GIN PROCESS CONTROL: IMPORTANCE TO THE COTTON INDUSTRY

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Abstract

Cotton quality in the bale reflects the history of the cotton and is not limited to cotton ginning. A computerized process control system can substantially improve fiber quality and increase the monetary returns to the cotton farmer and textile mill. The current process control system known as "IntelliGin"utilizes the cotton market price and the performance characteristics of gin machinery to determine the optimum drying level and machinery sequence. Cotton moisture, color, and foreign matter measurements are made with electronic devices at three stations in the gin system and are used to feed forward and feed backward to control the gin process. Special routing valves are used to bypass or select any combination of seed cotton cleaners, driers, and lint cleaners as directed by a computer. When gin machinery is bypassed, the quantity of marketable lint is increased and the amount of fiber damage is decreased. The gin process control system minimizes fiber damage and machinery usage while optimizing profits. Control of fiber moisture and gin machinery increases bale value, increases fiber length, increases fiber yield, reduces short fibers, reduces neps, improves removability of seed-coat fragments at the textile mill, and decreases the number of seed-coat fragments.

Introduction

Cotton quality after ginning is a function of its quality in the module or trailer as well as the type and degree of cleaning and drying that it receives during gin processing. Ginning includes drying, trash removal from seed cotton, lint-seed separation, trash removal from lint, and bale packaging. The efficiency of these processes is strongly influenced by the quantity of moisture and trash that the cotton contains. Four stages of seed cotton cleaning are normally used to remove trash from spindle-harvested Upland cotton. These stages consist of spiked cylinders as well as channel-saw type cylinders, though in some cases, combinations of both are used. The cleaners are designed to open the seed cotton and to remove trash fragments. After the ginning process, all lint is cleaned again with a relatively fine-toothed rotating saw cylinder in a device called a "lint cleaner." One to three stages of saw-type lint cleaning are used in conventional gins. An "air-type" lint cleaner is also available.

All cotton in a particular gin usually receives the same degree of cleaning. This occurs without regard to the amount of trash in the cotton initially or the fiber color, primarily because no automatic method exists for measuring the trash in cotton continuously during gin processing. Processing cotton at the gin is an intricate task which proceeds at rates as high as 100 bales per hour. Visual interpretation of the effect of each processing machine on the physical properties of cotton cannot be accurately done by humans. In the past, technological constraints precluded comprehensive online evaluation of the response of cotton fiber to gin processing. Cotton ginning systems consist of several different types of processing machines and each is designed for specific tasks. Each machine influences several physical properties of the cotton fiber and many of those properties must be measured with complex laboratory instruments. A computerized process control system can optimize fiber quality by "prescription" processing the cotton. The purpose of this report is to portray the advantages of selectively processing cotton at the gin. This is accomplished by describing the impact of individual machines on fiber quality with the understanding that the process control system uses the minimal number of machines required to achieve the desired results.

Discussion

Process Control System

The first computerized process control system was installed in a small-scale research facility at Stoneville, MS, and used special routing valves to bypass or select any combination of four seed cotton cleaners, two multi-path driers, and three lint cleaners as directed by a computer (Anthony 1990).

Initially, an infrared moisture meter and a High Volume Instrument (HVI) color and trash meter were installed at three locations in the gin system: 1) feed control, 2) feed hopper above the extractor-feeder, and 3) battery condenser (Anthony 1989). Stations 1 and 2 evaluate seed cotton whereas station 3 evaluates lint. These measurements are then used in the three-dimensional decision matrices that contain machinery decisions based on measurements of moisture, color, and foreign matter. Station 2 was subsequently moved to a position behind the gin stand (Figure 1). Similar installations in six full-scale gins have also been evaluated.

Potential Fiber Quality Improvements

Anthony (1991) developed the performance characteristics of each type of gin cleaning machinery and combination of machines (Anthony 1996a) in terms of their effect on fiber quality as a function of moisture and trash levels as well as cotton varieties. Specifically, the following machine treatments were considered (Anthony 1991):

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(1) Commander extractor-feeder and Continental 93 (20-saw) gin stand only (EFGS)
(2) Lummus cylinder cleaner and EFGS
(3) Continental Little David stick machine and EFGS
(4) Continental Impact cleaner and EFGS
(5) EFGS and one lint cleaner
(6) EFGS and two lint cleaners
(7) EFGS and three lint cleaners
(8) Cylinder cleaner, stick machine, Lummus Trashmaster, EFGS and two Continental 16-D lint cleaners
(9) Lummus Trashmaster and EFGS

Samples were taken before gin processing and at the feeder apron and lint slide to determine the characteristics of the seed cotton as well as the characteristics of the lint cotton. Foreign matter and moisture analyses were performed by the Cotton Testing Laboratory (CTL) at Stoneville (ASTM 1985a; ASTM 1985b; and Shepherd 1972). HVI and Smith-Doxey classifications were done by the Agricultural Marketing Service at Greenwood, MS (USDA, AMS 1994). Neps, seed-coat fragments and short fiber content were determined at the CTL at Stoneville, MS.

Lint moistures after processing were 4.1, 5.5 and 8.4% for the three levels. After processing, lint visible foreign matter averaged 3.0, 4.1 and 7.8% for the three trash levels (Table 1).

Foreign Matter

The visible and total foreign matter remaining in the ginned lint were a function of the variety, moisture, and machinery treatments. Visible lint foreign matter ranged from 3.9% to 6.2% as moisture increased, and from 2.0% to 7.4% as machinery changed (Figure 2).

Length Measurements

From a Machinery standpoint, values for staple length ranged from 36.0 for the EFGS only to 35.1 for the 3-lint cleaner treatment. All lint cleaner treatments decreased staple length. HVI length corresponded directly with moisture level and was 1.10, 1.11 and 1.12 in. respectively, for the low (4.1%), medium (5.5%), and high (8.4%) moisture level (Table 1). No difference existed in length values for the seed cotton cleaners. However, lint cleaners reduced the length by 0.01 in.

Mean lengths, as measured by the Peyer 101, for machinery ranged from 0.86 in. for the three lint cleaner treatment to 0.92 in. for the stick machine treatment (Table 2). Mean length decreased from 0.93 in. to 0.87 in. as lint moisture decreased from 8.4% to 4.1%. The short fiber content by weight (fibers less than 0.5 in. in length) increased from 4.6% to 8.7% as moisture decreased from 8.4% to 4.1%. Seed cotton cleaners did not increase the short fiber content but lint cleaners did. Lint cleaners increased the short fiber content to 6.8, 8.8 and 9.6%, respectively, as one, two and three stages of lint cleaning were used (Figure 3).

Uniformity and Strength

The uniformity was higher for the high moisture level, 82.8, than for the medium, 82.2, and low, 81.9, moisture levels (Table 1). The Machinery treatments caused the mean uniformity to vary (Figure 4) from 81.4 (three lint cleaners) to 82.8 (EFGS only or stick machine) with lint cleaners decreasing uniformity about 1.0; however, machinery differences were not significant. Strength means for moisture were 28.0, 28.6 and 29.2 g/tex, respectively, for cotton processed at 4.1, 5.5 and 8.4% fiber moisture (Table 1).

Seed-coat Fragments and Motes

The number of seed-coat fragments per 3 grams of lint (ASTM 1985c) were about 50% higher at the low moisture level than at the two higher levels (Table 3). Machinery did not significantly influence the number of seed-coat fragments (Figure 5). The weight of seed-coat fragments was significantly influenced by Moisture and Machinery. Means for the high moisture level were significantly higher (33.8 fragments) than for the other two moistures (28.5 fragments). Machinery strongly influenced fragment weight (Figure 4) with the seed cotton cleaners having no effect and lint cleaners decreasing the weight dramatically. The number and weight of motes were decreased dramatically by saw-type lint cleaners.

Neps

Small entanglements of cotton fibers called neps increase each time that cotton is manipulated. Mangialardi (1985) studied samples of cotton fiber collected in seven locations in a gin system and found that neps were increased from 6 to 16 per 100 $in.^2$ of web by simply removing cotton from the trailer pneumatically. Two stages of lint cleaning increased the number of neps dramatically from 18 to 34. Anthony (1991) reported that neps averaged 13.1 and 6.7 per 100 $in.^2$ of web for lint moisture contents of 4.1% and 8.4%, respectively, a decrease of 49% across all machines (Figure 6). He also reported that neps decreased by 15% and 42%, respectively, when one and two stages of lint cleaning were bypassed.

Monetary Returns

Evaluation of computer simulation models for process control suggest that bale values could be increased from $6.86 to $23.38 per bale (based on base price of 60.9 cents per pound for strict low middling and an initial lint moisture content of 6.0%) (Anthony 1985). Obviously, adjustments are required to reflect current market prices. Field experience at commercial gins indicate that these numbers are reasonable and are likely too low for current raw cotton and market conditions (Anthony et al., 1995; and Anthony and Byler 1995).

Fiber Improvement by Process Control

Control of the cotton ginning process minimizes machinery usage as well as drying (Anthony 1996b). Obvious benefits result both in monetary rewards and fiber quality. Control of fiber moisture will: 1) increase length about 4%, 2) reduce short fibers about 47%, 3) increase seed-coat fragment size about 18% and improve removability at the textile mill, 4) decrease the number of seed-coat fragments about 36%, 5) increase measured strength by 5%, and 6) increase fiber yield about 3%.

Control of machines by eliminating a stage of lint cleaning will: 1) increase fiber length about 2%, 2) reduce short fibers about 22%, 3) increase seed-coat fragment size about 21% and improve removability at the textile mill, 4) decrease neps about 15%, and 5) increase fiber yield about 2%. Eliminating two stages of lint cleaning will: 1) increase fiber length about 4%, 2) reduce short fibers about 38%, 3) increase seed-coat fragment size about 80% and improve removability at the textile mill, 4) decrease neps about 42%, and 5) increase fiber yield about 6%. Eliminating other cleaning machines will provide further reductions in fiber quality. Process control designed to maximize farmer monetary returns will also minimize the damage to cotton fiber during gin processing.

Experience

The gin process control system developed at the Stoneville Ginning Lab has been operated successfully. In addition, the system has been installed and validated in several commercial gins. Research and field experience clearly demonstrates that process control designed to maximize farmer monetary returns will also minimize the damage to cotton fiber during gin processing.

Disclaimer

Mention of a trade name, proprietary product, or specific machinery does not constitute a guarantee or warranty by the U.S. Department of Agriculture and does not imply approval of the product to the exclusion of others that may be available.

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Table 1. Main effect means for the dependent variables.

Variables	Lint moisture, %	Lint turnout, %	Lint foreign matter, %		Staple[6]	Length, in.
			Visible	Total		
Moisture, %						
Low	4.14c	33.92a	3.86c	5.54c	35.4c	1.10c
Medium	5.49b	34.00b	4.75b	6.28b	35.6b	1.11b
High	8.37a	33.78c	6.22a	7.52a	36.0a	1.12a
Machines						
Gin stand[2]	6.27ab	35.18a	7.41a	9.08a	35.9a	1.12a
Cylinder cleaner[3]	6.16ab	35.01ab	6.72b	8.40b	36.0a	1.12a
Stick machine[3]	6.07b	34.95b	6.64bc	8.21bc	36.0a	1.12a
Trash master[3]	6.31a	34.89b	6.50cd	8.28bc	36.1a	1.12a
Impact[3]	6.13ab	34.83b	6.40d	8.07c	35.9a	1.12a
One LC[3, 4]	5.86c	33.27c	3.84e	5.25d	35.5b	1.10b
Two LC[3, 4]	5.74c	32.57d	2.73f	4.07e	35.3c	1.10bc
Three LC[3, 4]	5.70c	32.04f	2.03h	3.27f	35.1d	1.10d
Standard[5]	5.79c	32.35e	2.22g	3.41f	35.3cd	1.10cd

[1]Means within each variable not followed by the same lowercase letter are significantly different at the 5% level as judged by Duncan's Multiple Range Test.
[2]Includes extractor-feeder.
[3]Includes extractor-feeder and gin stand.
[4]LC = Lint cleaner.
[5]Standard = drier, cylinder cleaner, drier, stick machine, Trashmaster, extractor-feeder/gin stand and two lint cleaners.
[6]Presented as thirty-seconds of an inch.

Table 1. Continued.

Variables	HVI					
	Rd	Plus b	Color	Trash	Strength, g/tex	Uniformity
Moisture, %						
Low	70.9a	7.7a	45.9c	4.8c	28.0c	81.9c
Medium	70.4b	7.6b	46.9b	5.1b	28.6b	82.2b
High	69.2c	7.6b	49.0a	5.6a	29.2a	82.8a
Machines						
Gin stand[2]	67.9e	7.4d	52.1a	6.0a	28.7ab	82.8ab
Cylinder cleaner[3]	68.5de	7.5c	49.9b	5.9a	28.6ab	82.9a
Stick machine[3]	68.3de	7.5cd	50.3b	6.0a	28.9a	82.8ab
Trash master[3]	68.3de	7.6c	49.9b	5.6b	28.5abc	82.6b
Impact[3]	68.8d	7.5c	49.3b	5.8b	28.6ab	82.8ab
One LC[3, 4]	71.3c	7.7b	45.6c	4.9c	28.5bc	81.9c
Two LC[3, 4]	72.3b	7.8a	43.2d	4.3d	28.5bc	81.8cd
Three LC[3, 4]	73.1a	7.9a	42.5d	3.9e	28.2c	81.4e
Standard[5]	72.9ab	7.8a	42.5d	4.0e	28.7ab	81.7ad

[1]Means within each variable not followed by the same lowercase letter are significantly different at the 5% level as judged by Duncan's Multiple Range Test.
[2]Includes extractor-feeder.
[3]Includes extractor-feeder and gin stand.
[4]LC = Lint cleaner.
[5]Standard = drier, cylinder cleaner, drier, stick machine, Trashmaster, extractor-feeder/gin stand and two lint cleaners.
[6]Presented as thirty-seconds of an inch.

Table 2. Means for fiber length characteristics by weight based on Peyer AL101[1].

Variables	Mean length, in.	Coefficient of variation	Short fiber content, %	Length (25% level), in.	Length (2.5% level), in.	Tuft length (25% level), in.
Moisture, %						
Low	0.87c	27.5a	8.7a	1.04c	1.28c	1.03c
Medium	0.90b	26.2b	6.7b	1.06b	1.31b	1.06b
High	0.93a	24.9c	4.6c	1.08a	1.34a	1.08a
Machines						
Gin stand[2]	0.91a	25.4d	5.5d	1.08a	1.32a	1.07a
Cylinder cleaner[3]	0.91a	25.2d	5.3d	1.08a	1.32a	1.07a
Stick machine[3]	0.92a	25.1d	5.3d	1.08a	1.32a	1.07a
Trash master[3]	0.91a	25.2d	5.2d	1.08a	1.33a	1.07a
Impact[3]	0.91a	24.9d	5.1d	1.07a	1.32a	1.06a
One LC[3, 4]	0.89b	26.3c	6.9c	1.06b	1.31b	1.05b
Two LC[3, 4]	0.87d	27.7b	8.8b	1.04d	1.29cd	1.04d
Three LC[3, 4]	0.86e	28.3a	9.5a	1.03e	1.29d	1.03d
Standard[5]	0.88c	27.5b	8.3b	1.05c	1.30bc	1.05c

[1]Means within each variable not followed by the same lowercase letter are significantly different at the 5% level as judged by Duncan's Multiple Range Test.
[2]Includes extractor-feeder.
[3]Includes extractor-feeder and gin stand.
[4]LC = Lint cleaner.
[5]Standard = drier, cylinder cleaner, drier, stick machine, Trashmaster, extractor-feeder/gin stand and two lint cleaners.

Table 3. Treatment means for seed-coat fragments based on three grams of lint[1].

Variables	Number of seed-coat fragments, per 3g lint	Weight of seed-coat fragments, mg/3g lint	Number of motes per 3g lint	Weight of motes per 3g lint
Moisture, %				
Low	121.88a	28.61b	3.05a	13.16a
Medium	81.35b	28.47b	2.76a	13.77a
High	77.93b	33.76a	3.23a	16.53a
Machines				
Gin stand[2]	92.25a	38.46a	3.61ab	21.03a
Cylinder cleaner[3]	99.67a	40.69a	3.11bc	18.42a
Stick machine[3]	99.03a	39.12a	4.58a	23.32a
Trash master[3]	94.19a	35.14a	3.89ab	20.16a
Impact[3]	92.33a	37.36a	3.81ab	20.14a
One LC[3, 4]	98.08a	25.76b	2.92bc	11.74b
Two LC[3, 4]	93.75a	21.41bc	2.03cd	5.35c
Three LC[3, 4]	86.83e	16.88c	1.23d	3.39c
Standard[5]	87.03a	17.44c	1.89cd	6.58bc

[1]Means within each variable not followed by the same lowercase letter are significantly different at the 5% level as judged by Duncan's Multiple Range Test.
[2]Includes extractor-feeder.
[3]Includes extractor-feeder and gin stand.
[4]LC = Lint cleaner.
[5]Standard = drier, cylinder cleaner, drier, stick machine, Trashmaster, extractor-feeder/gin stand and two lint cleaners.

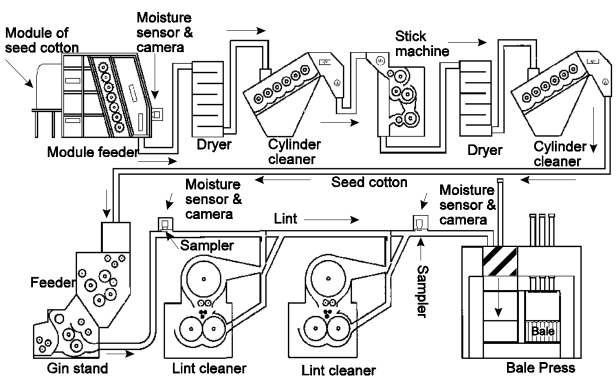

Figure 1. Schematic of a small-scale ginning system with video trash cameras installed at the feed control, after the gin stand, and condenser.

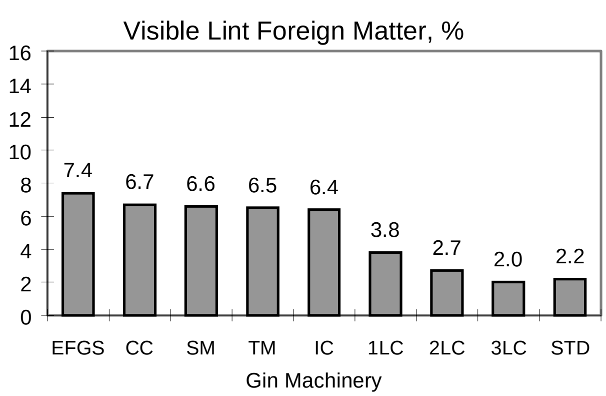

Figure 2. Visible lint foreign matter as a function of gin machinery where EFGS = extractor-feeder/gin stand only, CC = EFGS + CC, SM= stick machine + EFGS, TM = Trashmaster + EFGS, IC = Impact cleaner + EFGS, 1LC = Lint Cleaner + EFGS, 2LC = two lint cleaners + EFGS, 3LC = three lint cleaners + EFGS and STD = cylinder cleaner, stick machine, Trashmaster, EFGS and two lint cleaners.

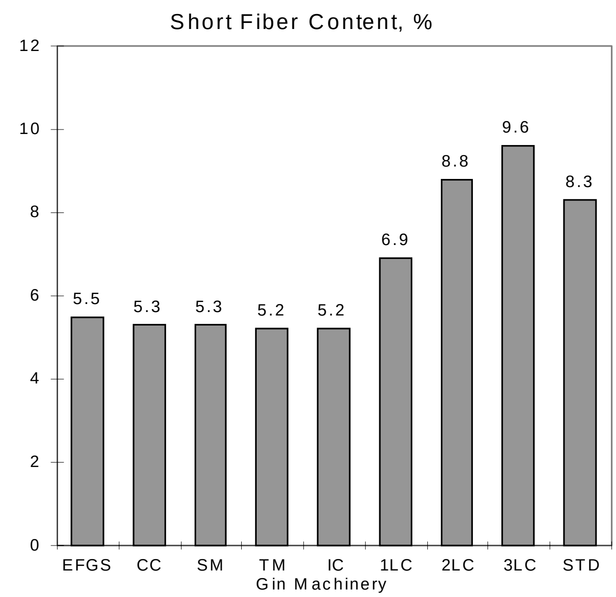

Figure 3. Short fiber content as a function of gin machinery where EFGS = extractor-feeder/gin stand only, CC = EFGS + CC, SM = stick machine + EFGS, TM = Trashmaster + EFGS, IC = Impact cleaner + EFGS, 1LC = lint cleaner + EFGS, 2LC = two lint cleaners + EFGS, 3LC = three lint cleaners + EFGS and STD = cylinder cleaner, stick machine, Trashmaster, EFGS and two lint cleaners.

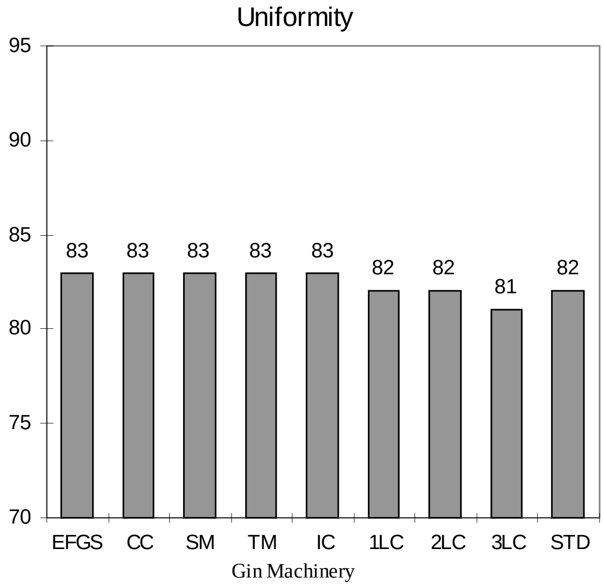

Figure 4. Uniformity as a function of gin machinery where EFGS = extractor-feeder/gin stand only, CC = EFGS + CC, SM = stick machine + EFGS, TM = Trashmaster + EFGS, IC = Impact cleaner + EFGS, 1LC = lint cleaner + EFGS, 2LC = two lint cleaners + EFGS, 3LC = three lint cleaners + EFGS and STD = cylinder cleaner, stick machine, Trashmaster, EFGS and two lint cleaners.

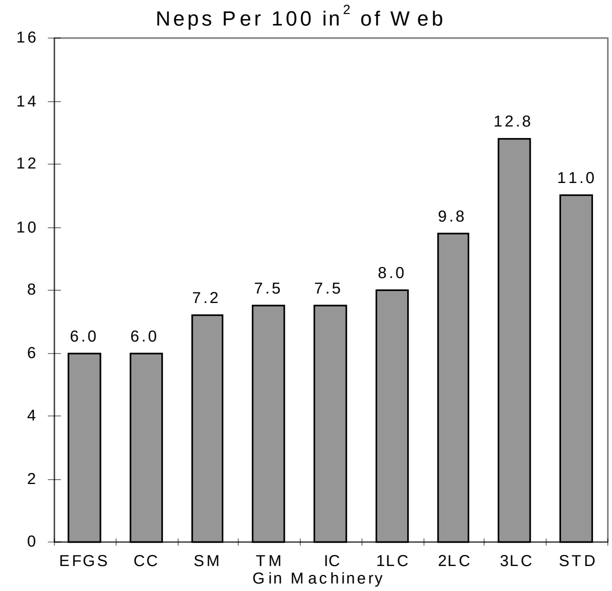

Figure 6. Neps averaged across moisture levels as a function of gin machinery where EFGS = extractor-feeder/gin stand only, CC = EFGS + CC, SM = stick machine + EFGS, TM = Trashmaster + EFGS, IC = Impact cleaner + EFGS, 1LC = lint cleaner + EFGS, 2LC = two lint cleaners + EFGS, 3LC = three lint cleaners + EFGS and STD = cylinder cleaner, stick machine, Trashmaster, EFGS and two lint cleaners.

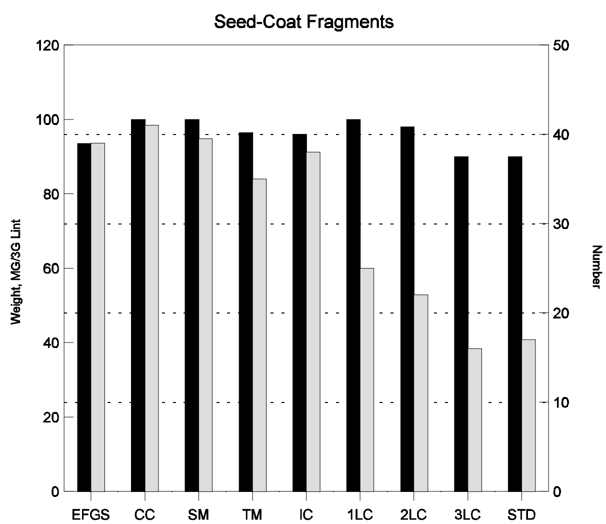

Figure 5. Seed-coat fragment number and weight as a function of gin machinery where EFGS = extractor-feeder/gin stand only, CC = EFGS + CC, SM = stick machine + EFGS, TM = Trashmaster + EFGS, IC = Impact cleaner + EFGS, 1LC = lint cleaner + EFGS, 2LC = two lint cleaners + EFGS, 3LC = three lint cleaners + EFGS and STD = cylinder cleaner, stick machine, Trashmaster, EFGS and two lint cleaners.