INFLUENCE OF GRID BAR SHAPE ON FIELD CLEANER PERFORMANCE – SCREENING TESTS

J.D. Wanjura
G.A. Holt
USDA ARS Cotton Production and Processing Research Unit
Lubbock, TX
J.A. Carroll
USDA ARS Livestock Issues Research Unit
Lubbock, TX

Abstract

Extractor type cleaners are used on cotton strippers and in the seed cotton cleaning machinery in the ginning process to remove large foreign material such as burrs and sticks. Previous research on the development of extractor type cleaners focused on machine design and operating parameters that maximize foreign matter removal and minimize seed cotton loss. Early research indicated that the shape of the grid bars used in extractors may influence the performance of these machines but no study was conducted to specifically address this issue. Therefore, the objective of this work was to evaluate the influence of grid bar cross sectional geometry on extractor performance with regard to foreign matter removal, seed cotton loss, and fiber quality preservation. Nine experimental grid bar geometries were evaluated against the conventional round grid bar geometry in twenty eight machine arrangements. During each test seed cotton was fed through a John Deere 7445 field cleaner at a constant rate and seed cotton samples were collected to determine the amount of foreign matter removed by the machine and the moisture content during cleaning. Results show that over half of the experimental machine arrangements removed more foreign material from the burr cotton than the conventional configuration. Six of the experimental machine arrangements exhibited both better cleaning performance and reduced seed cotton loss than the conventional configuration. AFIS and HVI fiber analyses indicated that the experimental machine arrangements did not damage the fibers more so than the conventional configuration. Two of the experimental machine arrangements were selected based on the results of the laboratory screening tests for use in field scale evaluations conducted during the 2008 cotton harvest season. The findings of this work confirm previous research in that a compromise must be reached when selecting the appropriate grid bar geometry for use in cotton stripper field cleaners based on foreign matter removal and seed cotton loss.

Introduction

Large foreign material such as burrs and sticks are removed by centrifugal force in extractor type cleaners as seed cotton is pulled across a series of grid bars by a rotating saw cylinder. This cleaning mechanism is called the “sling-off” principal and is used by extractors in the gin as well as those used onboard stripper harvesters (i.e. field cleaners). Many factors influence the performance of extractors including machine design, cotton moisture level, processing rate, adjustments, speed, and condition of the machine, the amount and nature of trash in the cotton, distribution of cotton across the machine, and the cotton variety (Baker et al., 1994). Field cleaners used on stripper harvesters have been shown to improve lint turnout, leaf and color grades of ginned lint, and help reduce the influence of immature fibers and neps on spun yarn (Baker and Brashears, 2000; Kulkarni et al., 2005; Bennett et al., 1995; Brashears, 1991). The use of field cleaners has helped Texas High Plains producers to stay profitable and competitive in the world fiber market against high quality hand harvested cotton from overseas.

Much of the work leading to the development of the field cleaners used today focused on identifying machine design and operating parameters which helped to maximize foreign matter removal and minimize seed cotton loss. Barker et al. (1969) and Smith and Dumas (1982) described work on field cleaners in which saw speed was evaluated and both observed improved foreign matter removal when operating the cleaners at the higher end of the ranges tested. However, ginning of the seed cotton was observed by both Barker et al. (1969) and Smith and Dumas (1982) when operating the cleaners at high speed.

Baker and Laird (1986) evaluated the influence of feeding position and grid spacing on extractor performance. They found that feeding burr cotton onto the saw at a position before the saw rotates through top-center maximizes foreign matter removal and minimizes seed cotton loss. The authors further observed that grid bar arrangements that differed from evenly spaced did not show any marked improvement in seed cotton cleaning. Baker and Laird (1986) found that a wider grid spacing around the saw will improve foreign matter removal but will tend to increase seed cotton loss and vice versa. The trade-off between foreign matter removal and seed cotton loss affected through grid bar arrangement has been observed by several researchers (Kirk et al.,1973, Kirk et al., 1970, and Wilkes et al., 1982).

Wilkes et al. (1982) observed improvement in foreign matter removal by field cleaners used on Allis Chalmers cotton strippers when replacing the angle iron grids located toward the bottom of the reclaiming saw with round grids. They found that acceptable levels of seed cotton loss could be achieved by spacing the round grids wider apart at the top of the saw and narrower toward the bottom of the saw. Brashears (1986) showed that seed cotton loss could be reduced while maintaining foreign matter removal by reversing the spacing recommendations made by Wilkes et al. (1982).

Kirk et al. (1970) developed performance relationships for an extractor type seed cotton cleaner based on five factors: grid bar diameter, grid bar spacing, saw to grid bar clearance, saw speed, and feeding rate. They found that the two most influential factors in predicting foreign matter removal and seed cotton loss were the distance between grid bars and grid bar diameter. This finding suggests that grid bar cross sectional geometry likely has a significant influence on the performance of field cleaners and other extractor type seed cotton cleaners.

The previous work discussed points out the influence of several design and operational parameters on extractor performance and the trade off between maximizing foreign matter removal and minimizing seed cotton loss. However, no study specifically investigates the influence of grid bar cross sectional geometry on field cleaner or extractor performance. Thus, the objective of this work is to investigate the influence of grid bar cross sectional geometry on field cleaner performance with regard to foreign matter removal, seed cotton loss, and fiber quality preservation.

Materials and Methods

Commercial field cleaners on modern stripper harvesters utilize grid bars with circular cross sectional geometry of varying diameter. Typically, the top two grid bars around the primary (upper) saw cylinder are larger in diameter than the remaining grids located around the primary and reclaiming (lower) saw cylinders. Nine experimental grid bar cross sectional geometries were evaluated against a conventional grid bar configuration in a field cleaner from a John Deere model 7445 cotton stripper in the ginning laboratory at the USDA ARS Cotton Production and Processing Research Unit, Lubbock, TX. The conventional grid bar arrangement consisted of the following configurations around the top and bottom saw cylinders:

- Top Saw
  - Four grid bars spaced 8.9 cm (3.5 in) apart (center to center distance)
  - Top two bars - 2.86 cm (1.125 in) diameter and 1.59 cm (0.625 in) saw to grid bar clearance
  - Bottom two bars - 2.22 cm (0.875 in) diameter and 1.27 cm (0.5 in) saw to grid bar clearance
- Bottom Saw
  - Five grid bars each with 2.22 cm (0.875 in) diameter and 1.27 cm (0.5 in) saw to grid bar clearance
  - Upper two bars spaced 8.9 cm (3.5 in) apart (center to center distance)
  - Lower three bars spaced 6.35 cm (2.5 in) apart (center to center distance).

The nine experimental grid bar geometries varied with regard to their approach and relief type (figure 1). The experimental grid bar cross sections evaluated are illustrated in figure 2.

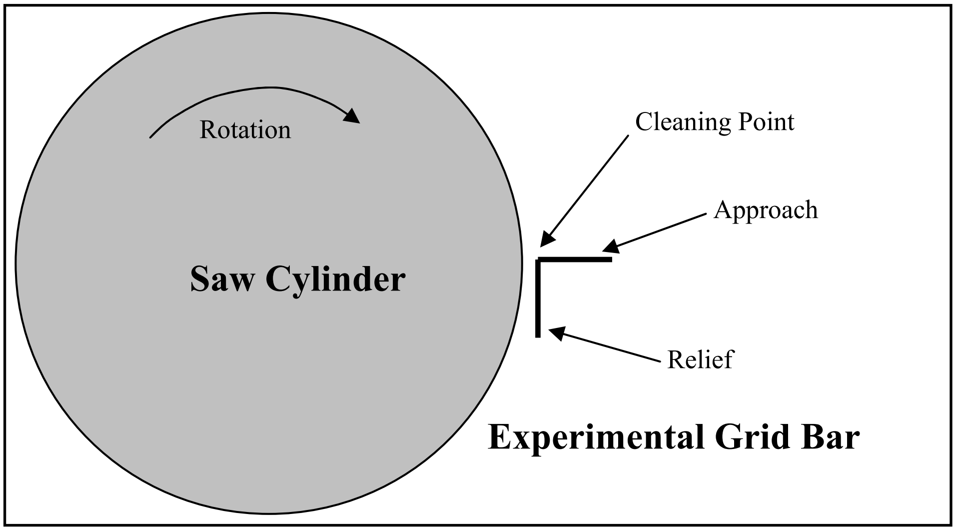

Figure 1. Schematic diagram of experimental grid bar and saw cylinder.

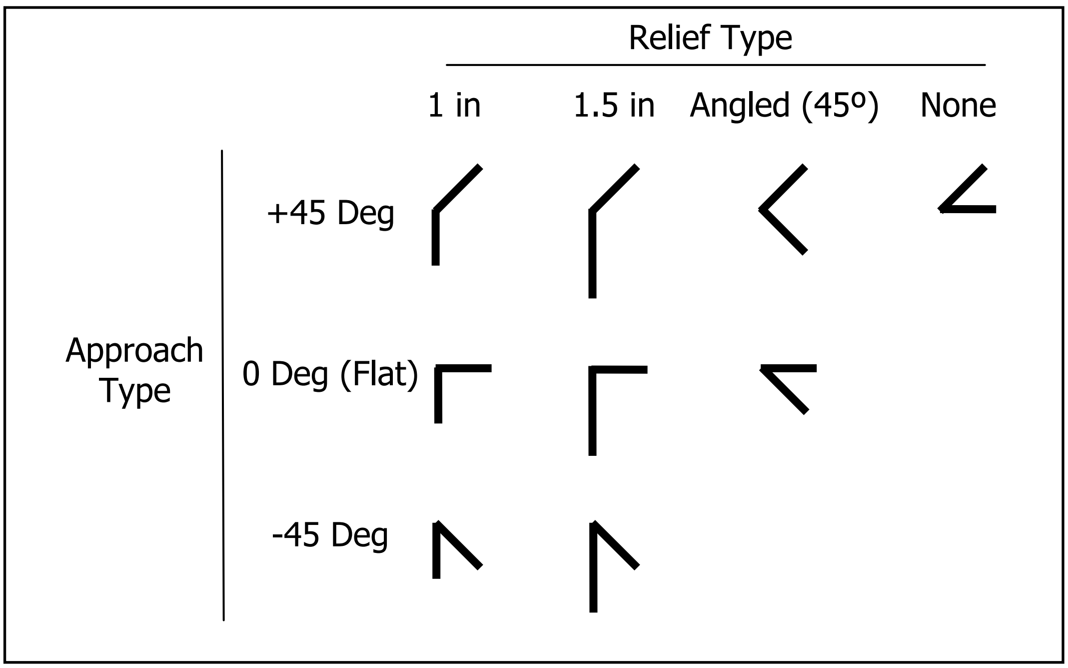

Figure 2. Cross section schematics of the experimental grid bars.

The length of the approach section on each of the experimental bars was 2.54 cm (1 in). The relief sections on the experimental grids were also 2.54 cm (1 in) long in each case except for the three grids that used a 3.81 cm (1.5 in) long relief. The grids were constructed from 14 ga sheet metal and reinforced along the length of the bar for structural rigidity. Grids having a zero degree (flat) approach with no relief, and -45 degree approach with an angled or no relief were not constructed because it was not possible to adequately reinforce the bars against excessive deflection. Spacing between cleaning points for the experimental grid bars were maintained as specified for the conventional configuration. Additionally, the saw to grid bar clearance was maintained as the conventional configuration for the experimental grid bars.

A series of screening tests were conducted on the conventional and experimental grid bars installed in the John Deere 7445 field cleaner under twenty eight machine configurations. The twenty eight machine configurations (table 1) were the treatments tested in a completely randomized experimental design with three replications per treatment. During each test, approximately 22.7 kg (50 lbs) of burr cotton (FiberMax 9063 B2RF, produced during the 2007 crop year) was fed through the machine at 43.6 kg/min (96 lbs/min). The primary and reclaiming saw cylinders were operated at 630 and 550 rpm, respectively. Internal guards installed in the field cleaner reduced the effective length of the machine to 38.1 cm (15 in) resulting in a processing rate of approximately 7.2 bales/hr-m (2.2 bales/hr-ft) of machine width. Burr cotton samples were collected before and after the material was processed through the machine for fractionation analysis (Shepard, 1972). Burr cotton samples were collected after the field cleaner for gravimetric moisture content analysis and the material removed from the burr cotton by the field cleaner was weighed and sampled for hand fractionation analysis.

Table 1. Machine arrangements tested in the John Deere 7445 field cleaner during the grid bar geometry screening tests.

Machine Arrangement	Top Saw Grid Bars	Bottom Saw Grid Bars
1*	Round - Control	Round - Control
2	+45 deg - 1 in Relief	+45 deg - 1 in Relief
3	+45 deg - 1.5 in Relief	+45 deg - 1.5 in Relief
4	+45 deg - Angled Relief	+45 deg - Angled Relief
5	+45 deg - No Relief	+45 deg - No Relief
6	Flat - 1 in Relief	Flat - 1 in Relief
7	Flat - 1.5 in Relief	Flat - 1.5 in Relief
8	Flat - Angled Relief	Flat - Angled Relief
9	-45 deg - 1 in Relief	-45 deg - 1 in Relief
10	-45 deg - 1.5 in Relief	-45 deg - 1.5 in Relief
11	Round - Control	+45 deg - 1 in Relief
12	Round - Control	+45 deg - 1.5 in Relief
13	Round - Control	+45 deg - Angled Relief
14	Round - Control	+45 deg - No Relief
15	Round - Control	Flat - 1 in Relief
16	Round - Control	Flat - 1.5 in Relief
17	Round - Control	Flat - Angled Relief
18	Round - Control	-45 deg - 1 in Relief
19	Round - Control	-45 deg - 1.5 in Relief
20	+45 deg - 1 in Relief	Round - Control
21	+45 deg - 1.5 in Relief	Round - Control
22	+45 deg - Angled Relief	Round - Control
23	+45 deg - No Relief	Round - Control
24	Flat - 1 in Relief	Round - Control
25	Flat - 1.5 in Relief	Round - Control
26	Flat - Angled Relief	Round - Control
27	-45 deg - 1 in Relief	Round - Control
28	-45 deg - 1.5 in Relief	Round - Control

*The “Round-Control” grid bar configuration for both top and bottom saws indicates the conventional grid bar configuration.

Approximately 9 kg (20 lbs) of the seed cotton cleaned during each test was ginned to produce lint for HVI and AFIS fiber analysis. Lint samples were sent to Cotton Incorporated (Cary, NC) for HVI and AFIS fiber analysis. Samples were collected to determine seed cotton moisture content during ginning and seed and lint weights were recorded after ginning.

The machine performance data from the laboratory screening tests in terms of foreign matter removal, seed cotton loss, and fiber quality preservation were used to select two machine configurations for use in field tests conducted during the 2008 harvest season. The field tests consisted of five harvesting treatments (picker, stripper with out field cleaner, stripper with conventional field cleaner, stripper with field cleaner machine arrangement 17, and stripper with field cleaner machine arrangement 7) applied randomly with three replications to each of 4 varieties (FiberMax 9063 B2RF, FiberMax 9180 B2RF, AFD 5065 B2RF, and D&PL 143 B2RF). Foreign matter and burr cotton samples were collected for fractionation and moisture content analysis and large burr cotton samples (200 – 300 lbs.) were collected for ginning tests. Data from the field tests are not complete at this time and will be presented in a future publication.

Machine performance and fiber quality data collected during the laboratory screening tests were analyzed using the General Linear Model procedure in SAS (SAS 9.1, SAS Institute Inc., Cary, NC). Significant differences between the control machine configuration (conventional grid bar configuration, machine arrangement 1 – table 1) and the other machine configurations were detected using Dunnett's two tailed test and a 0.05 level of significance.

Results and Discussion

The fractionation analysis on the burr cotton samples collected before the field cleaner were not significantly different by machine arrangement (table 2). Similarly, the seed cotton moisture content analysis data, shown in table 2, indicated no significant differences by machine arrangement.

Table 2. Fractionation and moisture content analysis results for the burr cotton samples collected before the field cleaner.

	Burrs	Sticks & Stems	Fine Trash	Total Foreign Material	Moisture Content
Mean (%)	24.8	4.6	9.6	39.0	8.4
Std. Dev. (%)	1.23	0.36	0.43	1.20	0.40
Max (%)	27.7	5.5	10.7	41.4	9.2
Min (%)	22.8	3.9	8.8	36.5	7.5
F	1.1	0.59	0.69	0.78	0.87
p > F	0.3676	0.9297	0.8572	0.7587	0.6508

The performance of the field cleaner with regard to foreign matter removal varied by foreign matter fraction and by machine arrangement (table 3). As expected for an extractor type cleaner, the larger foreign matter components (e.g. burrs and sticks and stems) were removed with greater efficiency than the fine trash component. It is unclear if the negative fine trash removal percentages for machine arrangements 4 and 14 are a consequence of variability in the fine trash content in the seed cotton after the field cleaner or that additional fine trash was generated in the field cleaner by the breaking up of larger foreign matter components. Significant differences between machine arrangements were observed for the percent of burrs ($p < 0.001$) and total foreign matter ($p < 0.001$) removed. Dunnett's test indicated significant differences between the control configuration (machine arrangement #1) and machine arrangements 2, 3, and 11 for the burr removal percentage and machine arrangements 2 and 3 for the percent of total foreign matter removed. However, the significant differences observed by Dunnett's test were for machine arrangements exhibiting poorer cleaning performance than the conventional arrangement. Over half of the machine arrangements tested exhibited higher percentages of total foreign matter removed than the control arrangement.

The seed cotton loss data from the fractionation analyses conducted on the samples of the material removed by the field cleaner are shown in table 3. Significant differences in the seed cotton loss data were observed between machine arrangements ($p = 0.002$). However, similar to the total foreign matter removal data, Dunnett's test indicated that machine arrangement 5 was the only configuration significantly different from the control - machine arrangement 1 due to substantially poorer machine performance. Machine arrangement 5 (table 1) used grid bars with a +45 degree approach and no relief around both saw cylinders and had the most open space between grid bars. Thus the relief type for machine arrangement 5 is likely the cause for excessive seed cotton loss.

Table 3. Average percent burrs, sticks and stems, fine trash, and total foreign matter removed by the field cleaner configured with 28 machine arrangements.

Machine Arrangement	Percent Removal: Burrs	Sticks & Stems	Fine Trash	Total Foreign Matter	Seed Cotton Loss (lbs/bale)
1	42.1	25.3	2.9	30.9	3.93
2	1.6*	12.5	5.8	4.2*	0.12
3	4.2*	28.1	1.1	7.4*	0.21
4	39.4	22.1	-1.2	26.9	2.51
5	48.9	31.6	0.5	35.1	22.35*
6	30.5	29.1	2.9	23.4	4.68
7	48.9	32.5	9.6	37.7	0.49
8	54.3	40.4	4.4	40.2	12.67
9	52.0	42.2	4.1	39.0	4.87
10	45.9	15.0	4.1	33.5	15.24
11	13.5*	5.0	1.2	10.0	0.19
12	22.2	17.3	3.8	17.3	0.57
13	51.3	27.6	0.1	36.1	2.05
14	56.4	32.8	-1.7	41.1	11.80
15	45.6	49.9	9.3	36.3	3.86
16	40.5	50.1	9.6	34.1	0.84
17	59.5	37.6	5.9	44.3	8.44
18	43.0	23.4	7.0	32.5	8.35
19	46.1	37.3	7.5	36.3	6.16
20	21.2	35.5	4.1	18.9	1.30
21	24.0	31.2	3.3	19.9	3.19
22	36.4	17.3	5.5	26.3	2.17
23	41.1	33.3	3.0	31.3	1.43
24	42.7	33.8	2.5	31.4	4.43
25	32.4	26.9	5.1	25.0	1.40
26	50.1	27.0	6.8	36.8	5.67
27	44.5	34.8	3.6	33.5	3.31
28	39.1	27.2	4.8	29.2	2.39
Mean	38.5	29.5	4.1	29.2	4.81
Std. Dev.	14.92	10.37	2.98	10.27	5.23
F	5.62	1.23	0.47	4.5	3.09
p > F	<0.001	0.2512	0.982	<0.001	0.002
MSD**	27.56	40.9	18.968	21.179	13.025

*Indicates that the difference between the control (machine arrangement #1) and experimental machine arrangements are different at the 0.05 level of significance according to Dunnett's two-tailed test.
**Minimum Significant Difference of Dunnett's test at $\alpha = 0.05$.

The percent of total foreign matter removed data is presented graphically in figure 3. Comparing approach types for a common relief type and installation location (i.e. top saw, bottom saw, or both) indicates that the -45 degree and flat approach types are more aggressive than the +45 degree approach with regard to total foreign matter removal. Similarly, comparing relief types across a common approach type and installation location indicates that the grid bars tend to remove more total foreign matter as the relief becomes shorter and angles away from the saw effectively increasing the open space between grid bars. This finding was expected as previous research has shown that grid bars spaced wider apart tend to remove more foreign material than those more narrowly spaced. The data presented in figure 3 also indicate that the machine arrangements with experimental grid bars installed on the bottom saw (with conventional grid bars installed around the top saw) tended to improve total foreign matter removal over the conventional configuration more than those configurations where the experimental grids were installed on the top or both saws. This finding indicates that the conventional circular cross section grid bars provide a benefit in terms of total foreign matter removal when installed around the primary cleaning saw (top saw).

The average seed cotton loss (lbs/bale) for each machine arrangement is shown graphically in figure 4. Machine arrangements for which the experimental grid bars were installed around the bottom or both saws tended to lose more seed cotton than the conventional arrangement compared to arrangements with the experimental grid bars installed around the top saw only. Similar to the total foreign matter removal data, comparing relief types across a constant approach type revealed more seed cotton was lost as the relief type resulted in more open space between the grid bars. Also, more seed cotton was lost as the approach type became more aggressive for a given relief type.

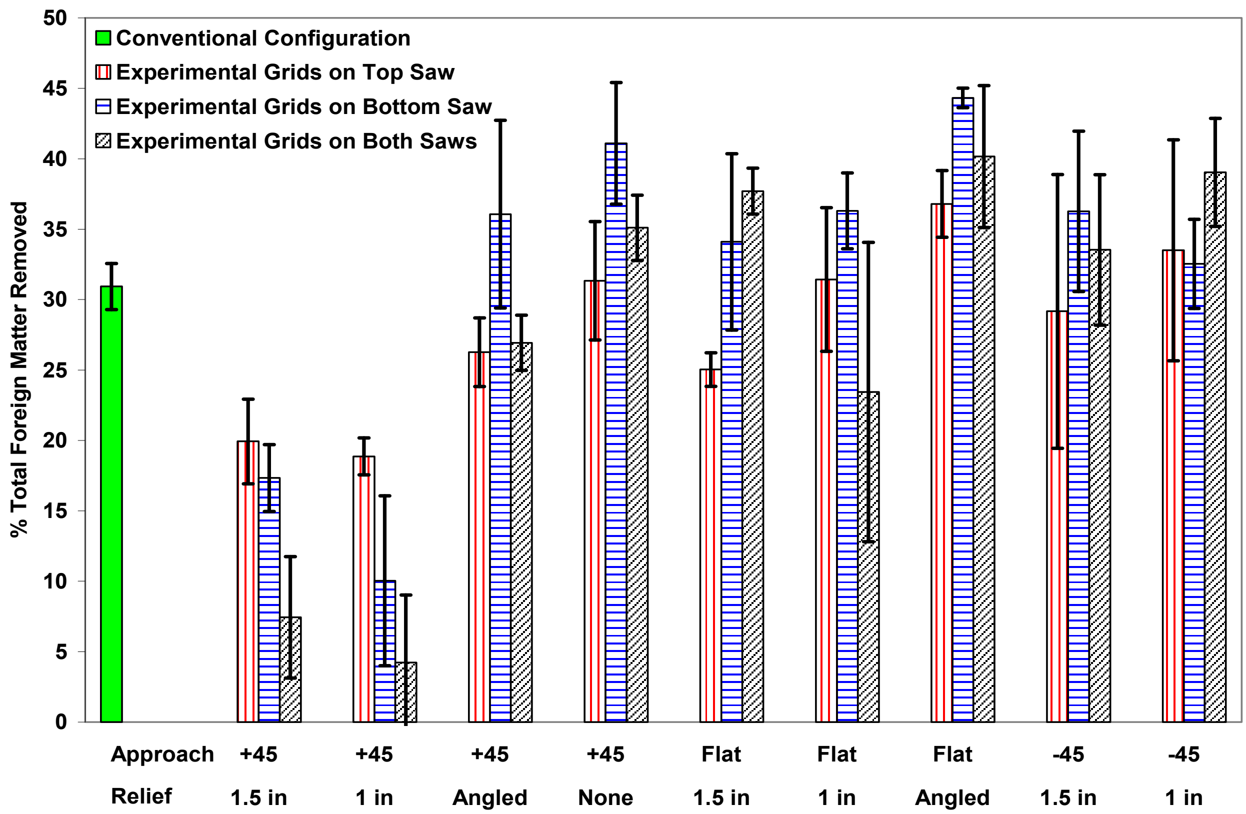

Figure 3. Percent of total foreign matter removed for the 28 machine configurations evaluated in the screening tests. Error bars indicate +/- 1 standard error.

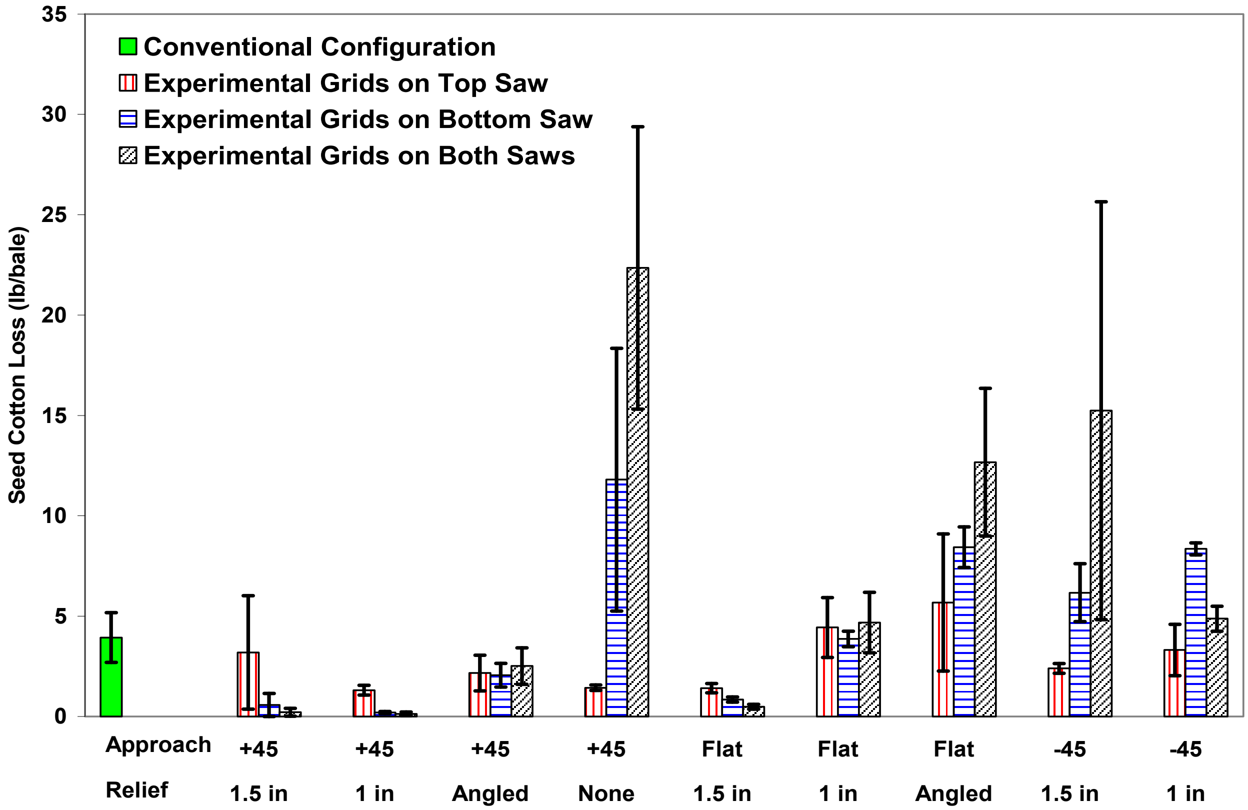

Figure 4. Seed cotton loss (lbs/bale) for the twenty eight machine arrangements tested shown with error bars representing +/- 1 standard error.

The results of HVI and AFIS analyses on the lint ginned from the cleaned seed cotton samples from the screening tests are presented in tables 4 and 5, respectively. The average moisture content of the seed cotton samples collected during ginning was 8.1% and ranged from 7.1 to 9.4%. The average lint to seed ratio measured over all samples was 0.626. No significant differences were observed in any of the HVI fiber properties presented in table 4. Significant differences were detected in the length by weight (L(w), $p = 0.0345$), length by weight CV (L(w) CV, $p = 0.0287$), short fiber content by weight (SFC (w), $p = 0.0362$), length by number (l(n), $p = 0.0175$), and short fiber content by number (SFC(n), $p = 0.0353$) data by machine arrangement according to ANOVA. However, Dunnett's test indicated no significant difference between any of the experimental machine arrangements and the control for the length by weight, length by weight CV, and length by number data. The same test indicated a significant difference between the control and machine arrangement 26 only for the short fiber content by weight and number data.

Table 4. HVI fiber properties measured from the fiber ginned from the seed cotton samples cleaned by the field cleaner during the screening tests.

	MIC	UHM	UI	STR	ELO	Rd	+b	AREA %	SFC%
Mean	4.1	1.24	83.0	31.3	6.0	79.8	8.6	0.5	8.3
Std. Dev.	0.1	0.02	0.7	0.6	0.3	2.0	0.7	0.2	0.3
F	1.659	1.477	0.875	1.367	0.870	0.844	0.836	1.174	1.465
p > F	0.055	0.109	0.641	0.160	0.646	0.679	0.688	0.300	0.114

The HVI and AFIS data presented indicate minor influences on fiber quality by machine arrangement. For the AFIS variables showing significant differences between treatments, the experimental machine arrangements exhibited improved fiber properties over the control arrangement.

Table 5. AFIS fiber analysis results for the fiber ginned from the cleaned seed cotton samples produced by the field cleaner during the screening tests.

	Mean	St. Dev.	F	p > F	MSD*	MA different than Control**	Observed Difference***
Nep size (um)	698.3	15.33	0.89	0.6151	-	-	-
Neps per Gm	314.8	34.69	1.51	0.0976	-	-	-
L(w) [in]	1.1	0.01	1.78	0.0345	0.029	none	-
L(w) CV [%]	34.1	0.91	1.83	0.0287	2.054	none	-
UQL (w) [in]	1.3	0.01	1.30	0.1998	-	-	-
SFC (w) [%]	6.9	0.64	1.77	0.0362	1.442	26 only	-1.467
L(n) [in]	0.9	0.02	1.95	0.0175	0.044	none	-
L(n) CV [%]	52.0	1.71	1.67	0.0535	-	-	-
SFC (n) [%]	24.3	1.74	1.78	0.0353	3.951	26 only	-4.067
L5% (n) [in]	1.5	0.01	1.09	0.3782	-	-	-
Total Cnt/g	523.7	95.76	1.41	0.1367	-	-	-
Trash Size [um]	366.3	16.94	1.48	0.1090	-	-	-
Dust Cnt/g	409.4	76.93	1.36	0.1645	-	-	-
Trash Cnt/g	114.0	22.00	1.40	0.1442	-	-	-
VFM [%]	1.9	0.40	1.56	0.0810	-	-	-
SCN Size (um)	1111.4	107.17	0.93	0.5672	-	-	-
SCN (Cnt/g)	20.2	5.39	0.89	0.6249	-	-	-
Fine [mTex]	164.6	4.82	1.26	0.2258	-	-	-
IFC [%]	5.0	0.76	1.46	0.1170	-	-	-
Mat Ratio	0.9	0.03	1.22	0.2636	-	-	-

*MSD = minimum significant difference according to Dunnett's test ($\alpha = 0.05$).
**Indicates machine arrangements (table 1) that were found to be significantly different than the control arrangement (machine arrangement 1, table 1) by Dunnett's test.
***Observed Difference = Experimental Machine Arrangement – Control Arrangement

The screening tests were conducted in an effort to identify machine arrangements that exhibit improved performance over the conventional machine arrangement in terms of foreign matter removal, seed cotton loss, and fiber quality preservation. Six of the experimental machine arrangements (machine arrangements 7, 13, 15, 16, 23, and 27, table 1) exhibited improved total foreign matter removal and reduced seed cotton loss compared to the conventional configuration (machine arrangement 1, table 1). Sixteen of the experimental machine arrangements produced higher total foreign matter removal percentages than the conventional configuration with the best (machine arrangement 17, table 1) exhibiting a 13.4% increase in total foreign matter removal. Given these findings, machine arrangements 7 and 17 were selected for use in the field tests conducted during the 2008 harvesting season. Machine arrangement 7 was selected because it exhibited the optimum balance between improved total foreign matter removal and reduced seed cotton loss compared to the conventional configuration. Machine arrangement 17 was selected because it exhibited the largest total foreign matter removal percentage.

Conclusions

Akin to findings from previous research on optimizing extractor performance, the total foreign matter removal and seed cotton loss data observed in this study indicate that a compromise must be reached in selecting the appropriate grid bar geometry for use in stripper field cleaners. In general, more aggressive geometries with more open space between grid bars tended to remove more foreign material but they also tended to remove more seed cotton. However, although not statistically significant, several of the grid bar geometries tested exhibited improved foreign matter removal and reduced seed cotton loss compared to the conventional circular grid bars (machine arrangements 7, 13, 15, 16, 23, and 27). HVI fiber analyses indicated no differences by machine arrangement. AFIS fiber analyses indicated significant differences for length measurements by weight and number as well as for short fiber content by length and number between machine arrangements. The observed differences in the significant AFIS parameters indicated that the experimental machine arrangements tended to produce improved fiber length properties than the control machine arrangement.

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Disclaimer

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