ANALYSIS OF COST MINIMIZATION OF COTTON CLEANING IN A SYSTEMS FRAMEWORK

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Abstract

By employing survey, regression, and simulation techniques, this research identifies the least cost cleaning configurations across the harvesting, ginning, and textile mill stages of cotton processing. Given the standard textile mill technology, the least cost cleaning configurations were found to include the use of a field cleaner in the harvesting stage and one lint cleaning in the ginning stage for the best and second best qualities of yarn. For the third best quality of yarn, the least cost cleaning configuration was found to not include the use of a field cleaner in the harvesting stage and one lint cleaning in the ginning stage. It was determined that if the recommended cleaning configurations are employed, the cotton industry could save between $0.30 and $0.60 per bale of cotton, depending on the desired yarn quality.

Problem and Objectives

Machine harvesting of cotton removes extraneous materials along with the cotton lint and seed which, if not thoroughly removed, may compromise the quality of the products coming out of the textile mill. Cotton cleaning is a multi-stage operation that involves stages of production, harvesting, ginning, and textile processing. Further, cleaning practices can vary significantly within each of these stages. At the production stage, varieties, soil type, and weather-related factors may have a significant impact on the cleanliness and quality of harvested cotton. Variation in cleaning activities may include time of harvesting and the use of a field cleaner on a stripper in the harvesting stage and a combination of one to three stages of lint cleaning at the gin plant. At the textile mill, variation in opening, carding and drawing practices can also affect the degree to which cotton is cleaned.

Production practices employed and the mix of cotton cleaning activities during harvesting, at the gin plant, and at the textile mill determine not only cotton cleanliness, but also fiber qualities. Therefore, the cost of cleaning cotton should include the cost of owning and operating the cleaning equip-ments in all three stages and the effects of cleaning activities on cotton quality factors. The debate surrounding cotton cleaning, however, has been limited to operational efficiency at the typical gin plant processing stage and market prices (bale value). For example, the USDA (United States Department of Agriculture) recommended combination of cotton ginning machinery, regardless of the cleaning practices used in the production stage and desired yarn quality, includes two lint cleanings. This processing procedure achieves satisfactory bale value and reduces damage to the inherent quality of the fiber, but it may not maximize the net cash value for each individual bale (Anthony, 1985).

From the overall industry perspective, it is important to know the most efficient (least cost) mix of cotton cleaning activities across the entire system of cotton handling. Market prices do not seem to guarantee implementation of the most efficient cleaning configuration in a system framework. Haskel (1973) suggests that price should not be considered because the segmentation and division of responsibility within the cotton industry contributes to excessive farm-to-mill costs. Excessive farm-to-mill costs are demonstrated by the fact that additional lint cleanings usually result in higher prices (Ethridge et al., 1994). This may be profitable for producers, but may not be efficient across the entire system if the objective is to minimize farm-to-mill cleaning costs.

The availability of alternative cleaning configurations raises the question of identifying the optimal approach. The optimal cotton cleaning configuration for the overall industry, given a specific production practice, would include a sequence of cleaning processes at the field, at the gin, and at the textile mill which can be accomplished at a minimum cost. If it is assumed that textile mills are usually targeting a desired quality of yarn, the issue is one of selecting least cost cleaning configurations across the harvesting, ginning, and textile mill stages to achieve the desired yarn quality.

No empirical research has focused on addressing the issue of cotton cleaning by integrating across the segments of the industry. Cost estimates and quality effects are not available for alternative cleaning configurations, making it difficult to suggest any preferred combination of cleaning that will minimize costs across the system. The general objective of this study is to determine optimal cotton cleaning configurations across the harvesting, ginning, and textile mill stages that can most efficiently deliver cotton with the desired level of cleanliness and quality characteristics.

Methods and Procedures

Given that there are alternative methods of cleaning cotton from the harvesting stage through the textile mill stage, conceptually the problem becomes one of cost MINIMIZATION (identifying the cleaning process across the three stages that delivers a certain degree of cotton cleanliness and quality at the least cost). The analysis was based on irrigated, stripper harvested cotton produced on an

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average farm size of 1,000 acres in the Southern High Plains.

Harvesting Stage

In the harvesting stage, the factors that were allowed to change were the variety and the use of a field cleaner. For the purpose of this analysis, secondary data for average yield per acre for high trash producing varieties (Lankart LX-571 and Cencot), medium trash producing varieties (Tamcot CAB-CS, Deltapine SR-383, and Deltapine 50), and low trash producing varieties (Paymaster HS-26, Paymaster 145, and All-Tex Atlas) of cotton were calculated by averaging agronomic yield data for 1988 through 1992 reported by Gannaway et al. (1992). The purpose of this exercise was to categorize cotton varieties into three groups (high, medium, and low trash) representing varieties with different trash content and yield. The low trash category represents low trash varieties of cotton with high yields (1.56 bales/acre), the medium trash category represents cotton varieties with medium trash content and yields (1.26 bales/acre), and the high trash category represents varieties with low yields (0.81 bales/acre) and high trash content.

The impact of the field cleaner on the cleanliness and quality of seed cotton was determined by collecting primary cotton sample data from the Agricultur-al Research Service office of the U.S. Department of Agriculture (ARS-USDA) in Lubbock, Texas. The cotton samples were of one cotton variety, Paymaster HS-26, and were all stripper harvested (some with the use of a field cleaner and some without). The trailer samples were ginned within two days of being harvested. During the ginning process, samples were taken at the feeder apron above the gin stand. For each of these samples, 200 grams of seed cotton were weighed and the burs and sticks were removed by hand. The samples were then placed in a pneumatic fractationator that separated the fine trash. Each foreign matter fraction and the seed cotton was weighed. The cotton samples were ginned using the standard sequence for stripper har-vested cotton and were sent to the USDA classing office in Lubbock, Texas where the quality attributes were measured. The data were compiled for all samples and an average was taken of the samples with similar treatments.

Several regression models were ran to obtain the affects a field cleaner on trash quality attributes of cotton. Each of the fractionation and quality attributes were specified as a function of the field cleaner. The field cleaner (FC) variable was specified as a dummy variable. The general specification of the regression model is given by:

$$(\text{Attr.})_i = \beta_o + \beta_1 (FC) + \mu_i, \qquad (1)$$

where $(\text{Attr.})_i$ represents each of the fractionation and quality attributes and FC is a dummy variable that equals one if the field cleaner was used in harvesting and zero otherwise.

Cleaning costs in the harvesting stage were determined by surveying several area producers in the Lubbock area and an area implement company. The annual ownership cost of a field cleaner was determined by assuming a ten year life. Costs were adjusted to determine the total ownership and operating cost per bale per year of a field cleaner. The cost of hauling cotton in modules to the gin plant was determined by surveying several ginners in the Lubbock area and by calculating the average number of bales that are transported in a module and hauling charge per module.

Ginning Stage

Impacts of the cleaning configurations in the gin on the cleanliness and quality of cotton were determined by employing a simulation model, GINQUAL (Barker et al., 1990). The varieties of cotton were ginned using the simulation model separately. The ginning rate and number of ginstands were set constant for the three varieties at 18.67 bales per hour and three ginstands. A single stream cleaning system with the standard machine sequence for gins was employed for the three varieties. The moisture content of the seed cotton was also set constant at fourteen percent for the three varieties. The three varieties were subjected to one to three lint cleanings each with three parallel lint cleaners in each stage.

The default initial trash content values given by the GINQUAL model for the seed cotton entering the gin was not altered for the three varieties of cotton that were not field cleaned. However, these values were adjusted for cotton that was field cleaned. This was accomplished by using the statistical estimates of the effects of the field cleaner derived from primary data collected for Paymaster HS-26. It was assumed, because of a lack of data, that the use of a field cleaner would affect the other two varieties in a similar manner.

The total cleaning cost in the gin plant was determined by surveying three ginners who operate gins in the Lubbock, Texas area. A survey pertaining to the costs associated with the gin operation was completed. The results from the survey were used in the GINMODEL, ginning cost simulator (Roy Childers, 1995). Output from GINMODEL consists of total and per bale ginning costs separated into fixed and variable components. The ginning cost simulator did not, however, account for the disposal cost of waste produced by the gin plant. Because gins pay a fixed amount per bale of cotton lint to dispose of the waste, waste disposal cost per bale was estimated and added to the estimated cleaning cost per bale from the GINMODEL.

Textile Mill Stage

Given the assumption that cotton is cleaned at the textile mill to obtain a desired quality yarn, the amount of cleaning that is done in the textile mill will depend on the cleanliness and quality of cotton that is delivered to the mill. Given the desired quality of yarn, some cotton may have to be cleaned more aggressively in the mill than others. Further, it is also possible that some cotton will not achieve the desired quality of yarn regardless of the cleaning process that is undertaken at the textile mill.

The desired level of cleanliness and quality for spinning was established with the aid of Trutzschler GMBH & Co., Germany and the International Textile Center at Texas Tech University. The data produced for each configuration from the GINQUAL model were analyzed and it was determined that no alteration in the cleaning process is needed at the textile mill. Therefore, a single cleaning configuration (Bennett 1995) in the textile mill was identified. The suggested method of spinning the cotton into yarn involved open-end spinning with the use of an opening roller which also removes some fine dust from the cotton lint.

Yarn qualities that can be obtained for the alternative cotton cleaning configurations were predicted with the aid of the International Textile Center, Lubbock, Texas to classify the cleaning configurations according to yarn qualities. This relationship can be expressed as:

$$CSP = C - (m * N_{ec}), \quad (2)$$

where CSP is yarn strength prediction, C is 382.5 + (52.26*HVI Strength) + (792.2*Length), m is 44.47 - [(23.96*Length) + (1.918*Mic)], and N_{ec} is the Yarn size and was held constant at 16.

By obtaining the HVI strength, length, and micronaire for each configuration from the GINQUAL model, the yarn strength was predicted for each configuration using equation (2) and grouped into three different quality categories based on strength. These yarn qualities ranged from: 2350 and above for the best quality yarn; 2200 and above for the second best quality yarn; and 2000 and above for the third best quality of yarn.

Finally, the total cleaning cost in the textile mill was determined. Because a single cleaning configuration was chosen for the textile mill to clean cotton coming out of alternative configurations, the only difference in cleaning cost in the textile mill was revenue loss due to lint loss and the disposal cost of waste produced at the textile mill. To obtain the revenue loss per bale, an econometric relationship reported by Chen, 1995 was used to determine prices paid by textile mills for cotton from each configuration. The pricing equation is given by:

$$Price = 8.5640(9-G1)^{0.1726}(8-G2)^{0.2444}(L)^{0.1674}e^{0.3706M-0.522MM}, \quad (3)$$

where Price is the price paid per pound for cotton lint, G1 is the first digit of the color grade, G2 is the second digit of the color grade, L is the length measurement of the cotton lint, M is the micronaire measurement, and MM is the micronaire measurement squared.

The price received by the textile mill for lint waste was obtained by surveying several textile mills in the United States and an average price per pound received for lint waste. The prices for each configuration were then subtracted from the estimated prices to determine the revenue loss per pound of cotton for each configuration. It was assumed that five percent of the cotton would be lost per bale in the textile mill (Smith, 1995). Revenue loss per bale for each configuration was determined by the product of the revenue loss per pound and twenty-four pounds (five percent of 480 pounds).

Trash generated at the textile mill for each configuration was estimated with the help of Trutzschler GMBH & Co., Germany. Trutzschler suggested that about ninety-nine percent of the trash is extracted from the cotton lint in pre-cleaning and carding at the textile mill. During open-end spinning using a rotor machine, eighty percent of the remaining trash in the cotton lint is removed (Smith, 1995). Therefore, the amount of trash extracted from the cotton lint before the rotor machine was determined by taking ninety-nine percent of the initial trash levels entering the textile mill (obtained from the GINQUAL simulation runs). The remaining trash levels were then multiplied by 0.8 (eighty percent) to determine the amount of trash removed during the rotor machine. These two trash levels were added to give the total amount of trash removed in the textile mill. The mills surveyed indicated that they discard the non-lint waste by using their own trucks to haul the waste to landfills. The average cost of using the landfill for these six textile mills was calculated to be \$0.015 per pound of waste material. The waste disposal cost was computed by multiplying the number of pounds of trash extracted in the textile mill from each configuration by the waste disposal cost (\$0.015) per pound at the textile mill.

Determination of the Least Cost Cleaning Configuration

The determination of the least-cost cleaning configuration was accomplished by combining the total costs of each alternative cleaning configuration which met the yarn quality specifications. This involved examining the different total costs associated with each possible configuration and identifying of the optimal configuration which provided the desired degree of cotton yarn quality at the least cost.

It should be noted that various cost components were excluded from this analysis (e.g., owning and operating costs of a stripper, pre-cleaning and operating costs of the gin, textile mill costs following the rotor machine, etc.) because they did not differ among configurations. Therefore, only differences in the reported total cleaning costs should be considered.

Results

Harvesting Stage

Results of regression models, estimated to obtain the effects of a field cleaner on trash and quality attributes, indicated that the use of a field cleaner does not affect the quality attributes of cotton lint, but does affect the trash levels entering the gin plant. Specifically, the field cleaner was found to be most effective in decreasing the bur and stick percent in seed cotton by 69.878 and 29.367 percent, respectively (The estimated equations are: Bur Percent = 21.698 - 15.157FC and Stick Percent = 6.048 - 1.776FC).

The only differences in the cleaning cost in the harvesting stage among the alternative cleaning configurations was the cost of owning and operating a field cleaner and the hauling cost. The ownership and maintenance cost of a field cleaner was calculated to be $1,990.00 per year. Taking the average lint yield for high trash varieties (0.81 bales), medium trash varieties (1.26 bales), and low trash varieties (1.56 bales) for a 1,000 acre cotton farm and a $70.00 per module (that can transport 11.33 bales of field cleaned cotton or 9 bales of non-field cleaned cotton) hauling cost, the cleaning cost was found to be $7.7778 per bale of non-field cleaned cotton regardless of the variety (Table 1). Field cleaned cotton, however, had a cleaning cost of $8.6351 per bale of high trash varieties, $7.7577 per bale of medium trash varieties, and $7.4539 per bale of low trash varieties implying a cost saving of $0.32 to $0.02 per bale for low and medium trash varieties that were field cleaned, respectively.

With a hauling cost of $60.00 per module, the cleaning cost associated with non-field cleaned cotton was $6.6667 per bale for all three varieties. Costs associated with field cleaned cotton had a cleaning cost of $7.7525 per bale for high trash varieties, $6.8750 per bale for medium trash varieties, and $6.5713 per bale for low trash varieties. Thus, it was not cost effective to use a field cleaner in the case of high or medium trash varieties at a reduced hauling charge of $60.00.

Ginning Stage

Results on the effect of field cleaner and varieties on quality parameters (Table 2) determined by the GINQUAL model indicated no significant difference in cotton quality between field cleaned and non-field cleaned cot-ton. The low trash variety possessed the highest strength, length, micronaire, reflectance, and uniformity followed by the medium trash varieties and the high trash varieties. The medium trash varieties had the highest +b of the three varieties, followed by the low trash varieties and the high trash varieties. Non-lint percent in the ginned cotton was found to be highest in cotton subjected to one lint cleaning and lowest with three lint cleanings in the gin plant. There was no significant difference in other quality characteristics among the three varieties.

Results pertaining to the cleaning costs in the gin plant (Table 3) indicated that a gin plant operating at about 19 bales per hour and at one hundred percent utilization had a total cleaning cost of $0.41 per bale for one lint cleaner, $0.79 per bale for two lint cleaners, and $1.11 per bale for three lint cleaners (all other costs held constant). Likewise, a gin plant at ninety percent utilization had an estimated cleaning cost of $0.42 per bale for one lint cleaner, $0.81 per bale for two lint cleaners, and $1.15 for three lint cleaners. Finally, a gin operating at eighty percent utilization possessed a cleaning cost of $0.45, $0.86, and $1.22 per bale for one, two, and three lint cleaners, respectively. It is important to observe that as the utilization rates decreased, the increase in cost for one lint cleaning was less than that of two and three lint cleanings.

Textile Mill Stage

Results on the effects of field cleaners, variety, and number of lint cleanings on the yarn quality in the textile mill, determined with the aid of yarn strength relationships obtained from the International Textile Center and the results of the GINQUAL model, indicated that the low trash varieties met the requirement of having the highest yarn quality by possessing a yarn strength of 2350 and above. Second, the medium trash and low trash varieties met the second best yarn quality with a yarn strength of 2200 and above. Finally, all three varieties (low, medium, and high trash varieties) were found to meet requirements for the third best quality of yarn with a yarn strength of 2000 and above.

Results of the cleaning costs in the textile mill (Table 4), determined by estimating the revenue loss due to lint loss and non-lint waste disposal cost, indicated that textile mills had lower costs associated with non-lint disposal as the number of lint cleanings in the gin plant increased. This can be seen by examining configurations 1, with a total cleaning cost in the textile mill of $13.9457 per bale, and configuration 2, with a total cleaning cost of $13.8535 per bale. It was also observed that in most cases textile mills had lower revenue losses when cotton is cleaned more in the gin plant (subjected to more lint cleaning). Again from Table 4, revenue loss associated with configuration 1 is $13.4449 per bale, while configuration 2 is $13.4375 per bale. The use of a field cleaner was found to not have a significant impact on the revenue loss in the textile mill with the exception of the high trash producing varieties. Generally, high trash producing varieties that had been field cleaned had a higher associated revenue loss than did non-field cleaned, high trash producing varieties. The total cleaning costs in the textile mill for each configuration, on the other hand, was generally observed to be less for field cleaned cotton that was subjected to a higher number of lint cleanings in the gin plant.

Determination of the Least Cost Cleaning Configuration

Results for cotton cleaning cost for the overall industry, for the two levels of module hauling cost ($70.00 and $60.00) and one hundred percent utilization in the gin plant are presented in Table 5 (Ninety and eighty percent utilization rates were not reported in this study because no differences were observed from the results found with one-hundred percent utilization). These results indicated that for the best and second best qualities of yarn with a strength of 2350 and above and 2200 and above, respectively, the low trash producing variety should be harvested with the use of a field cleaner, cleaned in the gin plant using only one lint cleaner, and sent to the textile mill for further processing at an estimated total cleaning cost of $22.7703 per bale. For the third best quality of yarn with a strength of 2000 and above, the high trash producing variety of cotton should be harvested without the use of a field cleaner, subjected to one lint cleaning in the gin plant, and further processed in the textile mill at a total estimated cost of $22.1335 per bale. No change in optimal cleaning configurations was observed when the hauling cost was decreased to $60.00 per module.

Results of this study clearly suggest that, given the standard cleaning and processing practices in the textile mill, the least cost cleaning configuration for achieving high and medium yarn quality is the use of a field cleaner in the harvesting stage and one lint cleaning in the ginning stage. However, if a low quality of yarn with a strength of 2000 and above is desired, then these results indicate that the high trash variety should be harvested without the use of a field cleaner but should still be lint cleaned only once in the gin plant.

Conclusions

The most prevalent cotton cleaning practice in the industry now does not include the use of a field cleaner in the harvesting stage. Further, it is currently a standard practice to employ two lint cleanings in the gin plant. Results from Table 5 indicate that if the existing cleaning practices are employed: the best quality of yarn can be produced by using configuration 14 at a total cleaning cost of $23.3864 per bale, and the second and third best qualities of yarn can be produced by using configuration 8 at a total cleaning cost of $23.3546 per bale.

Results from this study, however, suggest that the least cost configuration for the first and second best qualities of yarn is given by configuration 16 and for the third best quality of yarn is given by configuration 1. The least cost cleaning configurations are distinctly different from the currently used cleaning practices as configuration 16 include field cleaning in the harvesting stage and one lint cleaning in the ginning stage and configuration 1 includes no field cleaning but also one lint cleaning in the gin plant. If these least cost cleaning configurations are employed, the cotton industry could save about $0.62 per bale for producing the best quality of yarn, $0.57 per bale for producing the second best quality of yarn, and $0.29 per bale for producing the third best quality of yarn. It was further observed that the recommended optimal cleaning configurations can save about $0.32 per bale in the harvesting stage for the low and medium trash varieties and $0.38 per bale in the ginning stage. Cleaning costs at the textile mill, however, go up by about $0.09 per bale.

Why is it a general practice to lint clean cotton twice in the gin plant? The USDA recommends two lint cleanings because it achieves a satisfactory bale value. As suggested by Ethridge et al. (1994), gins often choose to use multiple lint cleanings because additional lint cleanings usually result in higher market prices. In fact, producer level prices estimated by the GINQUAL model based on loan rates clearly indicate that additional lint cleanings result in higher prices for producers in the market. Further, analysis of the GINQUAL results based on an econometrically derived producer price equation (Hudson et al., 1994) also revealed that producer level prices are consistently higher for cotton that is cleaned twice in the gin. This may suggest that the existing pricing structure does not reflect a cleaning system that is optimal for the entire industry. Changes in the pricing structure (premiums/discounts) should be focused on encouraging less lint cleaning in the gin plant rather than more.

Several other factors may be influencing this excessive farm-to-mill cleaning cost in the cotton industry. Currently, field cleaners are not being adopted readily on the Southern High Plains of Texas due to lack of reliable information about its effect on economic returns and quality characteristics of cotton lint. Also, there seems to be a perception that field cleaners damage cotton quality characteristics. However, results of this study do not support this perception as cotton harvested with the use of a field cleaner possessed virtually the same quality parameters as cotton harvested without. Further, the industry is perhaps unaware of the module transportation cost savings when cotton is harvested with the use of a field cleaner.

The cleaning inefficiency in the cotton industry can be attributed to many different factors. To decrease farm-to-mill cleaning costs, prices paid to producers for their cotton should be adjusted as to encourage more cleaning in the harvesting stage and less lint cleaning in the gin plant. Though moving toward an optimal cleaning practice may not benefit all individual sectors of the cotton industry, it should benefit the industry as a whole.

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Table 1. Cost of field cleaner and hauling stripper harvested cotton ($/bale) for alternative module hauling charges, with and without the use of a field cleaner.

	Hauling Cost/Module			
	$70.00		**$60.00**	
Variety	**With Field Cleaner**	**Without Field Cleaner**	**With Field Cleaner**	**Without Field Cleaner**
High Trash	8.6351	7.7778	7.7525	6.6667
Medium Trash	7.7577	7.7778	6.8750	6.6667
Low Trash	7.4539	7.7778	6.5713	6.6667

Table 2. Effects of a field cleaner and one, two, and three lint cleanings on quality parameters of cotton exiting the gin plant.

Var	Config. Number	Field Clean	# of LC	Str.	Mic	Leng.	Unif. Ratio	Refl.	+b	Color Grade	Comp. Grade	Trash Grade	Moist % (Wet Basis)	Non-lint %
High Trash	1	No	1	21.89	2.44	30.5	80.92	69.06	7.49	51	61	7	6.61	6.97
	2	No	2	22.22	2.44	30.4	80.13	69.96	7.67	51	60	6	6.50	5.79
	3	No	3	22.54	2.44	30.1	79.93	70.60	7.70	51	60	6	6.22	5.57
	4	Yes	1	21.89	2.45	30.5	80.74	69.37	7.84	51	61	7	6.52	6.66
	5	Yes	2	22.22	2.45	30.4	80.00	70.27	8.02	41	51	6	6.40	5.48
	6	Yes	3	22.54	2.45	30.1	79.79	70.90	8.05	41	51	6	6.13	5.26

Table 2. Effects of a field cleaner and one, two, and three lint cleanings on quality parameters of cotton exiting the gin plant. (continued)

Var	Config. Number	Field Clean	# of LC	Str.	Mic	Leng.	Unif. Ratio	Refl.	+b	Color Grade	Comp. Grade	Trash Grade	Moist % (Wet Basis)	Non-lint %
Medium Trash	7	No	1	25.06	3.39	32.5	81.43	69.37	7.75	51	60	6	6.50	5.74
	8	No	2	25.59	3.39	32.3	80.73	70.28	7.93	51	51	5	6.38	4.56
	9	No	3	26.11	3.39	32.1	80.52	70.91	7.96	41	50	5	6.11	4.34
	10	Yes	1	25.06	3.39	32.5	81.41	69.37	7.77	51	60	6	6.44	5.68
	11	Yes	2	25.59	3.39	32.3	80.70	70.27	7.94	51	51	5	6.32	4.50
	12	Yes	3	26.11	3.39	32.1	80.49	70.90	7.98	41	50	5	6.05	4.28

Table 2. Effects of a field cleaner and one, two, and three lint cleanings on quality parameters of cotton exiting the gin plant. (continued)

Var	Config. Number	Field Clean	# of LC	Str.	Mic	Leng.	Unif. Ratio	Refl.	+b	Color Grade	Comp. Grade	Trash Grade	Moist % (Wet Basis)	Non-lint %
Low Trash	13	No	1	26.47	3.68	33.0	82.24	69.38	7.74	51	60	6	6.47	5.47
	14	No	2	27.09	3.68	32.9	81.55	70.28	7.92	51	51	5	6.36	4.29
	15	No	3	27.70	3.68	32.6	81.34	70.91	7.95	41	50	5	6.08	4.08
	16	Yes	1	26.47	3.68	33.0	82.19	69.38	7.76	51	60	6	6.42	5.41
	17	Yes	2	27.09	3.68	32.9	81.49	70.28	7.93	51	51	5	6.30	4.23
	18	Yes	3	27.70	3.68	32.6	81.28	70.91	7.97	41	50	5	6.04	4.01

Table 3. Lint cleaning cost ($/bale) of cotton in the ginning stage for alternative utilization rates

	100 % Utilization		90% Utilization		80% Utilization	
# of Lint Cleanings	Total Cost	Cost Diff.	Total Cost	Cost Diff.	Total Cost	Cost Diff.
0	40.97		42.38		44.28	
		0.41		0.42		0.45
1	41.38		42.8		44.73	
		0.79		0.81		0.86
2	41.76		43.19		45.14	
		1.11		1.15		1.22
3	42.08		43.53		45.50	

Table 4. Revenue loss, non-lint disposal cost, and total cleaning cost in textile processing.

Variety	Config. Number	FC	# of LC	Revenue Loss	Cost of Non-lint Disposal	Textile Mill Total Cleaning Cost
High Trash	1	No	1	13.4449	0.5008	13.9457
	2	No	2	13.4375	0.4160	13.8535
	3	No	3	13.4152	0.4002	13.8154
	4	Yes	1	13.4605	0.4786	13.9391
	5	Yes	2	13.9825	0.3938	14.3763
	6	Yes	3	13.9593	0.3780	14.3373

Table 4. Revenue loss, non-lint disposal cost, and total cleaning cost in textile processing. (continued)

Variety	Config. Number	FC	# of LC	Revenue Loss	Cost of Non-lint Disposal	Textile Mill Total Cleaning Cost
Medium Trash	7	No	1	14.4741	0.4125	14.8866
	8	No	2	14.4591	0.3277	14.7868
	9	No	3	15.0124	0.3119	15.3243
	10	Yes	1	14.4741	0.4081	14.8822
	11	Yes	2	14.4591	0.3234	14.7825
	12	Yes	3	15.0124	0.3075	15.3199

Table 4. Revenue loss, non-lint disposal cost, and total cleaning cost in textile processing. (continued)

Variety	Config. Number	FC	# of LC	Revenue Loss	Cost of Non-lint Disposal	Textile Mill Total Cleaning Cost
Low Trash	13	No	1	14.5177	0.3931	14.9108
	14	No	2	14.5103	0.3083	14.8186
	15	No	3	15.0581	0.2932	15.3513
	16	Yes	1	14.5177	0.3887	14.9064
	17	Yes	2	14.5103	0.3040	14.8143
	18	Yes	3	15.0581	0.2881	15.3462

Table 5. Total cleaning cost for the harvesting, ginning, and textile mill stages and for the industry.

				Total Cleaning Cost				
Variety	Config. No.	FC	LC	Harvesting Stage	Ginning Stage	Textile Mill Stage	Industry	Yarn St.
High Trash	1	No	1	7.7778	0.41	13.9457	22.1335	2009
	2	No	2	7.7778	0.79	13.8535	22.4213	2024
	3	No	3	7.7778	1.11	13.8154	22.7032	2030
	4	Yes	1	8.6351	0.41	13.9391	22.9842	2009
	5	Yes	2	8.6351	0.79	14.3763	23.8014	2024
	6	Yes	3	8.6351	1.11	14.3373	24.0824	2030

Table 5. Total cleaning cost for the harvesting, ginning, and textile mill stages and for the industry. (continued)

				Total Cleaning Cost				
Variety	Config. No.	FC	LC	Harvesting Stage	Ginning Stage	Textile Mill Stage	Industry	Yarn St.
Medium Trash	7	No	1	7.7778	0.41	14.8866	23.0744	2281
	8	No	2	7.7778	0.79	14.7868	23.3546	2299
	9	No	3	7.7778	1.11	15.3243	24.2121	2317
	10	Yes	1	7.7577	0.41	14.8822	23.0499	2281
	11	Yes	2	7.7577	0.79	14.7825	23.3302	2299
	12	Yes	3	7.7577	1.11	15.3199	24.1876	2317

Table 5. Total cleaning cost for the harvesting, ginning, and textile mill stages and for the industry. (continued)

				Total Cleaning Cost				
Variety	**Config. No.**	**FC**	**LC**	**Harvesting Stage**	**Ginning Stage**	**Textile Mill Stage**	**Industry**	**Yarn St.**
Low Trash	13	No	1	7.7778	0.41	14.9108	23.0986	2378
	14	No	2	7.7778	0.79	14.8186	23.3864	2410
	15	No	3	7.7778	1.11	15.3513	24.2391	2431
	16	Yes	1	7.4539	0.41	14.9064	22.7703	2378
	17	Yes	2	7.4539	0.79	14.8143	23.0582	2410
	18	Yes	3	7.4539	1.11	15.3462	23.9101	2431