1	16,180	0a	53a	53a	5,890	36.4	1.84
Spindle	16.3	14,640	79b	143b	222b	6,270	42.8	1.69
Farm C (2018)								
Stripper	13.0	10,660	0a	37a	37a	4,224	39.6	1.43
Spindle	13.0	9,440	96b	84b	180b	4,105	43.5	1.39
Farm A (2020)								

Stripper	7.5	26,040	4a	20a	24a	8,890	34.1	3.92
Spindle	9.0	20,878	98b	74b	172b	9,077	43.5	4.00

Means for each parameter followed by different letter are significantly different at *P* d 0.05.

Fiber Quality

There were statistically significant differences in the fiber quality between the stripper and spindle harvested areas for all farms- see Table 3. In all cases the seed cotton harvested by the stripper contained statistically significantly more trash particles which covered a larger percent area. However, these significant differences did not influence the manual visual trash grade. Similarly, there were statistically significant differences in reflectance (Rd) and yellowness (+b) values which, with the exception of the trial in 2020, did not influence the visual color grade. However, in 2020 the visual colour grade of the stripper harvested at 21 (Strict Middling) was better than the spindle harvested cotton grade of 31 (Middling).

Apart from the trial in 2020, there were no significant differences between the two harvesting methods in HVI measured fiber quality in terms of UHML, SFI%, micronaire, strength and elongation, with the exception of UI% at Farm C with the spindle harvested cotton significantly more uniform than the stripper harvested cotton. There were slight differences in the fiber quality for 2020 with the stripper harvested fiber significantly stronger with less short fiber content as compared to the fiber from the spindle harvester.

Table 3. HVI measured fiber quality values

Harvesting Method	Mic	UHML inch	UI %	SFI %	Strength g tex^{-1}	EL %	Trash			Color	
							Count	% Area	Leaf	Rd	+ b
Farm A (2017)											
Stripper	4.60	1.054	79.5	9.3	28.2	4.4	13.2a	0.11	1.9a	83.0a	9.6a
Spindle	4.65	1.059	79.4	9.3	28.3	4.4	9.5b	0.09	1.6b	82.3b	9.0b
Farm B (2018)											
Stripper	4.86	1.046	80.5	11.3	30.4	4.3	11.6a	0.11a	2.0a	82.2a	10.1a
Spindle	4.88	1.048	80.6	11.1	30.4	4.2	8.4b	0.09b	1.4b	81.1b	9.5b
Farm C (2018)											
Stripper	4.78	1.089	80.2a	9.7	30.5	4.8	16.3a	0.16a	2.1	83.4a	9.3a
Spindle	4.78	1.098	80.9b	9.6	30.6	4.8	9.7b	0.09b	1.9	83.2b	8.7b
Farm A (2020)											
Stripper	5.08	1.153	82.4	8.1a	33.2a	5.0	33.0a	0.32a	3.0a	81.3a	7.8a
Spindle	5.07	1.148	82.1	8.4b	32.8b	5.0	24.3b	0.22b	2.8b	80.9b	7.4b

Mic= Micronaire, UHML= Upper Half Mean Length, UI%=Uniformity Index, SFI%=Short Fiber Index, EL%= Elongation, Rd= Reflectance, +b= Yellowness.

Means for each parameter followed by different letter are significantly different at *P* d 0.05.

Conclusion

This study was conducted on commercial scale dryland Upland cotton, producing < 2.5 bales ha^{-1} (low) and < 4.5 bales ha^{-1} (high), in Australia during three growing seasons. The study was conducted to determine the performance of John Deere on-board spindle and brush type stripper with on-board field cleaner, harvest systems in terms of 1) harvesting efficiency, 2) seed cotton yield, 3) lint turn out and 4) fiber quality as measured by High Volume Instrumentation (HVI).

The stripper harvesters had on average five times lower harvest losses while harvesting 26% more seed cotton. The seed cotton harvested by the stripper contained plant material which resulted on average in 18% lower lint turn out. Due to the favourable conditions during defoliation and harvesting the resultant seed cotton was able to be ginned with minimal heat and cleaning.
As the fiber was mature, there were overall no real differences in fiber quality between the two harvesting systems. Although there were significant differences in color in terms of Rd and +b and trash in terms of trash count and

% area as measured by HVI, this did not influence the visual color and trash grades which was better than the Australian base grade and resulted in a price premium.

This study has shown that round module stripper harvested cotton does not necessarily result in inferior fiber quality if the fiber is mature and if favourable conditions during defoliation and harvesting are experienced which allows the fiber to be ginned with minimal heat and cleaning.

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