INITIAL EVALUATION OF A METHOD TO IMPROVE CLEANING OF SEED COTTON, LINT, AND LINT CLEANER WASTE

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Abstract

Tests were performed to clean seed cotton, lint, and lint cleaner waste with cylinder cleaners operated with different types of grid bars and cylinder speeds. Results showed that more aggressive, square grid bars performed better than conventional round grid bars in cleaning all three types of material, but allowed more fiber to escape with the trash when cleaning seed cotton. Increasing cylinder speeds from 480 to 1100 rpm also increased the cleaning performance of the cylinder cleaners. Of the five types of grid bars evaluated in this study, the normal grid bars (3/8 in. round bars with 3/8 in. gaps between the bars) remained the preferred type for seed cotton cleaning. The cylinder cleaner with sharp, square grid bars operated at 1100 rpm cylinder speed cleaned lint better than the other treatments and was 80% as effective as a conventional saw-type lint cleaner. Also, a cylinder cleaner equipped with flat, square grid bars and operated at 1100 rpm appeared to be the best solution to balancing lint cleaner waste cleaning and fiber wastage. These modifications provide additional cleaning and may cause less fiber damage.

Introduction

Conventional cylinder cleaners are used in the gin's seed cotton cleaning system. Cylinder cleaners are typically equipped with spiked cleaning cylinders and concave grid sections constructed of 3/8 in.-diameter rods spaced approximately 3/8 in. apart. The spiked cylinders are normally operated at about 480 rpm. These machines may also be used to clean lint cleaner waste at some gins. Cylinder cleaners are not typically used for cleaning of ginned lint from Upland cotton varieties; instead, one or two saw-type lint cleaners is the industry standard.

Research into increasing the cylinder speed of cylinder cleaners has resulted in contradictory findings. Cocke (1972) found that operating cylinder cleaners over a range of cylinder speeds from 350 to 650 rpm had no significant effect on seed cotton cleaning performance or cotton quality. On the other hand, Read (1972) reported that increasing cylinder speed from 425 to 550 rpm increased the seed cotton cleaning efficiency significantly (17%).

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Saw-type lint cleaners, while effective at combing fibers and extracting trash, generally increase the nep (entanglements of cotton fibers) count and short fiber content (fiber less than 0.5 in. long) of ginned fiber. Mangialardi (1992) researched cleaning lint with different types of seed cotton cleaners common in the modern gin: six-cylinder cleaner, stick machine, Trashmaster, impact cleaner, and extractor feeder. His research revealed that, although the seed cotton cleaners had lower lint cleaning efficiencies than the saw-type cleaners, the seed cotton cleaners tended to be less aggressive causing less fiber damage. He concluded that seed cotton cleaners may be used to supplement or replace one of the two saw-type cleaners in the lint cleaning process.

Little work has been performed to determine the effects of different grid bar types (round, square, perforated metal) in conjunction with cylinder speeds for cleaning seed cotton, lint fiber, and lint cleaner waste. Further research in this area should lead to alternatives for better cleaning of seed cotton and lint cleaner waste, and less aggressive trash extraction from lint. The purpose of this research was to study the effects of different cylinder cleaner grid bars types and cylinder speeds on cleaning of seed cotton, lint, and lint cleaner waste.

Materials and Procedures

Ten different grid bar × cylinder speed combinations were used with a 1-ft wide six-cylinder cleaner in the US Cotton Ginning Laboratory's small-scale research gin (Microgin) which processes cotton at about 0.8 bale/hr. The grid bar types were round (fig. 1), flat, square with the flat side of the bars exposed to the cotton flow (fig. 2), sharp, square with the point or corner of the bar exposed to the cotton flow (fig. 3), and perforated metal with 1/4 in. holes on 3/8 in. centers (fig. 4). Cylinder speeds were 480 and 1100 rpm. A treatment identification was assigned to each combination to indicate the grid bar type, gap (or hole) size, and cylinder speed (table 1) in the following format:

Grid bar type(*gap size-cylinder speed*)

In some cases, additional machines were used in series with the six-cylinder cleaners. These were indicated by a "+" sign and a designation for the particular machine (i.e. LC = saw-type lint cleaner, SM = stick machine, and TM = Trashmaster cleaner).

Seed Cotton Cleaning

The seed cotton cleaning test design included 4 varieties × 7 cleaning treatments × 3 replications (84 test lots). Seed cotton varieties were Sure Grow 125 and Delta and Pine Land (DPL) 5415, DPL 5409, and DPL 33Bt. Twenty-one lots averaging 40 lb each were prepared from each cotton variety and allowed to condition overnight in mesh sacks at about 50% relative humidity (Rh) and 75° F. All experimental lots were processed in the Microgin. The cotton processing sequence included the feed control, one tower dryer, and one of seven cleaning treatments. The seven seed cotton cleaning treatments were Normal(3/8,480)+SM+TM, Normal(3/8,480), Flat(3/8,480), Sharp(3/8,480), Round(1/8,480), Round(1/8,1100), and Perforated(1/4,480).

Seed cotton processing rates were equivalent to approximately 0.84 bales per hr per ft of width; based on 1500 lb of seed cotton per bale. After each downtime to change grid bars or pulleys, a warm-up was performed by running 20 lb of seed cotton through the system. Dryer temperature was set to maintain seed cotton moisture at 6%.

During processing of each lot of seed cotton, samples were taken for moisture and foreign matter content determination. Foreign matter and moisture content were determined by pneumatic fractionation and standard oven drying procedures (Shepherd, 1972), respectively. Trash removed during each cleaning treatment and cleaned seed cotton were collected and weighed. Also, content analysis by fractionation was performed on the trash samples. These data were statistically analyzed by analysis of variance procedures (SAS, 1996) to detect differences in measured variables among seed cotton cleaning treatments.

Lint Cleaning

For lint cleaning, two varieties of cotton were used in the experiment: DPL 5415 and Sure Grow 125. Twenty-one lots of seed cotton averaging 35 lb each were prepared from each variety and allowed to condition in mesh sacks overnight at approximately 50% Rh and 75° F.

The 42 lots of seed cotton (2 varieties × 7 cleaning treatments × 3 replications) were randomly processed in the Microgin through the following ginning sequence: feed control, one tower dryer, six cylinder-cleaner, stick machine, Trashmaster, extractor/feeder, and gin stand (no lint cleaning). All lint for each lot (averaging 11 lb) was collected in separate bags and again allowed to condition. Three bags from each cotton variety were randomly assigned to each of seven lint cleaning treatments: LC, Normal(3/8,480), Normal(3/8,1100), Flat(3/8,480), Flat(3/8,1100), Sharp(3/8,480), and Sharp(3/8,1100). Lint was fed to the cylinder cleaners via the feed control, which broke-up and metered the lint at a processing rate of about 3.6 lb per min per ft of machine width. Lint fed to the saw-type lint cleaner was laid out on a 15-in. wide × 72-in. long chute and fed gradually by hand into the lint duct behind the gin stand to maintain a consistent batt on the condenser above the lint cleaner. After each downtime to change grid bars or pulleys, a warm-up was performed by running 20 lb of seed cotton through the system.

During processing of each lot, lint samples were taken for moisture and foreign matter content determination. Foreign matter content was determined using the Shirley Analyzer (Shepherd, 1972). Trash removed during each cleaning treatment and cleaned lint were collected and weighed. Also, relative lint wastage (amount of fiber in the trash collected) among lint cleaning treatments was determined by side-by-side visual observations of the trash collected.

Lint Cleaner Waste Cleaning

Three different types of lint cleaner waste was used for this experiment: lint cleaner waste from lint cleaned with one saw-type lint cleaner, lint cleaner waste from lint cleaned with two saw-type lint cleaners, and lint cleaner waste from lint cleaned with one saw-type cleaner mixed with that from lint cleaned with two saw-type cleaners. Eleven lots ranging from 10 to 20 lb were prepared from each type of lint cleaner waste and placed in bags to condition overnight in the Microgin at 50% Rh and 75°F.

One bag of lint cleaner waste from each type was randomly selected, fed via the feed control to a six cylinder-cleaner with one of 11 different combinations of grid bars and cylinder speeds. The 11 cleaning treatment combinations were Normal(3/8,480)+LC, Normal(3/8,480), Normal(3/8,1100), Flat(3/8,480), Flat(3/8,1100), Sharp(3/8,480), Sharp(3/8,1100) Round(1/8,480), Round(1/8,1100), Perforated(1/4,480), and Perforated(1/4,1100). Lint cleaner waste was fed by hand in a similar manner as previously described for lint to the saw-type lint cleaner for the Normal(3/8,480)+LC treatment. Processing rates were approximately 8.2 lb per min per ft of machine width. After each downtime to change grid bars or pulleys, a warm-up was performed by running 20 lb of seed cotton through the system.

Samples of the lint cleaner waste were taken from each lot for moisture and foreign matter content analysis. Cleaned lint cleaner waste and trash removed were collected and weighed. In order to obtain samples suitable for use with the Shirley Analyzer, all lint cleaner waste foreign matter samples were first processed through a single saw-type lint cleaner for pre-cleaning. The foreign matter content (total waste basis) of the samples was calculated as the difference in the initial lint cleaner waste foreign matter sample weight and weight of lint retrieved by the Shirley Analyzer converted to a percentage of the initial foreign matter sample weight. Cleaning efficiency (total weight basis) was calculated as the difference in foreign matter content between the uncleaned and cleaned lint cleaner waste weights converted to a percentage of the uncleaned foreign matter content. Also, relative fiber wastage (amount of fiber in the trash collected) among lint cleaner waste cleaning treatments was determined by side-by-side visual observations of the trash collected.

Results and Discussion

Seed Cotton Cleaning

Average weights of trash collected from cleaning ranged from 1.52 lb for treatment Normal(3/8,480)+SM+TM to 0.34 lb for Round(1/8,480) and were significantly different among seed cotton cleaning treatments (table 2). Analysis of the percentage of trash collected (100 × trash weight / pre-cleaned weight) during processing by each cleaning combination revealed significant differences among the treatments. The highest percentage of trash collected occurred for three machine treatment Normal(3/8,480)+SM+TM (normal cleaning with cylinder cleaner, stick machine, and Trashmaster). Treatments Sharp(3/8,480) and Flat(3/8,480) (square grid bars) had significantly lower percentage of trash collected than Normal(3/8,480)+SM+TM, but higher than Normal(3/8,480) (normal cylinder cleaner). Round(1/8,480), Round(1/8,1100), and Perforated(1/4,480) with only 1/8 in. spaces or 1/4 in. holes resulted in the lowest percent material removed and not significantly different from each other.

Fractionation analyses (table 3) showed that Normal(3/8,480)+SM+TM resulted in significantly lower levels of total trash and two trash constituents (hulls and small leaf) than all other treatments. For the single machine seed cotton cleaning treatments, Sharp(3/8,480) with the more aggressive exposed tips of square grid bars had significantly lower levels of total trash in the cleaned seed cotton. Round(1/8,480) with only 1/8 in. spaces and slower cylinder speed left the most total trash in the seed cotton. Analyses of the constituents of the total trash revealed no significant differences among treatments for bolls. Differences among single machine treatments were slight for hulls, sticks, grass, seed, and miscellaneous material. Levels of motes in the cleaned seed cotton were greatest for the treatments with only 1/8 in. bar spaces and perforated metal grids (treatments Round(1/8,480), Round(1/8,1100), and Perforated(1/4,480)), while treatments with the square grid bars (Sharp(3/8,480) and Flat(3/8,480)) had significantly lower levels. Treatments Sharp(3/8,480) and Flat(3/8,480) removed more small leaf than the other treatments, while Round(1/8,480) and Round(1/8,1100) removed the least, and Perforated(1/4,480) removed similar amounts to Normal(3/8,480) (normal cylinder cleaner). Pin trash levels in the cleaned seed cotton among Sharp(3/8,480), Perforated(1/4,480), and Flat(3/8,480) were significantly lower than all other single machine treatments and not different than the normal multi-machine cleaning treatment, Normal(3/8,480)+SM+TM. No significant differences were found in the fractionation analysis between cylinder speeds, treatments Round(1/8,480) and Round(1/8,1100), except for miscellaneous material.

Content analysis of the trash collected during each treatment revealed very significant differences in seed cotton wastage (amount of seed cotton in the trash) among treatments (table 2). Seed cotton wastage values for the normal cleaning sequence (Normal(3/8,480)+SM+TM) and the normal cylinder cleaner (Normal(3/8,480)) were 1.32 and 1.23%, respectively, and not significantly different. Square grid bars wasted considerably more seed cotton. Sharp(3/8,480) cotton wastage was 9.2% (more than 7 times Normal(3/8,480)+SM+TM) and Flat(3/8,480) was 2.4% (almost 2 time Normal(3/8,480)+SM+TM). The treatments with narrow spaced grid bars or perforated metal (Round(1/8,480), Round(1/8,1100), and Perforated(1/4,480)) all had cotton wastage values near 0%.

These results indicated that the more aggressive square grid bars (sharp and flat) cleaned seed cotton better that the normal grid bars typically used in cotton gins. However, the square grid bars tended to waste more cotton. Decreasing the gap size slightly between the square bars may decrease the cotton wastage, while maintaining a higher cleaning efficiency than normal grid bars, especially for the flat square bars, which is planned for further research.

Lint Cleaning

Analysis of the weight of trash collected during each lint cleaning procedure showed that percent trash collected (trash weight / pre-cleaned weight × 100%) ranged from 0.41 to 2.24% (table 4). As expected, LC had significantly higher percent trash collected. The square grid bar treatments, Flat(3/8,1100) and Sharp(3/8,1100), had the highest percentage of trash collected of the cylinder cleaner treatments. Percentage trash collected for the high cylinder speed (1100 rpm) treatments, Normal(3/8,1100), Flat(3/8,1100), and Sharp(3/8,1100), was always significantly higher than their corresponding low cylinder speed (480 rpm) treatments, Normal(3/8,480), Flat(3/8,480), and Sharp(3/8,480). Foreign matter analysis showed that lint cleaning efficiency (based on total waste) for LC was significantly higher than all other treatments, while Sharp(3/8,1100) and Sharp(3/8,480) had the highest efficiency of the cylinder cleaner treatments. High cylinder speed treatments always had higher lint cleaning efficiencies than low speed treatments, but only Sharp(3/8,1100) was significantly different from its low cylinder speed counterpart, Sharp(3/8,480).

Side-by-side visual observations of the trash collected revealed that the normal grid bars (3/8 in. bars with 3/8 in. gap between bars) and the flat, square grid bars (1/4 in. bars with 3/8 in. gap between bars) wasted similar amounts of lint and less than the other types of grid bars. The sharp, square grid bars (1/4 in. bars with 3/8 in. gap between bars) appeared to waste more lint than the normal and flat, square grid bars, but clearly less than the saw-type lint cleaner. Little difference was detected during the visual observations in the amount of lint wasted between treatments due to cylinder speeds.

These results indicated that the sharp, square grid bars, operated with 1100 rpm cylinder speed, cleaned the lint better than the other grid bar-cylinder speed configurations and was only about 20% less efficient than the saw-type lint cleaner. Visual observations showed that the sharp, square grid bars wasted more lint fiber than the other treatments, but considerably less than the saw-type lint cleaner.

Lint Cleaner Waste Cleaning

Analysis of weights of cleaned lint cleaner waste and trash collected for each treatment revealed significant differences in percentage trash collected (100 × trash weight / initial weight of lint cleaner waste) among treatments (table 5). As expected, Normal(3/8,480)+LC had a significantly higher value for trash percentage (53.2%) than the other treatments due to the added processing by the saw-type lint cleaner. Considering only the single machine treatments without Normal(3/8,480)+LC, analyses showed that the treatments with square grid bars and 1100 rpm cylinder speed (Sharp(3/8,1100) and Flat(3/8,1100)) removed significantly more trash than the other treatments. No significant differences were detected in percent trash collected among Sharp(3/8,480), Normal(3/8,1100), Flat(3/8,480), and Perforated(1/4,1100). Values for Normal(3/8,480) and Perforated(1/4,480) were not different and were significantly higher than Round(1/8,480) and Round(1/8,1100), which were also not different from each other. Increasing the cylinder speed from 480 to 1100 rpm significantly increased the percent trash collected for all treatments, except the round grid bar with 1/8 in. gap space treatments.

Foreign matter content analysis based on the Shirley Analyzer, revealed significant differences among lint cleaner waste cleaning treatments (table 5). Cleaning efficiency of the Normal(3/8,480)+LC was the highest; mainly due to the addition of the saw-type lint cleaner. Flat(3/8,1100) cleaning efficiency was significantly higher than Sharp(3/8,1100) and both were significantly higher than all other single machine treatments. Flat(3/8,480), Sharp(3/8,480), and Perforated(1/4,1100) cleaning efficiencies were not significantly different than the Normal(3/8,1100). Similarly, Sharp(3/8,480), Perforated(1/4,1100), and Perforated(1/4,480) treatments cleaned lint cleaner waste about the same as Normal(3/8,480). No significant difference was found between Round(1/8,1100) and Round(1/8,480) cleaning efficiencies. Lint cleaner waste cleaning efficiency always increased when cylinder speed was increased from 480 to 1100 rpm; significantly for the square grid bar treatments (flat and sharp).

Relative differences among lint cleaner waste cleaning treatments were observed (side-by-side visual comparison) in the level of wasted fiber (true motes and lint fiber) in the trash collected. Trash collected from the Normal(3/8,480)+LC treatment contained the most fiber. The Sharp(3/8,1100) trash contained similar amounts of true motes, but less lint fiber than Normal(3/8,480)+LC trash. Sharp(3/8,480), Normal(3/8,1100), Flat(3/8, 1100), and Flat(3/8,480) trash contained little lint fiber and true motes. Only small amounts of pills (small diameter motes) were observed in the trash from Normal(3/8,480) and Perforated(1/4,1100). Almost no fiber or motes were present in the Perforated(1/4,480), Round(1/8,1100), and Round(1/8,480), mainly due to the relatively small hole or gap sizes.

These results showed that the more aggressive square grid bars, especially the flat bars, operated with 1100 rpm cylinder speed, cleaned lint cleaner waste better than the other grid bar-cylinder speed combinations. The flat, square grid bars wasted less fiber than the sharp, square and much less than the normal grid bars plus a saw-type lint cleaner. Decreasing the gap size slightly between these flat square bars may decrease the cotton wastage, while maintaining a higher cleaning efficiency than normal grid bars, which is slated for future research.

Conclusions

Cylinder cleaners equipped with square grid bars, oriented either flat or sharp with point exposed to the cotton flow, and 3/8 in. spaces between the grid bars cleaned seed cotton better than a normal cylinder cleaner with round grid bars and similar spacing. Grid bar sections with narrow spaces (1/4 in. holes or 1/8 in. gaps) were significantly less efficient than normal grids based on weight of trash removed. However, square grid sections wasted considerably more seed cotton than normal grid bar sections and grid bar sections with narrow gaps wasted almost no seed cotton. Thus, the normal grid bars, 3/8 in. round bars with 3/8 in. gaps between the bars, remained the preferred type for seed cotton cleaning. Further research with increased cylinder speed and slightly decreased spaces between the grid bar to increase cleaning efficiency and reduce cotton wastage needs to be explored.

Lint cleaning efficiency based on total foreign matter analysis showed that the sharp, square grid bars operated with 1100 rpm cylinder speed cleaned lint significantly better than all other grid bar-cylinder speed combinations and was only about 20% less efficient than the saw-type lint cleaner. The percent trash removed from lint by cylinder cleaners with 1100 rpm cylinder speed was always higher than cylinder cleaners with the same grid bars and 480 rpm speed. The sharp, square grid bars (1/4 in. bars with 3/8 in. gap between bars) wasted more lint than the normal and flat, square grid bars, but clearly less than the saw-type lint cleaner. Thus, the cylinder cleaner with sharp, square grid bars operated at 1100 rpm cylinder speed may perform well as a supplemental lint cleaner or replacement for the first stage of saw-type lint cleaning. Further research will concentrate on the performance of this type of cleaner as a less aggressive alternative for lint cleaning.

Cylinder cleaners equipped with flat, square grid bars and operated at 1100 rpm cylinder speed removed significantly more trash from lint cleaner waste than other treatments. Also, increasing cylinder speed always significantly increased trash removal, except in the case of narrow grid bar spacing (1/8 in.). Cleaning efficiency always increased when cylinder speed was increased from 480 to 1100 rpm;

significantly for the square grid bar treatments. The flat, square grid bars wasted about as much fiber as the normal grid bars, less fiber than the sharp, square, and much less than the normal grid bars plus a saw-type lint cleaner. Thus, a cylinder cleaner equipped with the flat, square grid bars and operated at 1100 rpm appeared to be the best solution to balancing cleaning and fiber wastage. Research investigating narrower spacing between these flat, square grid bars to reduce fiber waste, while maintaining cleaning efficiency, will continue.

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References

Cocke, J.B. 1972. Effect of processing rate and speeds of cylinder-type cleaners on ginning performance and cotton quality. ARS 42-199, USDA, Washington, D.C.

Mangialardi, G.J. 1992. Preliminary search for new lint cleaning systems. In *Proc 1992 Beltwide Cotton Conference*, 1413-1416. Nashville, TN, 6-10 January.

Read, K.H. 1972. Cylinder cleaner speed influences cleaner efficiency. *The Cotton Gin and Oil Mill Press*, Nov. 25, 1972.

Shepherd, J.V. 1972. Standard procedures for foreign matter and moisture analytical tests used in cotton ginning research. Agricultural Handbook No. 422, USDA, Washington, D.C.

SAS User's Guide: Statistics Ver. 5, pp. 433-506. Cary, N.C.: SAS Institute, Inc.

Table 1. Cylinder cleaner treatment identifications and descriptions of grid bar-cylinder speed combinations

Treatment ID*	Grid bars			Cylinder speed (rpm)
	Type	Gap size (in.)	Dimension (in.)	
Normal (3/8,480)	Round	3/8	3/8	480
Normal (3/8,1100)	Round	3/8	3/8	1100
Flat (3/8,480)	Flat, square	3/8	1/4	480
Flat (3/8,1100)	Flat, square	3/8	1/4	1100
Sharp (3/8,480)	Sharp, square	3/8	1/4	480
Sharp (3/8,1100)	Sharp, square	3/8	1/4	1100
Round (1/8,480)	Round	1/8	1/4	480
Round (1/8,1100)	Round	1/8	1/4	1100
Perforated (1/4,1100)	Perforated metal	1/4 holes	3/8 centers	1100
Perforated (1/4,480)	Perforated metal	1/4 holes	3/8 centers	480

* Treatment ID indicates *grid bar type(gap size, cylinder speed).*

Table 2. Weight data and calculated percentages for seed cotton cleaning instruments

Treatment ID*	Weight data†‡				
	Seed cotton				
	Pre-cleaned (lb)	Post-cleaned (lb)	Trash collected (lb)	Trash collected (%)	Cotton Wastage§ (%)
Normal (3/8,480) +SM+TM	39.06 a	36.94 a	1.52 a	3.09 a	1.32 c
Sharp (3/8,480)	39.61 a	38.19 a	0.81 b	2.05 b	9.17 a
Flat (3/8,480)	39.85 a	38.44 a	0.73 b	1.83 c	2.54 b
Normal (3/8,480)	39.58 a	38.35 a	0.59 c	1.48 d	1.23 c
Round (1/8,1100)	37.08 a	36.07 a	0.38 d	1.02 e	0.03 d
Perforated (1/4,480)	40.26 a	39.24 a	0.44 d	1.10 e	0.001 d
Round (1/8,480)	39.64 a	38.72 a	0.34 d	0.84 e	0.00 d

* Treatment ID indicates *grid bar type(gap size, cylinder speed).*
† Each value is the average of three replications and four varieties.
‡ Values within same column followed by the same letter are not significantly different (P = 0.05).
§ Cotton wastage = 100 x weight of cotton in trash / total weight of trash.

Table 3. Cleaned seed cotton fractionation data (%) for seed cotton cleaning treatments

	Treatment ID*,†,‡,§						
Fract. data	Round (1/8,480)	Round (1/8,1100)	Perforated (1/4,480)	Normal (3/8,480)	Flat (3/8,480)	Sharp (3/8,480)	Normal (3/8,480) +SM+TM
Seed cotton	94.86 d	94.97 cd	95.02 cd	95.23 cd	95.38 c	95.94 b	97.16 a
Total trash	5.14 a	5.03 ab	4.98 ab	4.77 ab	4.62 b	4.06 c	2.84 d
Bolls	0.005 a	0.00 a	0.019 a	0.014 a	0.020 a	0.012 a	0.007 a
Hulls	1.76 abc	1.66 bc	1.92 ab	1.84 abc	1.97 a	1.60 c	0.55 d
Sticks	0.40 ab	0.37 ab	0.38 ab	0.41 a	0.40 ab	0.28 b	0.28 ab
Grass	0.037 ab	0.016 b	0.049 a	0.034 ab	0.026 ab	0.027 ab	0.029 ab
Seed	0.0004 b	0.0005 b	0.0002 b	0.003 a	0.0002 b	0.0005 b	0.00 b
Misc.	0.05 a	0.005 c	0.001 c	0.003 c	0.01 bc	0.0002 c	0.04 ab
Motes	1.92 a	1.92 a	1.87 ab	1.75 bc	1.71 cd	1.58 de	1.58 e
Small leaf	0.93 a	0.94 a	0.69 b	0.65 b	0.45 d	0.52 c	0.37 e
Pin trash	0.069 a	0.080 a	0.038 c	0.054 b	0.031 c	0.035 c	0.034 c

* Treatment ID indicates *grid bar type(gap size, cylinder speed).*
† Each value is the average of three replications and four varieties and five fractionation observations.
‡ Values are adjusted means (pre-cleaned fractionation data and moisture content as covariants) from SAS procedures.
§ Values within rows followed by the same letter are not significantly different (P = 0.05).

Table 4. Trash collected, foreign matter content, and lint cleaning efficiency for lint cleaning experiment

		Foreign matter†		Lint cleaning efficiency†	
Treatment ID*	Trash collected† (%)	Visible waste basis (%)	Total waste basis (%)	Visible waste basis (%)	Total waste basis (%)
LC	2.24 a	1.05 e	1.35 e	56.8 a	52.1 a
Sharp(3/8,1100)	1.27 b	1.63 d	1.85 d	29.7 b	41.6 b
Sharp(3/8,480)	0.52 de	1.87 ab	2.13 bc	17.8 de	31.3 c
Flat(3/8,1100)	0.85 c	1.75 c	2.02 c	26.7 bc	24.4 d
Normal(3/8,1100)	0.59 d	1.81 bc	2.22 ab	22.4 cd	23.4 d
Flat(3/8,480)	0.46 de	1.82 bc	2.25 ab	24.1 bc	23.0 d
Normal(3/8,480)	0.41 e	1.94 a	2.30 a	15.1 e	21.1 d

* Treatment ID indicates *grid bar type(gap size, cylinder speed).*
† Each value is the average of three replications and two varieties (and 3 foreign matter observations for foreign matter and efficiency).
‡ Values within columns followed by the same letter are not significantly different (P = 0.05).

Table 5. Foreign matter content and cleaning efficiency for lint cleaner waste cleaning experiment

		Foreign matter†	Cleaning efficiency†
Treatment ID*	Trash collected† (%)	Total waste basis (%)	Total waste basis (%)
Normal(3/8,480)+LC	53.2 a	14.1 f	79.2 a
Flat(3/8,1100)	42.6 b	40.3 e	39.8 b
Sharp(3/8,1100)	43.7 b	44.5 de	32.7 c
Flat(3/8,480)	35.1 c	49.2 cd	27.1 d
Normal(3/8,1100)	34.1 c	51.9 c	24.3 de
Sharp(3/8,480)	34.6 c	51.4 c	22.4 def
Perforated(1/4,1100)	32.9 c	51.9 c	22.3 def
Normal(3/8,480)	27.1 d	50.5 cd	21.5 ef
Perforated(1/4,480)	26.9 d	53.7 bc	18.6 f
Round(1/8,1100)	18.6 e	61.0 a	11.5 g
Round(1/8,480)	16.4 e	59.7 ab	11.3 g

* Treatment ID indicates *grid bar type(gap size, cylinder speed).*
† Each value is the average of three replications and four varieties (and 3 foreign matter observations for foreign matter and efficiency).
‡ Values within columns followed by the same letter are not significantly different (P = 0.05).

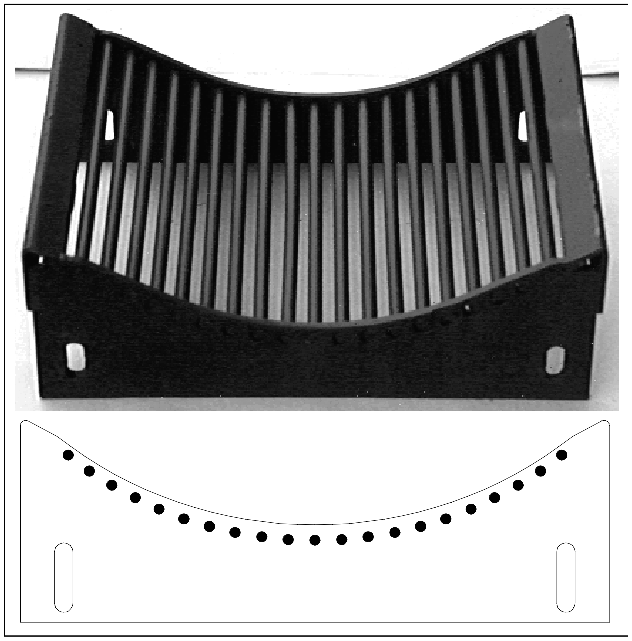

Figure 1-Round grid bar types.

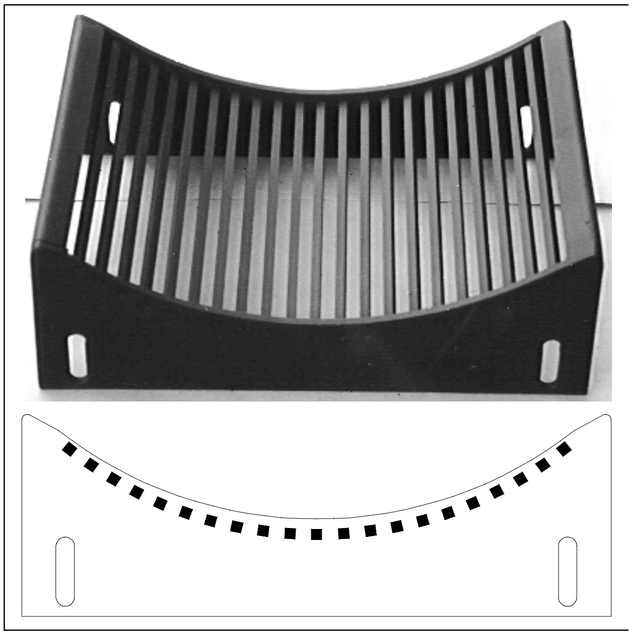

Figure 2-Flat, square grid bar types.

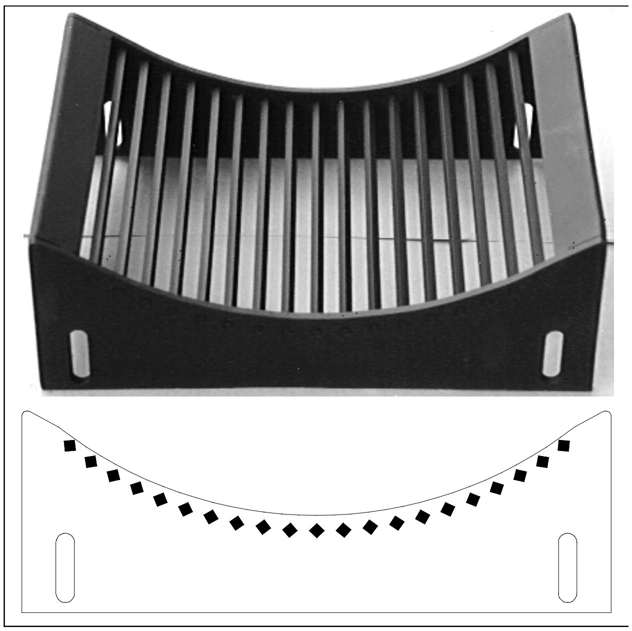

Figure 3-Sharp, square grid bar types.

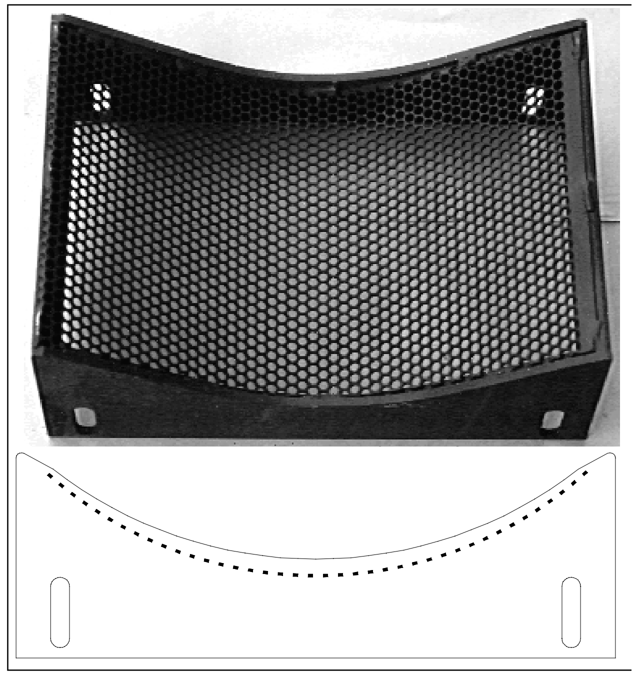

Figure 4-Perforated metal grid bar types.