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Cleaning Performance of Modified Cylinder Cleaners

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ABSTRACT

Saw-type lint cleaners are considered the most efficient and aggressive cleaners in the ginning industry. To look for a gentler cleaning alternative, a study was conducted over two seasons to evaluate the lint cleaning performance of modified cylinder cleaners. In crop year 2003, six cylinder configurations were made by varying the grid bar shapes, the spacing between grid bars, and a combination of these factors for each cylinder. Results indicated that all cylinder cleaner configurations yielded higher turnouts than the benchmark saw-type lint cleaner and its hybrid (a six cylinder cleaner with a special saw-type lint cleaner connected in series). The best overall cylinder cleaner was composed of 3 cradles of flat, square grid bars with a wide spacing (9.5 mm) between bars followed by another three cradles of flat, square grid bars with a narrow gap (6.4 mm) between bars. The second year of the study concluded that configuration 2004-1 composed of flat, square grid bars with a narrow spacing followed by wide spacing between grid bars (three cradles each) performed the best. This configuration provided the highest expected bale value ($321.5) and turnout (39.3%) with good reflectance (79.72), a low cleaning efficiency (18.0%), and the second lowest level of waste and neps (1.11 kg/bale and 208.1 neps/g for SG105, respectively). The best performer in 2003 ranked second in 2004.

Saw-type lint cleaners are the most popular and considered the most efficient cleaners in the ginning industry. Cleaning efficiencies in the range of 45% to 54% are achievable, depending on cotton cultivars, harvesting seasons, methods of harvesting, and other growing conditions (Mangialardi and Anthony, 2003; and Mangialardi and McCaskill, 1967). In a comprehensive study of the performance characteristics of a saw-type lint cleaner, Baker (1978) reported cleaning efficiency as high as 79.7%. As a result of combing the fibers aggressively, a saw-type lint cleaner, along with its efficiency, also causes higher fiber damage and increased short fiber content (Anthony et al., 1986). The trade-offs between fiber quality, classing grade, bale value, and profit to the cotton producers are well documented (Looney et al., 1963; Mangialardi, 1972; 1989; Barker and Baker, 1986; Columbus, 1990; Anthony et al., 2001).

Columbus and Anthony (1991) found that the same color grade and higher market prices could be obtained by adding three cycles of seed cotton cleaning through a cylinder cleaner before the gin stand and only one cycle of lint cleaning through a single saw-type lint cleaner after ginning. To develop a gentler cleaner, Mangialardi (1994) described a concept that included a flow-through air cleaner after the gin stand, followed by a revolving screen/inclined cylinder cleaner and one stage of saw-cylinder cleaner. Not less than 30 different types of lint cleaners were reviewed by Mangialardi and Anthony (2003). The efficiency of the saw-type lint cleaner was recognized and various means were explored to overcome many of its shortcomings, namely fiber damage, increased nep counts, and fiber loss to wastage and over-cleaning. Many of these efforts showed that the remedy usually compromised the performance of the cleaner. In addressing the issues of over-cleaning, Anthony (1999) devised a louver arrangement between the grid bars to selectively shunt the grid bar from the cleaning action. This device reduced fiber lost to wastage by up to 75% (Anthony, 2000).

Inclined cylinder cleaners are customarily deployed early in the ginning machinery sequence for seed cotton cleaning. Cocke (1972) investigated the effectiveness of a cylinder cleaner in terms of its operating speeds and processing rates and concluded that a cylinder cleaner used for seed cotton cleaning could operate in a wide range of speeds (350 to 650 rpm) and processing rates of up to 10 bales per hour without significant effect on lint color, fiber length, and fiber fineness. These findings were contradicted by Read (1972), who showed that higher cleaning

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efficiency could be obtained at higher cylinder speed for cleaning seed cotton.

Columbus and Mayfield (1995) verified that cylinder cleaners were gentler in cleaning and caused less damage to fiber than saw-type lint cleaners, but the grade improvement of two cylinder cleaners in series was inferior to a single saw-type lint cleaner.

Anthony (1997) studied the effectiveness of a cylinder cleaner in cleaning ginned lint and lint cleaner waste. A subsequent study explored the potential of four different grid bar designs for cylinder cleaners (Whitelock and Anthony, 2003). The four basic grid bar shapes considered were round, flat, and sharp squares, and a perforated screen. The spacing between adjacent bars was 9.5 mm (0.375 in.) or 6.4 mm (0.25 in.) and the width of the grid bars varied from 9.5 mm to 6.4 mm. The cylinder cleaner was used to clean seed cotton, ginned lint, and lint cleaner waste. Of the grid bar configurations studied, the sharp square at a high cylinder speed (1100 rpm) was the most efficient in cleaning (29.7%) but had excessive lint wastage. The flat squares had the best performance overall in terms of cleaning efficiency and fiber wastage. Although the sharp square (referred to as a diamond in this study) grid bars were the most efficient in cleaning, they also lost more fiber to wastage than the flat, square grid bars. The authors attributed the higher fiber loss to the wide spacing between bars (9.5 mm). The study concluded that cylinder cleaners with flat-, square-, and diamond-shaped grid bars are potentially gentler and more efficient cleaners.

The objective of this study was to determine an optimal cylinder cleaner configuration that would lose less fiber to waste, clean efficiently and gently, and yield higher turnout compared with a standard saw-type lint cleaner. To examine effects of cleaners on fiber quality, classing grade, fiber loss, and turnout, Advanced Fiber Information System (AFIS), and High Volume Instrument (HVI) properties were measured (both machines were manufactured by Uster Technologies, Inc., Charlotte, NC). Cleaning efficiency was based on measurements from a Shirley Analyzer (ASTM, 2004).

MATERIALS AND METHODS

Crop year 2003. The lint cleaning performance of modified cylinder cleaners was studied at the Cotton Ginning Research Unit, Stoneville, MS. The study considered three different grid bar configurations (cleaner treatments). Configuration 2003-1 consisted of three cradles of flat, square (6.4 mm wide) grid bars with 9.5-mm spacing between bars (Figure 1a) followed by another three cradles of flat, square (9.5 mm wide) grid bars with 6.4-mm spacing (Figure 1b). Configuration 2003-2 consisted of six cradles of diamond-shaped (9.5 mm wide) grid bars with a 6.4 mm spacing (Figure 1c). Configuration 2003-3 comprised of six alternating flat-, square-, and diamond-shaped (9.5 mm wide) grid bar cradles with the 6.4-mm spacing used in configurations 2003-1 and 2003-2. Additionally, two baseline configurations were included in the treatments for comparison. These configurations were the (40.6 mm or 16 in. diameter) saw-type lint cleaner (configuration 2003-4) and a cylinder cleaner (configuration 2003-5) comprised of six cradles of flat, square (6.4 mm wide) grid bars with 9.5-mm spacing between bars. Table 1 shows the cleaner treatment configurations studied in this experiment.

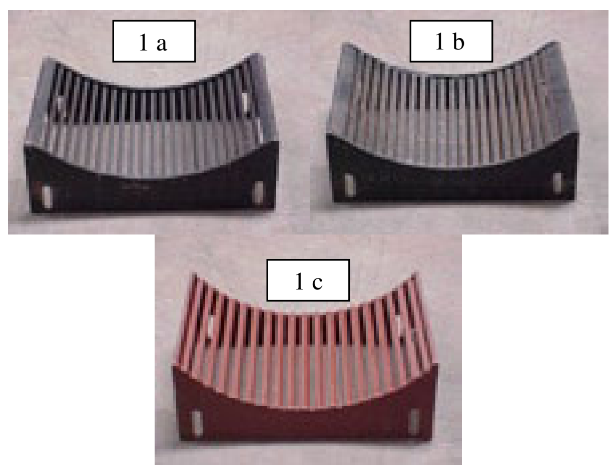

Figure 1. A) Flat, square grid bar: 6.4 mm wide and 9.5 mm spacing. B) Flat, square grid bar: 9.5 mm wide and 6.4 mm spacing. C) Diamond-shaped grid bar: 9.5 mm wide and 6.4 mm spacing.

In addition to cleaner treatments and seed cotton cultivars, other factors analyzed in this study included cylinder speed and lint moisture. The experiment was arranged in a split-split plot design in which cleaner treatments were the whole plots within each replicate (blocked), the cylinder speed was the subplot, and the two cultivars and two moisture levels randomized within subplots were the sub-subplots. Two baseline cleaner treatments (configurations 2003-4 and 2003-5) were included among the whole plots of cleaner treatment in a random order. The two baseline configurations were run at one moisture level (targeted 4.0%) and one cylinder speed (980 rpm) for both cultivars. Within a replicate block, the experiment required a total of 28 runs, 24 runs (3x2x2x2) for the first three configurations and four runs (two cultivars) for the baseline configurations. With three replicates for each run, the total number of runs for the experiment was 84 (3x28).

Seed cotton used in this study was harvested in the 2003 season. The two cotton cultivars, Stoneville 4892 (STV4892, Stoneville Pedigreed Seed Company; Memphis, TN) and Deltapine 555 (DPL555, Delta and Pine Land Seed; Scott, MS), were harvested by spindle pickers in September and October of 2003, respectively. Though the two cultivars were harvested from different fields, it was assumed there was no significant field effect between the cultivars. Approximately 50 lots of nominal 18.2 kg (40 lb) of seed cotton were prepared from each cotton cultivar. They were stored in mesh bags and allowed to condition over 72 h at 50% relative humidity and 24 °C (75 °F). Seed cotton was ginned in the microgin of the facility. The ginning sequence consisted of a shelf dryer 1, six-cylinder cleaner, stick machine, shelf dryer 2, six-cylinder cleaner, extractor-feeder, 20-saw (40.6-cm diameter) gin stand followed by an experimental six-cylinder cleaner subjected to various grid bar configurations. The experimental cylinder cleaner was used in place of the saw-type lint cleaner to clean lint in this study. Dryer 1 was set to low heat (38 °C or 100 °F), and dryer 2 was set to high heat (93 °C or 200 °F). For high moisture runs, seed cotton was routed to dryer 1 only. For low moisture runs, seed cotton was routed through both dryers to remove moisture. For every extended downtime because of cylinder speed or configuration changes, 18.2 kg (40 lb) of seed cotton was run through the system to warm up the machinery.

As the experiment was conducted, preliminary results revealed a potentially efficient cleaning grid bar configuration. Two new cylinder cleaner configurations (configuration 2003-6 and 2003-7, Table 1) were added. Configuration 2003-6 was composed of three flat, square grid bar cradles followed by three diamond-shaped grid bar cradles. Both grid bar types had narrow 6.4-mm spacings. Configuration 2003-7 was a hybrid cylinder cleaner composed of a cylinder cleaner, configuration 2003-6, followed by a special saw-type lint cleaner with one cleaning grid bar. With two cultivars, one moisture level (6%), one cylinder speed (980 rpm), and three replications, a total of 12 runs (2x2x3) were added to the experiment.

For each lot ginned, three seed cotton samples were collected at the feeder apron for foreign matter content evaluation, and three lint samples were collected before and after the experimental cylinder cleaner for HVI and AFIS analyses. Three samples were also collected for moisture evaluation after

Table 1. Grid bar configurations for modified cylinder cleaners

Cleaner treatment	Cylinder position number[y]					
	1	2	3	4	5	6
2003-1	A ■ ■	A ■ ■	A ■ ■	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■
2003-2	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦
2003-3	B ■ ■ ■	C ♦ ♦ ♦	B ■ ■ ■	C ♦ ♦ ♦	B ■ ■ ■	C ♦ ♦ ♦
2003-4	Saw-type lint cleaner					
2003-5	A ■ ■	A ■ ■	A ■ ■	A ■ ■	A ■ ■	A ■ ■
2003-6	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦
2003-7[z]	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦
2004-1	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■	A ■ ■	A ■ ■	A ■ ■
2004-2	A ■ ■	A ■ ■	A ■ ■	--[z]	--	--
2004-3	A ■ ■	A ■ ■	A ■ ■	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■
2004-4	Saw-type lint cleaner					
2004-5	B ■ ■ ■	B ■ ■ ■	B ■ ■ ■	C ♦ ♦ ♦	C ♦ ♦ ♦	C ♦ ♦ ♦

[y] A: 6.4 mm key stock turned flat surface to face the spiked cylinder with 9.5 mm spacing between grid bars (■ ■). B: 9.5 mm key stock turned flat surface to face the spiked cylinder with 6.4 mm spacing between grid bars (■ ■ ■). C: 9.5 mm key stock turned a sharp edge to face the spiked cylinder (diamond) with 6.4 mm spacing between grid bars (♦ ♦ ♦).

[z] A cylinder cleaner with a special saw-type lint cleaner with only one active grid bar.

the cylinder or saw-type lint cleaner. The cylinder cleaner was divided into two sections of three cylinders each; each section was equipped with a trash pan to collect trash separately. The experimental cylinder cleaner was installed in parallel with a saw-type lint cleaner (Fig. 2).

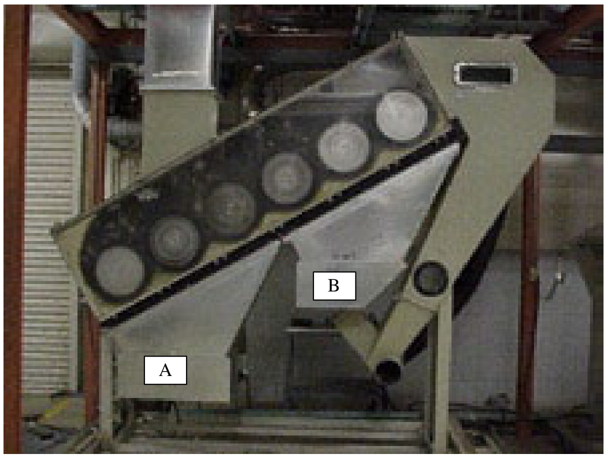

Figure 2. Experimental inclined six cylinder cleaner with trash hopper A and B

Crop year 2004. Based on the results of the first season of the study in 2003, the performance of another five modified cylinder cleaners were configured and studied in crop year 2004 at the same facility. Configuration 2004-1 was a cylinder cleaner that was composed of three cradles of flat, square (9.5 mm wide) grid bars with a 6.4-mm spacing between bars (Fig. 1a) followed by another three cradles of flat, square (6.4 mm wide) grid bars with a 9.5-mm spacing (Fig. 1b). Configuration 2004-2 was a hybrid cleaner that consisted of a cylinder cleaner with three cradles of flat, square (6.4 mm wide) grid bars with a 9.5-mm spacing, and the next three cylinder positions were blanked-off. A special saw-type lint cleaner with only one cleaning grid bar was connected in series with the cylinder cleaner. Cylinder cleaner configuration 2004-3 was the top performer from 2003. It was composed of three cradles of flat, square (6.4 mm wide) grid bars with a 9.5-mm spacing followed by three cradles of flat, square (9.5 mm wide) grid bars with a 6.4-mm spacing between bars. Configuration 2004-4 was a saw-type lint cleaner and was included as a baseline configuration for comparison. Configuration 2004-5 was another top performer from the study in crop year 2003. It had three cradles of flat, square (9.5 mm wide) grid bars with a 6.4-mm spacing between bars followed by three cradles of diamond-shaped grid bars (9.5 mm wide) with a 6.4-mm spacing between bars (Table 1).

In addition to cleaner treatments, the other factor considered in this study was seed cotton cultivars. Cylinder and saw speeds were set at a nominal 1000 rpm. Seed cotton was conditioned in a controlled environment 3 d before testing. The laboratory was controlled at 24 °C (75 °F) and 55% humidity. The experiment was based on a randomized complete block design with a split plot arrangement of treatments, where cleaner treatment was the main unit and seed cotton cultivars were the sub-units. For the two cultivars, five cleaner treatments and three replicates, the experiment required 30 treatment runs.

Seed cotton used in this study was harvested in the 2004 season. The two seed cotton cultivars, Stoneville 4892 (STV4892; Stoneville Pedigreed Seed Co.) and SureGrow 105 (SG105, Delta and Pine Land Seed), were harvested by spindle pickers in September and October of 2004, respectively. Approximately 15 lots of nominal 18.2 kg (40 lb) of seed cotton were prepared from each cotton cultivar. Seed cotton was ginned in the microgin at the Cotton Ginning Research Unit, Stoneville, MS. The dryers, ginning sequence, and equipment deployed were the same as used in the crop year 2003.

The sampling procedure was the same as practiced in crop year 2003. Samples were collected at proper locations of the ginning process to be analyzed for fractionation, moisture, HVI, AFIS, and Shirley Analyzer.

Statistics. Main effects of the experiments conducted in 2003 and 2004 were analyzed based on a mixed model according to Littell et al. (1996) using the SAS statistical software (version 9.1, SAS Institute; Cary, NC). The random effects were replication, replication by cleaner treatment, and replication by cylinder speed. Because of the imbalance in the designed experiment for crop year 2003 (the first three configurations included both low and high moisture and two cylinder speed runs, but the two baseline configurations 2003-4 and 2003-5 included only the low moisture and high cylinder speed runs), results of the experiments were sorted then analyzed by cylinder speed. All the means of the first five cleaner treatments could be compared at the high cylinder speed (980 rpm). Only the means of the first three cleaner treatments could be compared at the low cylinder speed (680 rpm). Also, by segmenting the data by moisture, the cleaner treatments could be compared at low and high moistures separately. Although cleaner treatments 2003-6 and 2003-7 were added at the end of the experiment, results of these two treatments could be combined and analyzed in aggregate with the other five cleaner treatment runs. The assumptions were that there were no significant observable changes in the environment or process that could bias the results because of time and the difference in variances of the two experiments. The adjusted means of the properties in each experiment were compared at $P = 0.05$. Results of the low cylinder speed runs (680 rpm) involved only the first three configurations. Their performance was similar to that in the high cylinder speed runs, and for the most part, there were no significant performance differences among these three configurations; therefore, results presented in the following discussion concentrated on the results and analyses of the high cylinder speed runs (980 rpm).

The main effects for the experiment conducted in 2004 were analyzed similarly to 2003. The random effects for this experiment were replicate and replicate by cleaner treatment. Mean were compared using least square difference (LSD) calculations.

To examine effects of the cleaner and its treatment factors on HVI and AFIS properties, variance of samples collected after the cleaner treatment was analyzed. If properties for the samples collected before the cleaner treatment were significant ($P \leq 0.05$), they were included in the model as a covariate.

Another aspect of the study in cleaner performance was to examine the trash collected in each test. The collected lint cleaner wastes were normalized to the amount of ginned lint and scaled to a 227-kg (500-lb) bale to account for variability in the amount of input seed cotton.

RESULTS

Moisture analysis. Moisture results from the standard oven test method (Shepherd, 1972) showed that the dryer strategy used to affect seed cotton moisture was partially successful when the laboratory was air-conditioned on the first day of testing. For the experiment conducted in 2003, low and high mean moisture levels achieved varied from 4% to 5% (low moisture level = 4.5% + 0.6%, high moisture level = 4.9% + 0.6%). While the treatment called for a difference of 2% moisture (from a low level of 4% to a high level of 6%), the method of controlling moisture described previously could effectuate only a 0.5% difference. Variability (standard deviation of 3 samples) of moistures within a treatment run was generally less than 0.5%.

Lint moisture measured from samples collected in the 2004 experiment varied from 3.72% to 5.6%, with an average of 4.4% and a standard deviation of 0.46%.

HVI data. Since the difference in variances between the first five cleaner treatments (2003-1 through 2003-5) and the last two treatments (cleaner configurations 2003-6 and 2003-7) added at the end of the experiment was small in 2003, results from all seven configurations investigated were combined and analyzed as an experiment. ANOVA results for the HVI properties are presented in Table 2. The low leaf number (2.84) produced by the saw-type cleaner (configuration 2003-4) indicated that it was the most efficient cleaner. A similar trend to leaf number was observed for percentage (trash) area. The saw-type cleaner (2003-4), along with configurations 2003-6 and 2003-7, had the highest reflectance values. Aggressive cleaning by the saw-type cleaner was demonstrated by its shorter fiber length (2.67 cm) than the cylinder cleaners. Strength, uniformity, and yellowness were not different among cleaners.

In the 2004 experiment, the low percentage (trash) area (0.0165 %) and leaf number (2.39) produced by the saw-type cleaner (2004-4) demonstrated its effectiveness in cleaning. The saw-type cleaner produced the highest reflectance (80.7) and cylinder cleaner configuration 2004-1 produced the lowest reflectance (79.8). Cylinder cleaner configurations 2004-5 and 2004-2 had significantly shorter fiber. Configuration 2004-3 produced the greatest uniformity (82.5%) and configuration 2004-2 generated least uniformity (81.8%). There were no differences in micronaire and strength among cleaning treatments.

There was an interaction between cylinder treatment and cultivar on yellowness. Across all cleaner treatments, yellowness of the smooth-leaf cultivar (SG105) was lower than the hairy-leaf cultivar (STV4892). The classing grades for all samples collected in the experiment were in the strict middling class (21). Less than 10% of the samples (three runs) were rated lower in the middling class (31). The lower grade bales were produced by cylinder cleaner configurations 2004-1 and 2004-3.

AFIS data. Results of the ANOVA for the AIFS properties measured in 2003 and 2004 are summarized in Table 3. The saw-type lint cleaner (configuration 2003-4) was consistently the more efficient cleaner, based on having the lowest dust value and among the lowest in visible foreign matter.

The hybrid cylinder cleaner (configuration 2003-7) was the most aggressive cleaner with the highest neps (268.6/g) and short fiber content (8.4%), and the shortest fiber length (2.42 cm).

In 2004 experiment, the saw-type cleaner (configuration 2004-4) was still the most efficient cleaner, as indicated by its low dust (227.4/g) and visible foreign matter (0.94%). Cylinder cleaner configurations 2004-1 and 2004-3 generated the fewest neps (208.1 and 208.6/g, respectively). Configurations 2004-2 and 2004-5 were the more aggressive cleaners base on their higher short fiber content (7.18% and 7.29%, respectively) and neps (253.4/g and 245.1/g, respectively), and shorter fiber lengths (2.45 cm for both). It was plausible that cylinder cleaner configuration 2004-5 had higher short fiber content and more neps not because it damaged more fiber, but rather that it retained more short fiber and neps because of its narrower gaps between grid bars. There were no significant differences in upper quartile length among cleaner treatments.

Lint turnout analysis. Turnouts from the 2003 and 2004 experiments are summarized in Table 4. In 2003, all of the cylinder cleaner configurations provided higher turnouts than from the saw-type lint cleaner (2003-4). There were no significant differences in turnout among the cylinder cleaners.

Turnouts from cylinder cleaners in 2004 were significantly higher than those from the saw-type lint cleaner (2004-4) and its hybrid (2004-2). Among the cylinder cleaner configurations, configuration 2004-1 yielded the highest turnout (+3.42% over the basis) followed by configuration 2004-3. Both configurations 2004-1 and 2004-3 used the same set of flat,

Table 2. Mean comparisons of HVI properties as affected by cleaner treatment and cotton cultivar

Source of variation	HVI property[x]								
	Micronaire	Strength (cN/tex)	Length (cm)	Uniformity (%)	Rd	Plus b [z]		% area	Leaf
Cleaner – 2003 [y]									
2003-1	4.44 ab	27.6 a	2.72 a	80.5 a	78.4 b	7.55 a		0.0427 a	3.21 b
2003-2	4.45 ab	27.1 a	2.74 a	80.8 a	78.1 b	7.57 a		0.0467 a	3.48 a
2003-3	4.41 bc	27.2 a	2.71 a	81.3 a	78.3 b	7.50 a		0.0451 a	3.41 ab
2003-4	4.37 c	26.2 a	2.67 b	80.7 a	79.4 a	7.64 a		0.0308 b	2.84 c
2003-5	4.48 a	27.1 a	2.73 a	80.6 a	78.9 ab	7.57 a		0.0377 ab	3.23 ab
2003-6	4.49 a	27.6 a	2.71 a	81.1 a	78.5 a	7.53 a		0.0372 b	3.25 ab
2003-7	4.42 bc	27.1 a	2.71 a	80.1 a	79.1 a	7.55 a		0.0334 b	3.25 ab
Cleaner – 2004						STV4892	SG105		
2004-1	4.80 a	28.1 a	2.78 a	82.1 ab	79.8 b	8.84 b	7.82 b	0.02864 a	3.03 a
2004-2	4.77 a	27.8 a	2.74 b	81.8 b	80.0 ab	8.98 ab	7.71 b	0.01854 bc	2.56 c
2004-3	4.78 a	28.1 a	2.78 a	82.5 a	80.0 ab	8.90 ab	7.89 ab	0.02331 b	3.13 a
2004-4	4.76 a	28.0 a	2.77 a	82.0 ab	80.7 a	9.11 a	8.06 a	0.01653 c	2.39 d
2004-5	4.78 a	27.6 a	2.74 b	82.1 ab	80.2 ab	9.09 a	7.86 ab	0.01798 c	2.83 b
Cultivar – 2003									
STV4892	4.37 b	27.3 a	2.70 a	81.6 a	78.2 b	8.07 a		0.0438 a	3.33 a
DPL 555	4.49 a	26.7 b	2.71 a	79.9 b	79.1 a	7.06 b		0.0385 a	3.14 a
Cultivar – 2004									
STV4892	4.82 a	27.8 a	2.75 b	82.5 a	79.4 b	-		0.02654 a	3.08 a
SG105	4.73 b	28.0 a	2.77 a	81.7 b	80.9 a	-		0.02002 b	2.50 b

[x] Means within a column for each source of variation followed by the same letter are not significantly different ($P = 0.05$) based on LSD.

[y] Main effects were analyzed at cylinder speed of 980 rpm for the 2003 crop year.

[z] In 2004, the interaction between cultivars and cleaners for plus B was significant.

square gird bars with narrow and wide spacings, except that the order of the placing the cradles was different. Configuration 2004-1 had three narrowly spaced cradles followed by three widely spaced cradles, and 2004-3 was led by three widely spaced cradles followed by three narrowly spaced cradles. Results on turnout revealed that the order for placing the narrow and wide spacing grid bar cradles did not make a difference in turnout.

Lint wastage. An ANOVA was performed on the collected cleaner wastes and their results are summarized in Table 4. The saw-type cleaner (configuration 2003-4) had significantly higher lint waste (3.0 kg/bale) than the cylinder cleaner configurations (2003-1, 2003-2, 2003-3, and 2003-6)

Configuration 2003-3, which was in the highest turnout group, lost the least fiber to waste. It verified the hypothesis that grid bars with narrow spacings lose less fiber to waste and increase turnout. Configuration 2003-5 with wide grid bar spacings lost as much fiber to waste (1.74 kg/bale) as configuration 2003-7 (1.81 kb/bale), the hybrid cylinder cleaner with narrow grid bar spacings plus a special saw-type lint cleaner with one cleaning grid bar.

In 2004, there was an interaction between cleaner treatment and cultivar for cleaner waste. Across all cleaners, waste of the smooth-leaf cultivar (SG105) was lower than that of the hairy-leaf cultivar (STV4892). For both cultivars, cleaner waste was significantly higher for the saw-type lint cleaner (configuration 2004-4) than for the other cleaners.

Cleaning efficiency model based on visible waste from a Shirley analyzer. Visible waste data recorded by the Shirley Analyzer were used to calculate the cleaning efficiencies for the treatments (Table 4). In 2003, the saw-type cleaner (2003-4) had the highest cleaning efficiency at 47.1% followed by its hybrid configuration (2003-7) at 27.8%. Cleaning

Table 3. Mean comparisons of AFIS properties as affected by cleaner treatment and cotton cultivar

Source of variance	AFIS property[z]					
	Neps/g	Dust/g	Visible foreign matter (%)	Length (cm)	Upper quartile length (cm)	Short fiber content (%)
Cleaner – 2003						
2003-1	212.5 c	341.4 a	1.75 a	2.45 a	2.94 a	7.66 b
2003-2	213.9 c	367.8 a	1.75 a	2.45 a	2.94 a	7.45 b
2003-3	225.7 bc	370.6 a	1.83 a	2.45 a	2.93 a	7.85 b
2003-4	240.1 b	240.1 b	1.27 b	2.44 a	2.92 a	7.66 b
2003-5	231.7 b	357.7 a	1.68 ab	2.44 a	2.92 a	7.70 b
2003-6	228.8 c	324.6 a	1.66 ab	2.45 a	2.92 a	7.37 b
2003-7	268.6 a	304.8 a	1.46 ab	2.42 b	2.92 a	8.43 a
Cleaner – 2004						
2004-1	208.1 c	369.9 a	1.60 a	2.47 a	2.93 a	6.96 b
2004-2	253.4 a	298.8 ab	1.28 ab	2.45 b	2.91 a	7.18 ab
2004-3	208.6 c	348.1 a	1.52 a	2.47 a	2.94 a	6.94 b
2004-4	224.5 b	227.4 c	0.94 b	2.47 a	2.93 a	6.95 b
2004-5	245.1 a	278.5 bc	1.26 ab	2.45 b	2.92 a	7.29 a
Cultivar – 2003						
STV4892	224.9 a	399.0 a	1.90 a	2.47 a	2.93 a	6.99 a
DPL 555	224.7 a	272.0 b	1.41 b	2.43 b	2.93 a	8.34 b
Cultivar – 2004						
STV4892	213.1 b	341.2 a	1.13 a	2.46 a	2.91 a	6.92 b
SG105	242.8 a	267.9 a	1.51 a	2.46 a	2.93 b	7.21 a

[z] Means within a column for each source of variation followed by the same letter are not significantly different (*P* = 0.05) based on LSD.

efficiencies of the cylinder cleaners (configurations 2003-1, 2003-2, 2003-3, 2003-5, and 2003-6) that ranged from 9.3% to 17.0% were not significantly different and were significantly lower than the saw-type cleaner and its hybrid.

In 2004, cleaning efficiency of the saw-type lint cleaner (49.5%) was twice as high as its hybrid in configuration 2004-2 (25.2%). Among cylinder cleaners, configuration 5 (flat-, square-, and diamond-shaped grid bars with narrow gaps) cleaned most efficiently (30.3%), and configuration 3 was the least efficient cleaner (9.0%).

Fiber content in cleaner waste. The data from both years showed that a saw-type lint cleaner generated the greatest amount of waste and cylinder cleaners the least. To learn more about the lost fiber, waste collected from the 2004 experiment was analyzed by a Shirley Analyzer to determine its content. The analyzer separated cleaner waste into recoverable lint fiber and trash particles. Percentages of recoverable fiber, and trash particles were calculated by proportioning the percentages of useful fiber and trash particles to the actual amount of waste collected in each run (Table 5).

The interaction between cleaner treatment and cultivar showed that total waste from the smooth-leaf cultivar (SG105) was lower than waste from the hairy-leaf cultivar (STV4892). The waste from the smooth leaf cultivar generated by the saw-type cleaner (2004-4) contained the highest amount of good fiber (2.5 kg/bale), and configurations 2004-1 and 2004-3 had the least (0.2 kg/bale). The cylinder

Table 4. Mean comparisons of quality and performance parameters among cleaner treatments and cultivars

Source of variation	Performance parameter[v]					
	Rd	Cleaning efficiency based on Shirley visible waste (%)	Lint cleaner waste (kg/bale)[w]		Lint turnout over base (%)	Expected bale value over base ($)[x]
Cleaner – 2003						
2003-1	79.0 ab	16.97 c	1.30 c		+3.80 a	+12.02
2003-2	78.3 b	9.31 c	1.17c		+3.49 a	+11.04
2003-3	78.2 b	9.89 c	1.12c		+2.62 a	+8.28
2003-4	79.8 a	47.10 a	3.00a		38.92 b[y]	316.13[z]
2003-5	78.7 b	15.92 c	1.74 b		+3.37 a	+10.64
2003-6	78.5 b	9.62 c	1.03 c		+1.03 a	+3.24
2003-7	79.1 a	27.77 b	1.81 b		+2.49 a	+7.88
Cultivar – 2003						
STV4892	78.2 b	20.81 a	1.96 a		-4.3 b	-13.08
DPL555	79.1 a	18.87 a	1.36 b		+9.4 a	+29.81
Cleaner – 2004			STV 4892	SG105		
2004-1[u]	79.72 b	17.99 c	1.76 c	1.11 b	+3.42 a	+10.64
2004-2	80.06 ab	25.10 b	2.74 b	1.41 b	+1.45 bc	+4.50
2004-3	80.00 ab	8.99 d	1.64 c	1.05 b	+2.42 ab	+7.53
2004-4	80.61 a	49.48 a	7.00 a	4.41 a	37.99 c[y]	310.85[z]
2004-5	80.28 ab	30.32 b	2.51 b	1.21 b	+1.87 ab	+5.81
Cultivar – 2004						
STV4892	78.72 b	28.27 a	-		0.4 b	-1.31
SG105	82.0 a	24.48 a	-		4.1 a	+12.69

[v] Means within a column for each source of variation followed by the same letter are not significantly different (*P* = 0.05) based on LSD.

[w] The interaction between cleaners and cultivars for lint cleaner waste was significant in 2004.

[x] Based on 1500 lb seed cotton with class 31, 3 leaf at the 2004 loan rate ($0.5415/lb).

[y] Basis for turnout in 2003 or 2004.

[z] Basis for expected bale value in 2003 or 2004

cleaners not only generated less cleaner waste in comparison to a saw-type lint cleaner and its hybrid, but its waste also contained less recoverable, useful fiber and higher percentages of trash particles.

For the hairy leaf cultivar (STV4892), the saw-type lint cleaner expelled a total of 7.0 kg (15.4 lb) per bale of waste (Table 4). The waste consisted of approximately 3.17 kg/bale (45.2%) of potentially recoverable good fiber, and 3.85 kg (8.5 lb) per bale (54.8%) of trash particles (Table 5). For the same cultivar, cylinder cleaner configuration 2004-1 only expelled 0.27 kg (0.6 lb)/bale (15.1%) of good fiber and 1.50 kg (3.3 lb)/bale (85.0%) of trash particles. By eliminating this waste composition, configurations 2004-1 and 2004-3 achieved the same classing grade (strict middling, 21) as the saw-type lint cleaner 90% of the time.

Varietal effects. In 2003, the smooth leaf cultivar (DPL555) had higher reflectance, and lower strength, uniformity, and yellowness than the hairy leaf cultivar (STV4892) (Table 2). The smooth leaf cultivar was easier to clean than the hairy leaf cultivar, based on lower values in dust and visible foreign matter. Fiber length was shorter and short fiber content for the smooth leaf cultivar was significantly higher than the hairy leaf cultivar (Table 4).

In 2004, STV4892 fiber was shorter (HVI) and lower in reflectance, neps, upper quartile length, and short fiber content compared with the SG105 (Tables 2 and 3). Cultivar STV4892 was harder to clean than SG105 as shown by its higher percentage (trash) area and leaf.

The smooth leaf cultivars (DPL 555 and SG105) produced higher turnouts and lost less fiber to waste than the hairy leaf cultivar (STV4892). Cultivars played little role in cleaning efficiency based on visible waste measured by a Shirley Analyzer (Table 4). The ranking orders of fiber content in wastes according to cleaner treatments were similar for all cultivars, but fiber content in waste from STV 4892 was higher than from SG105 (Table 5).

Optimal configurations. Effects of cleaner treatments on HVI and AFIS properties were presented earlier (Tables 2 and 3). Treatment means for reflectance and neps with other performance parameters of interest, cleaning efficiency, lint cleaner waste, and turnout, are presented in Table 4. Of special interest were color grade and nep formation by the cleaner treatments. Reflectance (Rd) was the classing property most affected by cleaner treatments. The aggressiveness of a cleaner was revealed by its nep formation and short fiber content. The saw-type lint cleaner (2003-4) and its hybrid (2003-7) cleaned most efficiently and provided the best color, but lost more fiber to waste and yielded lower turnouts. Since fiber loss and turnout directly affected profits, these measurements must be balanced by the marginal gain in cleaning efficiency, classing grade (reflectance), and nep creation.

The performance of the first four cylinder cleaner configurations (configurations 2003-1, 2003-2, 2003-3, and 2003-5) were similar for most properties; however, configuration 2003-1 appeared to perform better based on the parameters evaluated. Its reflectance was the best after the saw-type cleaner (2003-4) and configuration 2003-7 (0.8 units lower than the saw-type and 0.1 units lower than the hybrid configuration), and its cleaning efficiency also ranked third after the saw-type lint cleaner and configuration 2003-7. Its turnout was the best among all cleaners and was 3.8% to 1.3% higher than the saw-type and

Table 5. A summary for the lint content in waste analyzed by a Shirley Analyzer for cleaners and cultivars in the 2004 crop year

Cleaner treatment	Cleaned fiber in waste[y,z]				Total waste in waste[y]			
	STV4892		SG105		STV4892		SG105	
	kg/bale	%	kg/bale	%	kg/bale	%	kg/bale	%
2004-1	0.27 c	15.05 c	0.20 cd	18.13 cd	1.49 c	84.95 c	0.91 b	81.87 a
2004-2	0.73 b	26.85 b	0.44 b	31.55 b	2.00 b	73.15 b	0.97 b	68.45 c
2004-3	0.22 c	13.20 c	0.19 d	17.98 d	1.43 c	86.80 c	0.86 b	82.02 a
2004-4	3.17 a	45.17 a	2.46 a	55.67 a	3.85 a	54.83 a	1.96 a	44.33 d
2004-5	0.59 b	23.84 b	0.34 bc	27.94 bc	1.92 b	76.16 b	0.87 b	72.06 b

[y] The interaction of cultivars and lint cleaners for fiber in the waste and total waste was significant. Means within a column followed by the same letter are not significantly different ($P = 0.05$).

[z] Lint recovered from waste by a Shirley Analyzer.

configuration 2003-7 cleaners, respectively. Lastly, its “penalty” in terms of lint wastage was 1.70 to 0.52 kg (3.7 to 1.1 lb)/bale lower than the saw-type and its hybrid cleaner. Since cotton processed by all cleaner treatments evaluated in this study attained essentially the same classing grade (middling, 31), the expected bale value for the cleaner treatments were differentiated primarily by their turnout. Thus, configuration 2003-1 was the best performer based on performance parameters considered and its highest expected bale value ($328.15).

Results from the study in 2004 were also summarized in Table 4. Since 1% of turnout was equal to 6.8 kg of good fiber in a bale [based on 681.8 kg (1500 lb) of seed cotton and $1.10/kg ($0.50/lb) of cotton] or $7.50 per bale of additional profit for the producer, configuration 2004-1 appeared to perform the best based on its high turnout and low fiber waste, without apparent penalty in reflectance and classing grade, despite its higher visible foreign matter and dust values. Additionally, short fiber content produced by configuration 2004-1 was similar to that produced by the aggressive saw-type lint cleaner (2004-4), but with a lower nep count. Configuration 2004-1 was also the best performer based on its highest expected bale value ($321.49, +$10.64 over the basis). Configuration 2004-3, which performed best when tested in 2003, ranked second among configurations tested in 2004 (+$7.53 over the basis).

SUMMARY

Cleaning performance of six different cylinder cleaner configurations were compared with a saw-type cleaner in crop year 2003. Two new configurations and two top performers from 2003 were compared with a saw-type cleaner in 2004. These configurations were formed by varying the shapes of grid bars, spacing between grid bars, and a combination of these factors in each cylinder position. Results from the first-season study revealed that the saw-type lint cleaner (configuration 2003-4) and its hybrid (configuration 2003-7) were the most efficient cleaners, because they produced the highest level of reflectance and the lowest level of trash, which included leaf, percentage trash area, dust, and VFM. The cleaning efficiency of the saw-type cleaner and its hybrid was also the highest among all seven configurations studied in 2003 and the five configurations in 2004; however, turnout was among the lowest and their cleaner wastage was also the highest.

In both years, all HVI and AFIS properties generated by all cylinder-cleaner configurations displayed a similar trend. The lower levels of neps produced by cylinder cleaners indicated that they were gentler cleaners. Length, upper quartile length, and short fiber content of the cylinder cleaners were not different from the saw-type lint cleaner and its hybrid. Turnout of cylinder cleaners was generally higher, and cleaner waste levels, cleaning efficiencies, and reflectance were lower. In considering the tradeoffs among quality measures in neps, reflectance, cleaning efficiency, fiber wastage, turnout, and expected bale value, cylinder configuration 2004-1 and 2004-3 were considered the optimal cleaners among the configurations studied in the two years. These configurations were composed of six cradles of flat, square grid bars with wide or narrow spacing.

The model for the lint waste verified the hypothesis that cylinder cleaners with narrow grid bar spacings lost less fiber to waste, cleaned less efficiently, and yielded higher turnout.

The cleaning efficiency analyses showed that the saw-type lint cleaner was still the more efficient cleaner and also yielded the best color fiber; however, in considering other performance parameters of interest, such as lint cleaner waste, lint turnout, and reflectance for color grade, cylinder cleaner configuration 2004-1 and 2004-3 had the overall best balanced performance. It cleaned gentler and create fewer neps than the saw-type lint cleaner and its hybrid. Waste generated by cylinder configuration 2004-1 was merely 25% of that produced by a saw-type lint cleaner.

The smooth leaf cultivars were easier to clean than the hair-leaf cultivars. They had higher reflectance, and lower fiber strength, uniformity, and yellowness. The smooth leaf cultivars had higher short fiber content and shorter fiber.

CONCLUSION

Results from the experiments conducted in the two seasons demonstrated that a saw-type lint cleaner and its hybrid were more efficient in cleaning with a higher reflectance, although not necessarily a higher classing grade. Short fiber content and fiber length of the saw-type lint cleaner were not significantly different from those of cylinder cleaners, but neps generated by cylinder cleaners were lower, indicating their gentler cleaning potential. Results from the second season study further supported that a cylinder cleaner with narrow gap, flat, square grid bars (three positions) followed by wide gap, flat, square grid bars (three positions) lost less fiber to waste and performed the best overall. This configuration achieved the highest turnout, best expected bale value, low fiber waste, moderate cleaning efficiency, and good reflectance. These experiments indicated that cylinder configuration 1 in both years of the study (2003 and 2004) might be viable gentler alternatives to saw-type lint cleaners. These configurations could potentially yield 2% more in turnout without apparent compromise in classing grade.

These findings apply only to the cotton cultivars used in this study. Further research is needed with cotton of poorer color and higher trash content.

DISCLAIMER

Mention of a trade name, dollar value, propriety product or specific equipment does not constitute a guarantee or warranty by the United States Department of Agriculture and does not imply approval of a product to the exclusion of others that may be suitable.

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