2240 COTTON QUALITY AS AFFECTED BY CHANGES IN THE SPINDLE PICKER

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Abstract

Three cotton varieties were grown under furrow-irrigated conditions in southern New Mexico and hand-harvested in a way that kept individual bolls intact. The cotton bolls were conditioned in a controlled atmosphere and then subjected to a single cotton picker spindle operating at a speed of 1000 - 3000 rpm. Two spindle designs were studied, a 12.7 mm (½") round, tapered, barbed spindle and a 4.8 mm (3/16") square spindle that was straight and smooth. Mass measurements were taken to determine the portion of seed cotton not picked and the portion that would fly off and not stick to the spindle. A force gage was used to determine the peak force that was needed to pull the seed cotton from the spindle. Moisture content of the bolls was 9 to 10 % d.b. Results showed that the smaller, straight spindle was more aggressive in removing cotton from the boll. There was approximately twice as much flyoff from the barbed spindle than from the smaller straight spindle at any given speed. Flyoff also increased exponentially for each spindle type as the speed was increased for both spindle types. The peak force required to remove the seed cotton from the spindle ranged from 50 to 100 % more for the smaller straight spindle than from the barbed spindle. For both spindles, the peak force requirement was approximately doubled each time the speed was increased by 1000 rpm, indicating an exponential relationship between speed and wrap tightness. Additionally, field tests were conducted for the 2005 and 2006 crop years by the USDA, Agricultural Research Service, Southwestern Cotton Ginning Research Laboratory in Mesilla Park, New Mexico. Three cotton varieties were grown under furrow-irrigated conditions in southern New Mexico and harvested with a modified 1-row cotton picker each year using a ground speed of 0.85 m/s and spindle speeds of 1500, 2000, and 2400 rpm for the 2005 crop and spindle speeds of 2000, 3000, and 4000 rpm for the 2006 crop. The tests were replicated 4 times. Stalk losses in the field were significantly greater at a spindle speed of 1500 rpm than for speeds of 2000 rpm or greater for all varieties. This indicates that a spindle speed of at least 2000 rpm is needed for the picker to adequately function. Stalk losses were greater with speeds of 3000 and 4000 rpm than for a speed of 2000 rpm with the Pima variety. The number of spindle twists in a 1000 g seed cotton sample and the percent of seed cotton that was spindle twists was greater for the 3000 and 4000 rpm spindle speeds than for the 2000 rpm spindle speed. Both measurements of spindle twists in seed cotton nearly doubled when spindle speed increased from 2000 to 3000 rpm and then increased more when spindle speed increased to 4000 rpm. The increase in spindle twists makes preserving fiber quality while ginning a greater challenge. HVI classing data also showed no significant differences among treatments except for upland lint samples collected before lint cleaning. In these samples, there were higher levels of trash with spindle speeds of 3000 and 4000 rpm than with a speed of 2000 rpm. The differences were no longer significant for samples collected after lint cleaning. No significant differences were observed for AFIS dust count, trash count, or upper quartile length. Differences were significant for nep count in the raw stock from the bale with the Delta Pine and ACALA varieties, but not with the Pima. Differences in AFIS short fiber content were significant in the raw stock from the bale with the ACALA and Pima varieties, but not with the Delta Pine variety. These nep count and short fiber differences disappeared as the fiber was further processed.

Introduction

Beginning in 1850, over 800 ideas were patented for devices to mechanize cotton harvest before the first commercially viable cotton picker was developed in the 1930's. At this time. two picker designs were developed. John Rust observed that cotton could be picked by a smooth, small diameter spindle that was wet with water. The cotton could be doffed from the spindle by pulling it through two closely spaced plates. The Rust design was engineered by Mr. Rust, than produced and marketed by the Allis Chalmers Company and the Ben Pearson Company. The Rust picker worked well in dry, clean cotton, but eventually faded from production due to a lack of further engineering development (Holley, 2000). The International Harvester Company (and later The John Deere Company) developed a spindle picker design that used a tapered, barbed spindle, also wet with water, to pick the cotton. The cotton was doffed from the spindle using a rotating doffing pad made of rubber (later polyethylene) to grab the fibers and pull them from the spindle. This design was more successful than the Rust picker when harvesting wet cotton and in cotton fields that had excessive weed growth. Furthermore, the engineering provided by the two companies have allowed to picker design to evolve and meet the needs of producers for larger and faster machines (Holley, 2000).

The mechanical picker collected bits of leaves, burrs, stalks, and other trash that made cotton quality lower than if it were hand-picked. This necessitated the development of additional seed cotton cleaning equipment for use in the gin. Over time, spindle picking has become the preferred method of harvesting most cotton in the U.S. Improvements to spindle pickers over the years have primarily focused on increasing the number of rows that can be harvested with 1 pass of the machine from 1 row to up to 6 rows; as well as increasing the travel speed of the harvester from around 1.9 to up to 5 miles per hour.

Improvements to the cotton harvester have primarily focused on increased capacity in order to reduce the cost of harvesting. As cotton harvesters have gotten bigger and faster, spindle speeds have increased. As the speed has increased, cotton fibers can wrap more tightly around the spindle. Spindle sizes have also decreased in both diameter and length in order to reduce the weight of the picker head. As spindle diameter decreases, cotton fibers will wrap around the spindle more and become tighter on the spindle. As spindle length decreases, cotton plants must be further compressed as they pass through the picking zone. These changes have resulted in a general decrease in cotton fiber quality, particularly regarding spindle twists, preparation, and neps (Hughs, et al. 2000).

Spindle pickers require meticulous adjustment in order to minimize harvest losses and to maximize fiber quality (Williford et al, 1994). Avoiding the harvest of high moisture cotton is another requirement to minimize harvest losses and to maximize fiber quality (Mayfield et al, 1998). Deviations from these highly recommended practices will result in significant quality degradation and increased harvest losses, both of which can cost the grower.

Objective

The objective of this study was:

- To compare fiber quality, harvest losses, and trash content of three varieties of spindle-picked cotton using differing spindle speeds.

Materials and Methods

Laboratory study

A laboratory study was conducted using individual cotton bolls subjected to a single spindle with a variable speed drive. In this study, three cotton varieties were grown under furrow-irrigated conditions in southern New Mexico and hand-harvested in a way that kept individual opened bolls intact, including the burrs, bracts, and a short stem. The cotton bolls were conditioned in a controlled atmosphere of 21 ^{o}C (70 ^{o}F) and 65 % r.h. for 1 week, attaining a moisture content of 9 to 10 % d.b. Leaf particles were manually cleaned from the bolls, then they were subjected to a single cotton picker spindle operating at a speed of 1000, 2000, or 3000 rpm. Two spindle designs were studied, a 12.7 mm (½”) round, tapered, barbed spindle and a 4.8 mm (3/16”) square spindle that was straight and smooth. The spindle in use was moistened with water when at operating speed and just prior to subjecting the boll to it. Mass measurements were taken to determine the portion of seed cotton not picked and the portion that would fly off and not stick to the spindle. A force gage was used to determine the peak force that was needed to pull the seed cotton from the spindle.

Field studies

Test plots approximately 0.6 hectares (1.5 acres) in area of each of three cotton varieties were grown during each of the 2005 and 2006 growing seasons at the Leyendecker Plant Science Research Center, Las Cruces, New Mexico. The three cotton varieties grown were: Delta Pine 565, a conventional upland cotton; Acala 1517-99, an upland cotton with enhanced staple length and strength; and Delta Pine 744, a conventional Pima cotton. The cotton was planted in early May, which is 2 weeks later than the normal planting date. The delay was due to unusually wet weather in the Las Cruces area in April and field conditions were too wet to plant any earlier. All cotton was grown on ridged 1.02 m (40 inch) rows and furrow irrigated as needed during the growing season. Chemical herbicides and insecticides were applied as needed and in accordance to customary practice for the growing region including defoliation and boll opening chemicals that were applied prior to harvest in 2005, but not in 2006.

The 2005 cotton was harvested during 21 February to 1 March 2006. The 2006 cotton was harvested during 15 February to 2 March 2007. A modified International Harvester model 4M-120 1-row spindle picker was used to harvest the cotton (Figure 1). The 1-row picker used 14.3 mm (9/16 inch) spindles that had 6.0 cm (2.4 inches) of the spindle tip extending into the picking zone. Picking zone width for the picker was adjusted to 7.0 cm (2.8 inches) at the narrowest part. Modification of the picker was done so that spindle speed could be varied independently of drum speed. The picker was operated at a ground speed and drum speed of 0.85 m/s (1.9 mi/hr), while spindle speeds were varied among 1500, 2000, and 2400 rpm for the 2005 crop year test and among 2000, 3000, and 4000 rpm for the 2006 crop year test. Results from the three speed combinations were compared for all three varieties tested. Each test lot consisted of 2 adjacent rows of cotton, each 180 to 200 m (600 to 650 ft) long. Four replications of each combination of test conditions were conducted. Seed cotton harvested from each lot was dumped into a trailer for temporary storage. Two seed cotton samples of about 60 grams each were randomly selected and placed in sealed metal cans for subsequent seed cotton moisture determination. A seed cotton sample of about 500 grams was randomly selected and bagged for spindle twist analysis. Black plastic sheeting was placed over each lot in order to keep the lots separated for subsequent ginning and fiber quality analysis. Ambient air temperature and relative humidity in a shaded location were measured with an aspirated psychrometer during the five to ten minutes required to harvest each lot (Table 1).

Figure 1. The modified 1-row cotton picker in action. The drive for the spindles was separated from the drum drive. A hydraulic motor (in blue on the picker head) powered the spindles and doffers. A 37 kW (50 hp) diesel-powered hydraulic pump unit (in gray) was added to power the hydraulic motor.

Table 1. Harvest dates, air conditions, and cotton moistures for the 2005 and 2006 crop year field studies.

Cotton variety	Harvest dates	Air temperature, degrees C	Air relative humidity, percent	Seed cotton moisture at harvest, percent d.b.	Lint yield from harvested seed cotton, bales/acre
Delta and Pine Land 565	2/22 – 23/06	16 – 18	7 – 12	3.9 – 4.9	2.35
	2/15 – 16/07	12 – 13	20 – 27	6.4 – 7.2	2.05
Acala 1517-99	2/21 – 22/06	13 – 18	10 – 14	3.8 – 4.8	2.25
	2/16 – 20/07	11 – 15	21 – 41	6.4 – 7.5	1.70
Pima DP 744	3/1/06	19 – 25	7 – 13	4.8 – 5.6	2.05
	2/20 – 3/2/07	7 – 21	7 – 35	5.5 – 7.3	1.75

Ambient weather conditions were mild and slightly less humid than normal with the ambient air dry bulb temperature ranging from 13 to 25 ^oC overall for the 2005 crop and from 7 to 21 ^oC overall for the 2006 crop. The ambient air relative humidity ranged from 7 to 14 % overall for the 2005 crop and from 7 to 41 % overall for the 2006 crop (Table 1). This resulted in the seed cotton being drier than normal. Seed cotton moisture at harvest ranged from 3.8 to 5.6 % (dry basis) for the 2005 crop and from 5.5 to 7.5 % for the 2006 crop. At these moistures, less fiber damage would be expected than would occur if the seed cotton was wetter.

Test lots for the 2005 crop year test were ginned during March 2006 and for the 2006 crop year test during March and April 2007. Seed cotton cleaning used 2 cylinder cleaners and 1 stick machine with no drying. Upland varities were saw-ginned and Pima cotton was roller-ginned. One saw type lint cleaner was used for the Upland cotton and 2 Aldrich beater / air jet cleaners were used for Pima cotton. Seed cotton samples were collected for fractionation analysis before and after seed cotton cleaning. Seed cotton samples were collected for moisture analysis before seed cotton cleaning and before ginning. Lint samples were colleted for high volume instrument (HVI) analysis before and after lint cleaning. Shortly after ginning, the bales were shipped to the USDA, Agricultural Research Service, Cotton Quality Research Unit in Clemson, South Carolina, where they were stored for about 6 months with AFIS and spinning test analyis competed after storage.

Results and Discussion

Laboratory study

Moisture contents were determined using an air oven method. Average moisture content of the varieties that were conditioned at 21^{o}C and 65% r.h. was 9.8 % d.b. for Delta Pine 90B, 8.8 % for Acala 1517-99, and 9.8 % for Pima S7.

Results (Table 2) showed that the smaller, straight spindle was more aggressive in removing cotton from the boll. It is suspected that this is because the barbs on the tapered spindle act as small fans and create air currents that detract from their ability to pick the cotton. Because of these air currents there was approximately twice as much flyoff from the barbed spindle than from the smaller straight spindle. It should be noted that the air systems on cotton pickers should gather any seed cotton that does not stick to the spindle, so the flyoff is not necessarily a loss. Flyoff also increased exponentially for each spindle type as the speed was increased.

The peak force required to remove the seed cotton from the spindle ranged from 50 to 100 % more for the smaller straight spindle than from the barbed spindle. The smaller distance around the spindle allows more wrap of the fibers and thus the greater force for them to be removed. For both spindles, the peak force requirement was approximately doubled each time the speed was increased by 1000 rpm, indicating an exponential relationship between speed and wrap tightness.

Table 2. Performance data for the 2005 laboratory study.

Variety	Spindle	Speed, rpm	Moisture, % d.b.	Unpicked %	Flyoff %	Force, kg (lb)
Delta & Pine Land 565	12.7 mm t.b. (½” t.b.)	1000	9.8	3.5	1.8	0.14 (0.30)
		2000		0.5	19.6	0.42 (0.92)
		3000		0.25	50.4	0.85 (1.87)
	4.8 mm str. (3/16” str.)	1000		0.1	2.6	0.37 (0.81)
		2000		0	11.8	0.84 (1.86)
		3000		0	25.4	1.63 (3.60)
ACALA 1517-99	12.7 mm t.b. (½” t.b.)	1000	8.8	2.75	3.8	0.23 (0.50)
		2000		1.1	23.8	0.53 (1.17)
		3000		0.15	57.2	1.03 (2.26)
	4.8 mm str. (3/16” str.)	1000		0.35	0.4	0.35 (0.78)
		2000		0	10.2	0.80 (1.77)
		3000		0	34.2	1.46 (3.21)
Pima S7	12.7 mm t.b. (½” t.b.)	1000	9.8	0.15	6.4	0.28 (0.62)
		2000		0	26.1	0.69 (1.52)
		3000		0	43.6	1.12 (2.47)
	4.8 mm str.	1000		0	2.2	0.64 (1.42)

(3/16” str.)	2000	0	17.8	1.04 (2.29)
	3000	0	26.7	1.95 (4.31)

<u>Field studies</u>
Stalk loss, or the amount of seed cotton that was not removed from the plant by picking, was significantly different for spindle speed and variety in the 2005 crop year test. For each variety, stalk loss was significantly greater with a spindle speed of 1500 rpm than for spindle speeds of 2000 and 2400 rpm (Table 3). Differences between 2000 rpm and 2400 rpm were not significant. This indicates that spindle speed should be at least 2000 rpm for the picker to work adequately under the conditions of this test. In the 2006 crop year test, there were no significant differences among spindle speeds ranging from 2000 to 4000 rpm for the Delta and Pine Land 565 and Acala 1517-99 varieties. The Pima variety showed a higher stalk loss as for spindle speeds of 3000 and 4000 rpm than for a spindle speed of 2000 rpm. Examination of the stalk loss samples showed a large portion of the Pima stalk loss samples were spindle twists that apparently were pulled from the spindle by the plant.

Table 3. Stalk loss (%) for the 2005 and 2006 crop year field studies.

	Spindle speed - 2005			Spindle speed - 2006		
Cotton variety	1500 rpm	2000 rpm	2400 rpm	2000 rpm	3000 rpm	4000 rpm
Delta and Pine Land 565	3.3a	1.1b	1.2b	2.8	2.4	3.1
Acala 1517-99	1.6a	0.9b	0.7b	1.0	1.5	1.7
Pima DP 744	7.8a	3.6b	2.8b	1.1b	2.0a	2.4a

Note: When comparing across rows, different letters denote statistically significant differences using the student Neuman-Keuls test at the 5% level.

The number of and percent of spindle twists in the harvested seed cotton increased as the spindle speed increased for the 2006 crop year test (Table 4). The number of spindle twists per 1000 grams approximately doubled when spindle speed increased from 2000 to 3000 rpm for all varieties, then increased more when spindle speed increased to 4000 rpm. This data confirms what many ginners have thought – that the increased spindle speeds have made ginning cotton a greater challenge if fiber quality is to be preserved.

Table 4. Spindle twists in harvested seed cotton for the 2006 crop year field studies.

	Number per 1000 grams			Percent of sample by weight		
Cotton variety	2000 rpm	3000 rpm	4000 rpm	2000 rpm	3000 rpm	4000 rpm
Delta and Pine Land 565	32c	61b	80a	18c	31b	41a
Acala 1517-99	28b	64a	69a	16b	36a	40a
Pima DP 744	25c	53b	75a	19c	29b	38a

An analysis of trash collected from ginning showed no significant differences among treatments. Fractionation samples remain to be analyzed.

High volume instrument (HVI) classing data also showed no significant differences among treatments for the 2005 crop year. For the 2006 crop year, there were differences in the HVI trash levels (Table 5). Trash levels in samples after ginning but before any lint cleaning showed higher levels of trash with spindle speeds of 3000 and 4000 rpm than occurred with a spindle speed of 2000 rpm for the Delta Pine and ACALA varieties, but there were no differences with the Pima variety. Lint cleaning reduced trash levels more for the samples with higher trash levels so that there were no significant differences among samples that were collected after lint cleaning.

Table 5. HVI trash levels in lint samples for the 2006 crop year field studies.

Cotton variety	Percent trash area before lint cleaning			Percent trash area after lint cleaning		
	2000 rpm	3000 rpm	4000 rpm	2000 rpm	3000 rpm	4000 rpm
Delta and Pine Land 565	0.40b	0.58a	0.60a	0.25	0.28	0.30
Acala 1517-99	0.90b	1.18a	1.23a	0.43	0.50	0.48
Pima DP 744	0.58	0.58	0.58	0.30	0.34	0.33

Samples from the bales were tested on an Advanced Fiber Information System (AFIS), along with samples taken from the card sliver and after the finisher drawing stage. Properties analyzed included short fiber content, nep count, dust count, trash count, and upper quartile length. No significant differences were observed for dust count, trash count, or upper quartile length. Differences were significant for nep count in the raw stock from the bale with the Delta Pine and ACALA varieties, but not with the Pima. These nep count differences disappeared as the fiber was further processed. The Delta Pine variety had the highest neps at 2400 rpm while the ACALA variety had the highest neps at 1500 rpm (Table 6).

Table 6. AFIS nep count per gram for the 2005 crop year field study.

Cotton variety		Spindle speed		
		1500 rpm	2000 rpm	2400 rpm
Delta and Pine Land 5690	Raw stock	330b	341b	373a
	Card sliver	36	40	43
	Finisher drawing	30	37	36
Acala 1517-99	Raw stock	341a	304b	322ab
	Card sliver	46	48	46
	Finisher drawing	48	50	49
Pima DP 744	Raw stock	184	192	183
	Card sliver	32	33	35
	Finisher drawing	35	29	31

Differences in AFIS short fiber content were significant in the raw stock from the bale with the ACALA and Pima varieties, but not with the Delta Pine variety. These short fiber differences disappeared as the fiber was further processed. The ACALA variety had the highest short fiber content at 1500 rpm while the Pima variety had the highest short fiber content at 2400 rpm (Table 7).

Results from open-end spinning tests were received in December 2006. No significant differences were observed among the data. Properties analyzed included opening and cleaning waste, total card waste, ends down, yarn strength, yarn elongation, neps, thick places, and thin places.

Table 7. AFIS short fiber count (%) for the 2005 crop year field study.

Cotton variety		Spindle speed 1500 rpm	2000 rpm	2400 rpm
Delta and Pine Land 5690	Raw stock	14.0	13.7	14.5
	Card sliver	15.8	16.3	15.2
	Finisher drawing	15.5	15.4	15.4
Acala 1517-99	Raw stock	10.5a	9.8b	9.9b
	Card sliver	11.1	11.6	10.8
	Finisher drawing	11.1	11.5	11.8
Pima DP 744	Raw stock	5.8b	6.1b	6.7a
	Card sliver	7.2	7.6	7.6
	Finisher drawing	7.3	7.7	7.8

Summary

Spindle picking of cotton was developed in the 1930's to 1940's as a means to speed up and reduce the cost of harvest. Improvements to spindle pickers over the years have primarily focused on increasing the number of rows that can be harvested with 1 pass of the machine from 1 row to up to 6 rows; as well as increasing the travel speed of the harvester from around 0.85 to up to 2.25 (1.9 to 5 miles per hour). As cotton harvesters have gotten bigger and faster, spindle speeds have increased. As the speed has increased, cotton fibers can wrap more tightly around the spindle. Spindle sizes have also decreased in both diameter and length in order to reduce the weight of the picker head. As spindle diameter decreases, cotton fibers will wrap around the spindle more and become tighter on the spindle. As spindle length decreases, cotton plants must be further compressed as they pass through the picking zone. These changes have resulted in a general decrease in cotton fiber quality, particularly regarding spindle twists, preparation, and neps.

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