OPTIMIZING SPINDLE SPEED FOR COTTON PICKERS

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Field tests were conducted for the 2006, 2007, 2008 and 2009 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 (1.9 mi/hr) and spindle speeds of 2000, 3000, and 4000 rpm for the 2006 and 2007 crops and spindle speeds of 2000, 2300, 2700 and 3000 rpm for the 2008 and 2009 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. An analysis of trash collected from ginning showed no significant differences among treatments. 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. In 2006, differences were significant for AFIS nep count and short fiber count in the raw stock from the bale with all three varieties. Both neps and short fiber content increased when spindle speed was increased from 2000 to 3000 rpm and from 3000 to 4000 rpm. These nep count and short fiber differences were diminished, but did not disappear as the fiber was further processed. For AFIS dust count and trash count, significant differences were noted in the raw stock, with higher levels of dust and trash at speeds of 3000 rpm or greater. Differences in dust count and trash count disappeared as the fiber was further processed.

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, then 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 John Deere) 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 spindle-picked cotton fiber over a range of harvest speeds on 3 varieties of cotton in order to determine an optimum spindle speed range.

Test plots approximately 1.5 acres in area of each of three cotton varieties were grown during each of the 2006, 2007, 2008 and 2009 growing seasons at the Leyendecker Plant Science Research Center, Las Cruces, New Mexico. The three cotton varieties grown were: Fibermax 969, an 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; however, defoliation and boll opening chemicals were not used and harvest was delayed until after a killing frost.

Harvest dates were: 15 February to 2 March 2007 for the 2006 crop, 28 November to 6 December 2007 for the 2007 crop, 17 December to 29 December 2008 for the 2008 crop, and 16 November to 22 December 2009 for the 2009 crop. A modified International Harvester model 4M-120 1-row spindle picker was used to harvest the cotton (Figure 1). The 1-row picker used 9/16 inch spindles that had 2.4 inches of the spindle tip extending into the picking zone. Picking zone width for the picker was adjusted to 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 1.9 mi/hr, while spindle speeds were varied among 2000, 3000, and 4000 rpm for the 2006 and 2007 crop year tests and among 2000, 2300, 2700 and 3000 rpm for the 2008 and 2009 crop year tests. Results from the three speed combinations were compared for all three varieties tested. Each test lot consisted of 2 adjacent rows of cotton, each 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 2006 and 2007 crop year field studies.

Cotton variety		Harvest dates	Air temperature, degrees F	Air relative humidity, percent	Seed cotton moisture at harvest, percent d.b.	Lint yield from harvested seed cotton, bales/acre
Fibermax 969	2006-	2/15 – 16/07	53 – 55	20 – 27	6.4 – 7.2	2.05
	2007-	11/28 – 12/6/07	52 - 58	22 - 58	6.7 – 9.9	2.25
Acala 1517-99	2006-	2/16 – 20/07	51 – 59	21 – 41	6.4 – 7.5	1.70
	2007-	11/29 – 12/6/07	53 - 62	25 - 46	7.2 – 8.3	1.65
Pima DP 744	2006-	2/20 – 3/2/07	45 – 70	7 – 35	5.5 – 7.3	1.75
	2007-	12/4 – 12/6/07	50 - 59	21 - 67	6.5 – 10.9	1.55

Ambient weather conditions were mild and slightly less humid than normal with the ambient air dry bulb temperature ranging from 45 to 70 $^{\circ}$F overall for the 2006 crop and from 50 to 62 $^{\circ}$F overall for the 2007 crop. The ambient air relative humidity ranged from 7 to 41 % overall for the 2006 crop and from 21 to 67 % overall for the 2007 crop (Table 1). For the most part, this resulted in the seed cotton being drier than normal. Seed cotton moisture at harvest ranged from 5.5 to 7.5 % (dry basis) for the 2006 crop and from 6.5 to 10.9 % for the 2007 crop. At lower moistures, less fiber damage would be expected than would occur if the seed cotton was wetter.

Test lots for each crop year were ginned during the following March and April (yet to be done for the 2009 crop). Seed cotton cleaning used 2 cylinder cleaners and 1 stick machine with no drying. Upland varieties 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 collected 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 analysis competed after storage.

Stalk loss, or the amount of seed cotton that was not removed from the plant by picking, was significantly different across spindle speed for the Pima variety in the 2006 crop year test and for all varieties in the 2007 crop year test. For each variety with significance, stalk loss was significantly greater with a spindle speed of 4000 rpm than for spindle speeds of 2000 and 3000 rpm (Table 2).

Table 2. Stalk loss (%) for the 2006 and 2007 crop year field studies.

Cotton variety		Spindle speed 2000 rpm	3000 rpm	4000 rpm
Fibermax 969	2006-	2.8	2.4	3.1
	2007-	2.4b	2.8b	3.7a
Acala 1517-99	2006-	1.0	1.5	1.7
	2007-	2.7b	2.7b	3.5a
Pima DP 744	2006-	1.1b	2.0a	2.4a
	2007-	1.2b	1.3b	2.0a

Note: When comparing across rows, different letters denote statistically significant differences using the Student-Newman-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 and 2007 crop year tests (Table 3). 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.

Cotton variety		Number per 1000 grams 2000 rpm	3000 rpm	4000 rpm	Percent of sample by weight 2000 rpm	3000 rpm	4000 rpm
Fibermax 969	2006-	32c	61b	80a	18c	31b	41a
	2007-	8c	15b	21a	5c	8b	11a
Acala 1517-99	2006-	28b	64a	69a	16b	36a	40a
	2007-	12c	25b	38a	7c	14c	22c
Pima DP 744	2006-	25c	53b	75a	16c	29b	38a
	2007-	14c	28b	40a	8c	15c	20c

Table 3. Spindle twists in harvested seed cotton for the 2006 and 2007 crop year field studies.

An analysis of trash collected from ginning showed no significant differences among treatments.

For the 2006 and 2007 crop years, there were differences in the HVI trash levels (Table 4). 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 Fibermax 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.

Cotton variety		Percent trash area before lint cleaning 2000 rpm	3000 rpm	4000 rpm	Percent trash area after lint cleaning 2000 rpm	3000 rpm	4000 rpm
Fibermax 969	2006-	0.40b	0.58a	0.60a	0.25	0.28	0.30
	2007-	0.60b	0.78a	0.77a	0.35	0.37	0.38
Acala 1517-99	2006-	0.90b	1.18a	1.23a	0.43	0.50	0.48
	2007-	0.95b	1.13a	1.16a	0.55	0.55	0.58
Pima DP 744	2006-	0.58	0.58	0.58	0.30	0.34	0.33
	2007-	0.67	0.68	0.65	0.35	0.35	0.38

Table 4. HVI trash levels in lint samples for the 2006 and 2007 crop year field studies.

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. For the 2006 crop year, significant differences were observed for neps, short fiber content, dust count, and trash count in all three varieties. Neps increased significantly when spindle speed was increased from 2000 to 3000 rpm (Table 5), but short fiber content, and dust count did not increase. Results for trash content were mixed. All four factors, neps, short fiber content (Table 6), dust count (Table 7) and trash count (Table 8) increased significantly in all varieties as spindle speed was increased from 3000 to 4000 rpm. This indicates that the 3000 rpm and 4000 rpm spindle speeds produced more damage in the cotton fiber than the 2000 rpm spindle speed. The nep count and short fiber differences were diminished, but did not disappear as the fiber was further processed. Differences in dust count and trash count disappeared as the fiber was further processed.

Table 5. AFIS nep count per gram for the 2006 crop year field study.

		Spindle speed		
Cotton variety		2000 rpm	3000 rpm	4000 rpm
Fibermax 969	Raw stock	356c	380b	414a
	Card sliver	73c	82b	89a
	Finisher drawing	63c	69b	76a
Acala 1517-99	Raw stock	275c	292b	333a
	Card sliver	86c	93b	104a
	Finisher drawing	56b	57b	65a
Pima DP 744	Raw stock	226c	256b	326a
	Card sliver	59c	72b	83a
	Finisher drawing	69b	70b	80a

Table 6. AFIS short fiber count (%) for the 2006 crop year field study.

		Spindle speed		
Cotton variety		2000 rpm	3000 rpm	4000 rpm
Fibermax 969	Raw stock	12.7b	13.0b	15.3a
	Card sliver	13.5c	14.2b	15.3a
	Finisher drawing	12.9b	12.7b	14.3a
Acala 1517-99	Raw stock	7.5b	7.9b	8.9a
	Card sliver	9.8b	10.0b	10.7a
	Finisher drawing	9.5b	9.5b	10.1a
Pima DP 744	Raw stock	5.8b	6.2b	6.7a
	Card sliver	7.1b	7.3b	7.7a
	Finisher drawing	6.5b	6.6b	7.2a

Table 7. AFIS dust count (per gram) for the 2006 crop year field study.

		Spindle speed		
Cotton variety		2000 rpm	3000 rpm	4000 rpm
Fibermax 969	Raw stock	370b	387b	438a
	Card sliver	58	65	62
	Finisher drawing	54	56	63
Acala 1517-99	Raw stock	505b	530b	603a
	Card sliver	55b	59b	71a
	Finisher drawing	51	54	52
Pima DP 744	Raw stock	479b	463b	532a
	Card sliver	73	72	80
	Finisher drawing	75	67	73

Table 8. AFIS trash count (per gram) for the 2006 crop year field study.

		Spindle speed		
Cotton variety		2000 rpm	3000 rpm	4000 rpm
Fibermax 969	Raw stock	63c	72b	80a
	Card sliver	5	6	6
	Finisher drawing	7	7	7
Acala 1517-99	Raw stock	95c	105b	120a
	Card sliver	8	8	8
	Finisher drawing	7	7	7
Pima DP 744	Raw stock	30b	32b	38a
	Card sliver	2	1	2
	Finisher drawing	1	1	1

Results from open-end spinning tests for the 2006 crop year tests showed no significant differences 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. The 2007, 2008 and 2009 crop year tests remain to be analyzed.

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 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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Disclaimer

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References

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