PRELIMINARY COMPARISON OF WASTE AND COTTON FIBER LOSS USING A SHIRLEY ANALYZER AND SHIRLEY TRASH SEPARATOR

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Abstract

Waste measurements obtained on lint cotton using the Shirley Trash Separator (STS) were compared to those obtained using the standard Shirley Analyzer (SSA). The objective was to determine whether the STS can be used to measure fine trash not captured by the SSA and if the STS can be used to predict total waste content expected using the SSA. Two studies and preliminary tests for a third study were conducted to compare the two machines. Tests showed that visible waste contents were significantly lower with the STS and invisible and total waste contents were slightly lower in the first study but higher in the second study. Preliminary results of the third study indicate a significant temperature rise may have occurred in the STS lint box thereby reducing initial weights of cleaned lint. This would, in turn, inflate invisible and total waste values indicated in studies 1 and 2. Tests showed that weighing the lint after conditioning and using those weights instead of those obtained immediately after lint collection decreased calculated invisible waste quantities substantially. This is more in line with what is expected since the STS was designed to catch what previously went out as invisible waste in the SSA. These tests have shown that the STS can be used to measure fine trash not collected by the SSA.

Introduction

The amount of trash in cotton is a major factor in determining the quality and grade of cotton. The Shirley Analyzer, first produced over 50 years ago and described by Pfeiffenberger (1944), has been used in a standard laboratory reference method for measuring the non-lint content of cotton (ASTM, 1996). Non-lint content can be broken down into two components - visible and invisible waste. Invisible waste includes fiber loss and is determined by adding visible waste collected after cleaning to cleaned lint and subtracting that amount from the amount of lint introduced to the machine. A machine of newer technology, the Shirley Trash Separator Model SDL/102, was designed to collect more of what previously went out as invisible waste by analyzing it into four components instead of one. Knowing more about the fine trash in lint cotton would be helpful in evaluating ginning machinery and lint cleaning treatments. This paper compares the two units to see if the newer unit can be used to predict waste contents determined using the standard Shirley analyzer. The units are hereafter referred to as STS and SSA, respectively.

Studies have been done to investigate errors that occur with the SSA, and other methods have been presented as alternatives to the SSA. Montalvo and Mangialardi (1983) investigated systematic errors that occur with the SSA. The authors found that, due to lint in the visible waste, the SSA slightly overestimated true visible waste. The Microdust and Trash Monitor or MTM (Shofner and Williams, 1986) had been presented as a more rapid method of determining visible, invisible, and total foreign matter in ginned lint. Anthony (1987) compared measurements made by the MTM to those made by the SSA using regression analysis. He found that the MTM did not accurately predict foreign matter in ginned lint as measured by the SSA and found that lint cleaning treatment in the gin was a better predictor of SSA visible and total waste than were the MTM values.

ASTM Method D2812 (ASTM, 1996) indicates the method for operating the SSA to determine non-lint content. The method employs air and aggressive mechanical action to separate trash from lint. In operation, a 100-g lint specimen is placed onto a feed tray, and is passed slowly by a rotating feed roll to a rapidly revolving cylinder (called a taker-in) containing several teeth. As the cotton is broken up, an air blast carries the lint around the bottom of the flow plate and up on a revolving condenser. Trash and heavy particles drop into a front waste chamber while cleaned lint and light dust are carried to a rear chamber where lint is collected. The fine dust is sucked through perforations and exhausted. Without disturbing trash in the waste chamber, the lint is passed through a second time, collected, and weighed immediately.

The STS (Shirley Developments Limited, 1984) uses the same principle as the SSA to feed lint and separate lint from coarse trash using the feed roll and taker-in. However, the STS has provisions for recovery of fine trash. Recovery of fine trash is accomplished using a fixed screen (instead of a rotating condenser to collect the lint), and two stationary filters. Trash larger than 150 microns collects in the rear tray below perforations in a screen and in the first mesh filter. The second mesh filter collects dust between 50 and 150 microns. The STS is supposed to provide more uniform and lower invisible loss across the range of trash contents.

Objective

The objective of this study was to compare waste measurements obtained on lint cotton using the Shirley Trash Separator (STS) to those obtained using the standard Shirley Analyzer (SSA). This can determine whether the STS can be used to measure fine trash not captured by the SSA and if the STS can be used to predict total waste content expected using the SSA.

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Three separate studies were conducted to meet the above objective. Two of the three studies are presented in this paper and preliminary findings from Study 3 are also discussed.

For Study 1, cleaned lint quantities, visible waste, and invisible waste amounts were recovered from the SSA and STS using two varieties of hairy- and smooth-leaf cottons exposed to four levels of lint cleaning (Mangialardi, 1988).

For Study 2, cleaned lint quantities, visible waste, and invisible waste amounts were recovered from the SSA and STS using 56 cotton varieties placed through three lint cleaners (one cleaning treatment). One replication through each machine was conducted for each cotton.

For Study 3, cleaned lint quantities, visible waste, and invisible waste amounts were recovered from the SSA and STS using nine cottons placed through two lint cleaners (one cleaning treatment). Thus, more data were obtained in a limited range of visible waste content influenced only by cotton type. When study 3 has been completed, cleaned lint and waste will also be analyzed to determine the nature of the material removed and remaining fiber from both machines.

Procedures

Study 1 - Lint samples were obtained from ginning bales of four cotton varieties. Two of each represented hairy- and smooth-leaf varieties. Varieties of hairy-leaf cottons were DES 119 and ST 825, and the smooth- leaf varieties were DPL 20 and DPL 50. For each cotton, four lint cleaner treatments were applied: none, one, two, and three stages of lint cleaning. From each lint cleaner, three 300-g samples were obtained. From each 300-g sample, 100-g subsamples of lint were fed into each Shirley analyzer for the comparative study. The test was then replicated again for each cotton. Thus, 192 lint specimens were tested in the experiments (4 cottons x 4 lint cleaners x 3 samples x 2 machines x 2 test replications).

Study 2 - This study was preliminary to Study 3 and was designed to obtain a large amount of data in a limited range of visible waste content. One replication of SSA data from another study had already been obtained on 56 lint samples in 1995. A 100-g sub-sample of lint from each variety was passed through the STS after conditioning. Therefore, a total of 112 samples were processed (56 cottons x 2 machines).

Study 3 - Lint samples were obtained from ginning bales of 9 cotton varieties (STA LA887, DPL 50, DPL 51, HZ1215, STV132, STV474, SG125, SG404, and HS2G). Lint samples for each cotton were taken after the second lint cleaner and stored for the comparative study. One-hundred gram subsamples were extracted from 300-g samples and fed into each machine. When the study has been completed, ten replications will have been conducted on each machine for each of the nine cottons. A total of 180 specimens will be processed (9 cottons x 10 reps x 2 machines).

Experimental evaluations of the two Shirley Analyzer machines were conducted at the U.S. Cotton Ginning Lab under controlled ambient conditions (70^0 F, 55% RH). The lint specimens were also conditioned to this environment for 24 hours prior to testing. For both machines, trash trays, filters, and delivery boxes were swept clean before introduction of each specimen. A 100-g specimen of lint was weighed to the nearest 0.01 gram after conditioning. Fifty grams of each 100-g specimen was spread uniformly on the feed tray. Hard lumps were teased out as the first fraction and remaining 50-g of cotton was passed through. For each machine, trash collected was left in the trash box as the lint was passed through again. For the STS, trash was left in both front and rear chambers, and dust was left undisturbed in filters as the lint was passed through again. Small amounts of lint found in the trash trays were also passed back through after the first pass. After the second pass, trash-entrained lint from the front tray of the STS was passed through again, and all lint left in trays was collected and weighed as “recovered lint.” Cleaned lint, trash collected in trays, and dust from filters were weighed to the nearest 0.01 gram.

Statistical Analysis

For studies 1 and 2, experiments were conducted and results were analyzed as a completely random design with a factorial arrangement of treatments. Mean waste and cleaned lint amounts from the two machines were compared. In addition, regression analysis was accomplished to determine the correlation between SSA and STS visible, invisible, and total waste amounts for study 1. Analyses were performed at the 5 and 1% levels of probability using the General Linear Models procedure (SAS, 1988).

Results

Study 1 - Data set means for different cotton varieties, lint cleaning treatments, and Shirley analyzers are shown in Table 1. Several trends can be noted here. As expected, hairy-leaf cottons DES 119 and ST 825 exhibited higher total foreign matter contents than the two smooth-leaf varieties across all lint cleaning and machine treatments. These values were 4.61 and 4.28% respectively compared to 2.44 and 3.70% respectively. Expected reductions in trash contents as a function of number of lint cleaners is also illustrated. Visible, invisible, and total waste in the samples averaged 2.68, 1.25, and 3.93% when tested on the standard Shirley (SSA), compared to the lower waste contents of 2.46, 1.12, and 3.59% measured with the Shirley trash separator. When using the STS, an average 0.13 and 0.25% waste was collected in the rear tray and two fine filters at the rear of the machine, respectively. These two fine trash components would be expected to become a portion of invisible waste if using the SSA .

Table 2 indicates that average differences in waste amounts between machines were significant at the 1% level. There were also significant interactions between Shirley analyzer treatments and both cotton type (hairy or smooth) and lint cleaners for the waste measurements. The interaction Machine*Lint Cleaners was significant at the 1% level for visible and total waste, and significant at the 5% level for invisible waste. The interaction Machine*Type was significant at the 1% level for total waste, significant at the 5% level for visible waste, and not significant for invisible waste content.

Differences in the visible waste content attributed to different Shirley analyzer machines averaged 0.79 and 0.45% for the hairy- and smooth-leaf types using zero lint cleaners, compared to only 0.04 and 0.06% differences after 3 lint cleaners, respectively (Table 3). Total waste differences attributed to the two machines were 0.84 and 0.34% before lint cleaning for the hairy- and smooth-leaf cottons, compared with corresponding differences of 0.13 and 0.19% after 3 lint cleaners. Although changes in Shirley Analyzer waste content were consistent with cotton types and stages of lint cleaning, the level of differences shown most clearly at the extremes of cleaning is probably the reason data shows significant treatment interactions.

Correlation coefficients and corresponding probability levels are shown for both machines in Table 4. For the pooled data, correlation coefficients (r) relating visible, invisible, and total waste contents between the two machines were 0.99, 0.49, and 0.98, respectively. Each of these r values were significant at the 0.01 level of probability. Correlation coefficients for data obtained at each of the four lint cleaner levels ranged from 0.96 to 0.98, 0.31 to 0.70, and 0.92 to 0.96 for visible, invisible, and total waste measurements. All of these were significant at the 0.01 level of probability showing good correlation, except for invisible waste obtained from one and two lint cleaner cottons which were not significant at the 0.05 level of probability.

These data were fitted to linear regression equations relating SSA foreign matter contents to STS foreign matter contents (Figures 1-3):

Visible Waste:	$Y = -0.142 + 1.148 * X$	(1)
Invisible Waste:	$Y = 0.813 + 0.388 * X$	(2)
Total Waste:	$Y = -0.056 + 1.110 * X$	(3)

where Y = predicted waste content obtained on the SSA
X = actual waste obtained with the STS

Confidence intervals are also shown in the figures. Since each equation represents a different waste variable as indicated above, X and Y represent different variables in each equation. Although scatter should be similar, equations (2) and (3) may actually require modification to reflect even lower invisible and total waste quantities derived for the STS. These findings are based on preliminary results of Study 3, to be discussed subsequently.

Study 2 - Means for the two Shirley analyzer machine treatments across the 56 cotton varieties are illustrated in Table 5 along with Analysis of Variance illustrated in Table 6. Consistent with findings from Study 1, visible waste content was found to be lower with the STS and was significant at the 5% level. However, invisible waste content for the STS was found to be significantly higher (at the 1% level) than that for the SSA. This contradicts results from Study 1, which indicates lower invisible waste from the STS, albeit by a very small difference with cleaner cottons (Table 3). Study 3 was begun with an eye on this problem and it was found that the cleaned lint from the STS required conditioning before final weights were taken. Preliminary tests using 5 replications on DPL50 cotton showed an average increase in lint weight of 0.71% after 24 hour conditioning in the standard laboratory environment. The STS literature (Shirley Developments, 1984) indicates that the drive motor's proximity to the lint box might cause the lint to lose some moisture. The amount of moisture loss is indeed significant. The bottom two rows of Table 5 show invisible waste and total waste results of Study 2 if the 0.71% increase in lint weight were applied. Invisible and total waste figures decrease markedly to those below the SSA as would be expected. Results of Study 1 will also be affected and equations (2) and (3) would be shifted to reflect these lower values. Scatter of the data should be comparable, however.

Summary and Conclusions

Experiments were conducted to compare waste measurements obtained on lint cotton using the Shirley Trash Separator (STS) to that obtained using the Standard Shirley Analyzer (SSA), and to determine whether the STS could be used to measure fine trash that is not captured using the SSA. For Study 1, lint specimens were obtained from ginning two replications of four cotton varieties using zero, one, two, and three stages of saw-cylinder lint cleaning. For Study 2, cleaned lint quantities, visible waste, and invisible waste amounts were recovered from the SSA and STS using 56 cotton varieties placed through three lint cleaners (one level of cleaning). One replication through each machine was conducted for each cotton. Results from Study 3 are preliminary.

Data analysis from Study 1 indicates average total waste content indicated by the STS was lower than that obtained using the SSA, and this was statistically significant at the 1% level. Differences between the two machines were smaller on the cleaner cotton samples. Correlations for all waste components between the two machines were very good and were all significant at the 1% level for the pooled data, represented by equations 1-3. As has been stated, preliminary results of Study 3 indicate that equations (2) and (3) may actually require shifting to reflect even lower invisible waste quantities than those indicated for the STS. The visible waste correlation (represented in equation 1) would not be affected.

When using the STS, and average of 0.35% of waste was collected in the rear tray and 50- and 150-micron filters at the rear of the machine. This fine trash would normally become a portion of the invisible waste observed using the SSA.

As indicated, an attempt was made to resolve the larger invisible waste quantities observed with the STS in Study 2. It was suggested that the procedure for collecting cleaned lint be carefully scrutinized since this quantity, added to observed visible waste, determines the quantity of invisible waste when subtracted from the initial lint quantity. It was found that the cleaned lint introduced to the STS requires conditioning before final weights are taken. It should be noted that the 0.71% weight increase in STS cleaned lint is probably a conservative value. Percent weight increases for the 5 replications of DPL50 actually increased in a logarithmic fashion with time (or sample number) from a low of 0.23% to a high of 1.02%. This might indicate increased drying with subsequent samples as the machine warms up. Not enough samples were taken to determine the "stabilized" value, however, and although the amount of time cleaned lint stayed in the lint box was probably consistent between samples due to the regimented nature of the test, the exact amount of time for each sample was not recorded. The 0.71% weight increase was applied to the values of Table 5 (Study 2) only for illustration. Actual conditioned lint quantities are being used to determine invisible waste for Study 3 and invisible waste quantities appear to be very low. This is consistent with what is expected since the STS was designed to "catch" what previously went out as invisible waste in the SSA.

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Table 1. Means for variety of cottons, lint cleaners, and Shirley Analyzer machine treatments, Study 1

Item	Waste collected (g)				Shirley waste, %		
	Front tray	Rear tray	Two filters	Recovered Lint	Visible	Invisible	Total
Variety							
DES 119	3.34	0.15	0.21	0.14	3.45	1.16	4.61
ST 825	3.02	0.14	0.30	0.16	3.16	1.12	4.28
DPL 20	1.17	0.08	0.25	0.10	1.28	1.16	2.44
DPL 50	2.27	0.14	0.23	0.13	2.39	1.30	3.70
Lint Cleaners							
0	4.23	0.18	0.29	0.19	4.37	1.25	5.65
1	2.41	0.13	0.25	0.12	2.53	1.20	3.73
2	1.85	0.10	0.23	0.11	1.96	1.13	3.09
3	1.31	0.09	0.22	0.11	1.41	1.15	2.56
Machine							
SSA	2.68	-	-	-	2.68	1.25	3.93
STS	2.22	0.13	0.25	0.13	2.46	1.12	3.59

Data are averages from two replications, three samples per replication.
Data for individual items are averages across all other factors.
Recovered lint is fiber recovered from front tray, rear tray, two filters of the STS.

Table 2. Analyses of variance for measurements attributed to the Shirley Analyzer treatments, Study 1

Source of variation	D.F.	Mean squares for				
		Cleaned lint	Front tray waste	Waste		
				Visible	Invisible	Total
Machine	1	5.88**	10.18**	2.37**	0.79**	5.54**
Machine*lncl	3	0.49**	1.03**	0.84**	0.10*	0.41**
Machine*type	1	0.27**	0.13**	0.11*	0.04	0.35**
Cot*machine (type)	2	0.18*	0.12**	0.09*	0.02	0.12*
Type*lncl*machine	3	0.12*	0.09**	0.08*	0.02	0.17*
Cot*lncl*machine (type)	6	0.04	0.01	0.02	0.05	0.05
Error	80	0.04	0.02	0.02	0.03	0.04

** = Significant at the 1% level of probability
* = Significant at the 5% level of probability

Table 3. Visible and total waste means shown by cotton types, lint cleaners and Shirley Analyzer treatments, Study 1

Lint Cleaners	SSA treatment		STS treatment	
	Hairy leaf type	Smooth leaf type	Hairy leaf type	Smooth leaf type
Visible waste, %				
0	5.95	3.41	5.16	2.96
1	3.34	1.86	3.20	1.74
2	2.62	1.40	2.50	1.33
3	1.85	1.02	1.81	0.96
Invisible waste, %				
0	1.23	1.29	1.18	1.39
1	1.26	1.36	0.95	1.21
2	1.21	1.20	1.09	1.06
3	1.17	1.24	1.08	1.11
Total waste, %				
0	7.18	4.70	6.34	4.35
1	4.60	3.22	4.15	2.95
2	3.83	2.60	3.55	2.39
3	3.02	2.26	2.89	2.07

[1] Data are the averages from 12 samples (2 varieties x 2 replications x 3 samples).

Table 4. Correlations between visible, invisible, and total waste measured by two Shirley Analyzer machines, Study 1

Lint cleaners and waste component	Correlation coefficient (r) and its significant probability level for the waste component shown		
	SSA visible waste	SSA Invisible waste	SSA total waste
0 lint cleaner: (n=24)			
STS visible waste	.98 (.01)	.03 (.89)	.98 (.01)
STS invisible waste	-.18 (.40)	.70 (.01)	-.08 (.73)
STS total waste	.94 (.01)	.23 (.27)	.96 (.01)
1 lint cleaner: (n=24)			
STS visible waste	.96 (.01)	-.08 (.73)	.94 (.01)
STS invisible waste	-.20 (.34)	.38 (.07)	-.10 (.64)
STS total waste	.90 (.01)	.07 (.75)	.92 (.01)
2 lint cleaners: (n=24)			
STS visible waste	.98 (.01)	.12 (.57)	.94 (.01)
STS invisible waste	.08 (.71)	.31 (.13)	.16 (.47)
STS total waste	.96 (.01)	.22 (.30)	.95 (.01)
3 lint cleaners: (n=24)			
STS visible waste	.98 (.01)	.16 (.45)	.89 (.01)
STS invisible waste	.14 (.51)	.66 (.01)	.36 (.08)
STS total waste	.94 (.01)	.39 (.06)	.94 (.01)
Pooled data: (n=96)			
STS visible waste	.99 (.01)	.09 (.36)	.98 (.01)
STS invisible waste	.12 (.23)	.49 (.01)	.19 (.07)
STS total waste	.97 (.01)	.20 (.05)	.98 (.01)

STS = Shirley trash separator, SSA = Standard Shirley Analyzer

Table 5. Means for Shirley Analyzer machine treatments, Study 2.

Machine	Cleaned lint (g)	Shirley waste, %		
		Visible	Invisible	Total
SSA	97.71	1.06	1.23	2.29
STS	97.40	0.95	1.64	2.59
With 0.71% avg. lint weight increase applied to STS				
SSA	97.71	1.06	1.23	2.29
STS	98.08	0.95	0.97	1.92

Differences in means are all significant at the 5% level judged by LSD for the actual test (first 2 rows of data above)

Table 6. Analysis of variance for measurements attributed to Shirley Analyzer treatments, Study 2.

Source	D.F.	F values for waste		
		Visible	Invisible	Total
Cotton	55	1.53	0.73	1.02
Machine	1	6.06*	32.28**	14.50**
Error	52			
Corr. Total	108			

* Significant at 5% level of probability
** Significant at 1% level of probability

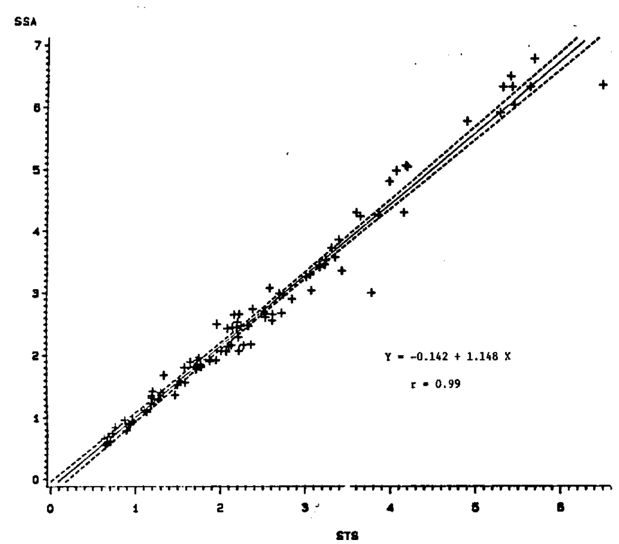

Figure 1. Visible Waste Calibration.

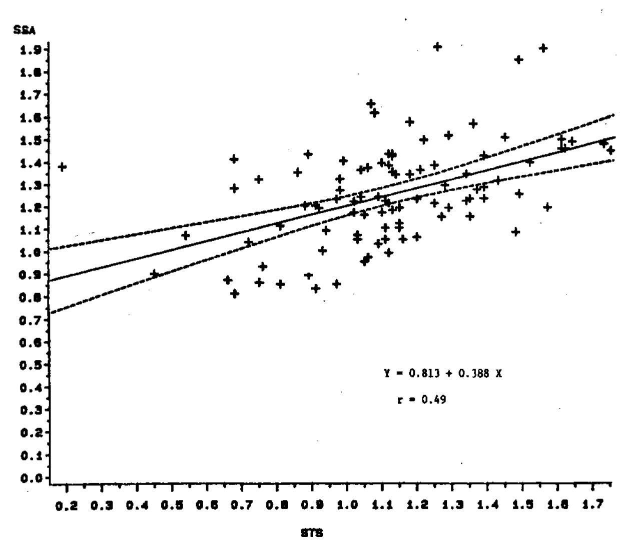

Figure 2. Invisible Waste Calibration.

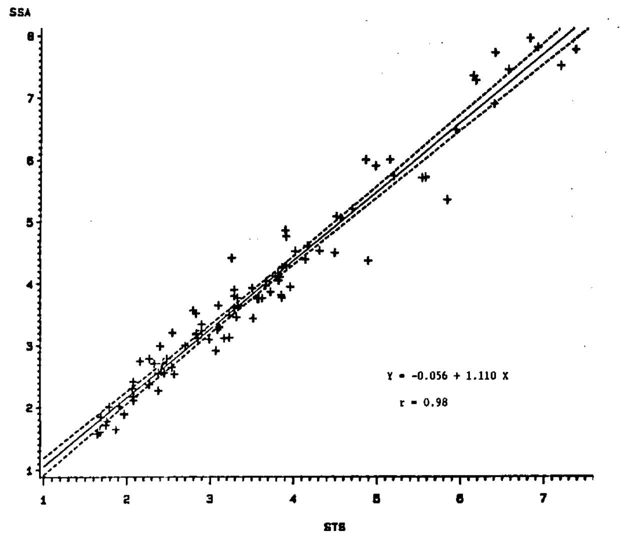

Figure 3. Total Waste Calibration.