Ginning: A New Frontier

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ABSTRACT

The quality of baled cotton fiber is not solely dependent on ginning, but reflects the entire history of the bale including variety, soil type, geographical location, cultural practices, storage, ginning, etc. Controlling the appropriate factors before ginning and prescribing the appropriate gin cleaning and drying needs of cotton can substantially improve fiber quality and increase monetary returns to the farmer and textile mill. The current process control system known as "IntelliGin[1]" utilizes the cotton market price and the performance characteristics of gin machinery to determine the optimum drying level and machinery sequence. Cotton moisture, colour, 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, dryers, 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, fiber length, fiber yield, reduces short fibers, neps, improves removability of seed-coat fragments at the textile mill, and decreases the number of seed-coat fragments.

Introduction

Since the invention of the cotton gin in 1792 by Eli Whitney and subsequent invention of the forerunner for the modern day cotton gin by Henry Holmes in 1794, enormous advancements have occurred in cotton ginning. The basic lint seed separation or ginning process has improved from just a few pounds per hour to well over 20,000 pounds per hour per machine. Additional machines such as seed cotton cleaners, as well as methods to dry the fiber in the seed cotton form and methods to clean the fiber after the ginning process have been added. The bale packaging process has improved from simple bagging of the lint to production of well-protected, uniform bales weighing in excess of 500 pounds with densities in excess of 26 lb/ft^3.

A brief review of individual machine functions is necessary to fully appreciate the ginning process. Cotton possesses its highest fiber quality and best potential for spinning soon after boll opening. Lint quality of the cotton[1] in the bale depends on many factors, including variety, weather conditions, cultural and harvesting practices, moisture and trash content, and ginning processes.

The principal function of the cotton gin is to separate lint from seed, but it must also be equipped to remove a large percentage of the foreign matter from the cotton that would significantly reduce the value of the ginned lint. A ginner must have two objectives: (1) to produce lint of satisfactory quality for the grower's market and (2) to gin the cotton with minimum reduction in fiber spinning quality to meet the demands of its ultimate users, the spinner and the consumer. Mechanical handling and drying may modify the natural quality characteristics of cotton. Accordingly, quality preservation during ginning requires the proper selection and operation of each machine that is included in a ginning system. At best, a ginner can only preserve the quality characteristics inherent in the cotton when it enters the gin. The following paragraphs briefly discuss the function of the major mechanical equipment and processes in the gin (Figure 1).

Green-Boll Trap

Cotton is transported from a trailer or module into a green-boll trap (not shown) in the gin. The trap removes green bolls, rocks, and other heavy foreign matter. These heavy materials are removed early in the ginning system to prevent damage to machinery and to preserve fiber quality by removing immature cotton contained in unopened bolls.

Automatic Feed Control

The automatic feed control provides an even, well-dispersed flow of cotton to facilitate efficient operation of the gin's cleaning and drying system. Cotton that is not well dispersed can travel through

[1] 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.

the drying system in clumps, only its surface being dried.

Dryers

In the first stage of drying, heated air conveys the cotton through the shelves for 10-15 sec. The temperature of the conveying air is regulated to control the amount of drying. To prevent fiber damage, the temperature to which the cotton is exposed during normal operation should never exceed 350 $_{o}$F. Temperatures above 300 $_{o}$F can cause permanent physical changes in cotton fibers. Dryer-temperature sensors should be located as near as possible to the point where cotton and heated air mix together. If the temperature sensor is located near the exit of the tower dryer, the mixpoint temperature could actually be 100-200 $_{o}$F higher than the temperature at the downstream sensor. The downstream temperature drop results from the cooling effect of evaporation and from heat loss through the walls of machinery and piping.

Cylinder Cleaners

Drying continues as warm air moves the seed cotton to the cylinder cleaner, consisting of six or seven revolving, spiked-cylinders, rotating at 400-500 rpm. The cylinders scrub the cotton over a series of grid rods or screens, agitate the cotton, allowing fine foreign materials such as leaves, trash, and dirt, to pass through the openings for disposal. Cylinder cleaners break up large wads and generally condition cotton for additional cleaning and drying. Processing rates of about two bales per hour per foot of cylinder length are common.

Stick Machines

The stick machine removes larger foreign matter, such as burs and sticks, from the cotton. Stick machine saws hold the fiber while the centrifugal force created by saw cylinders rotating at 300-400 rpm to "slings off" foreign material. Foreign matter slung off by the reclaimer feeds into the trash-handling system. Processing rates of 1.5-2.0 bales/hr/ft of cylinder length are common.

Conveyor-Distributor

After going through another stage of drying and cylinder cleaning, cotton is distributed to each gin stand by the conveyor-distributor. It is important to keep the conveyor-distributor full so that the last gin stand will be supplied with cotton.

Extractor-Feeder

Located above the gin stand, the extractor-feeder meters seed cotton uniformly to the gin stand at controllable rates and cleans seed cotton as a secondary function. The moisture content of cotton fiber at the extractor-feeder apron is critical. The moisture must be low enough that foreign matter can be easily removed in the gin stand. However, the moisture must not be so low (below 5 percent) as to result in the breakage of individual fibers as they are separated from the seed. This breakage causes an appreciable reduction both in fiber length and lint turnout. From a quality standpoint, cotton with a higher content of short fibers produces excessive waste at the textile mill and is less desirable. Excessive breakage of fibers can be avoided by maintaining fiber moisture content at 6-7 percent at the extractor-feeder apron.

Gin Stand

The modern gin plant typically has multiple gin stands. Cotton enters the gin stand through a huller front. The saws grasp the cotton and draw it through widely spaced ribs known as huller ribs. The locks of cotton are drawn from the huller ribs into the bottom of the roll box. The actual ginning process--separation of lint and seed--takes place in the roll box of the gin stand. The ginning action is caused by a set of saws rotating between ginning ribs. The saw teeth pass between the ribs at the ginning point. Here the leading edge of the teeth is approximately parallel to the rib, and the teeth pull the fibers from the seed, which are too large to pass between the ribs. Ginning at rates above those recommended by the manufacturer can cause fiber quality reduction, seed damage, and choke-ups. Gin stand saw speeds are also important. High speeds tend to increase the fiber damage done during ginning.

Lint Cleaners

It is very important for cotton to flow uniformly and be well dispersed, particularly as it leaves the gin stand. Cotton is conveyed from the gin stand through lint ducts to condensers and formed again into a batt. The batt is removed from the condenser drum and fed into the saw-type lint cleaner. The batt should be of uniform thickness and be evenly spread over the entire width of the lint cleaner; otherwise, poor cleaning and excessive fiber loss will result.

Inside the lint cleaner, cotton passes through the feed rollers and over the feed plate that applies the fibers to the lint cleaner saw. The saw carries cotton under grid bars that are aided by centrifugal force in removing immature seeds and foreign matter. The proper setting of the clearance between the saw tips and grid bars is important. The grid bars must be straight with a sharp leading edge to avoid reducing cleaning efficiency and increasing lint loss. Increasing the lint cleaner's feed rate above the manufacturer's recommended rate will decrease cleaning efficiency and increase loss of good fiber. Lint cleaners can improve the grade of cotton by removing foreign matter. In some cases, lint cleaners may improve the colour of lightly spotted cotton by blending to produce a white grade. They may also improve the colour grade of spotted cotton to light spotted or perhaps white colour grade. Fiber length can be damaged by excessive lint cleaning, especially when the cotton is too dry. Ginners should determine the number of lint cleaners that gives maximum bale value based on a compromise between increased grade, reduced staple length, and reduced turnout. The standard ginning process described is used on nearly all the cotton bales produced in the United States, regardless of their foreign matter level or the desired end product. A new technology, the Computerized Gin Process Control System (CGPCS) (Anthony, 1990), marketed under the name "IntelliGin" is now available to prescription process cotton (Anthony 1998). The IntelliGin is based on many US Department of Agriculture (USDA) patents that are licensed to Zellweger Uster of Knoxville, TN, for manufacturing and marketing.

Bale Press

The cleaned cotton is compressed into bales, which must then be covered to protect them from contamination during transportation and storage. Most bales in the United States are gin universal density. These bales are packaged at densities of 28 lb/ft3. In most gins cotton is packaged in a "double-box" press wherein the lint is initially compacted in one press box by a mechanical or hydraulic tramper; then the press box is rotated, and the lint is further compressed to about 40 lb/ft3. In 1997, about 98 percent of the bales in the United States were gin universal density bales. Bales should be packaged and tied only in material approved for storage by the Commodity Credit Corporation loan program. Bales of other sizes, weights and densities are produced in other countries.

Purpose

Cotton ginning systems consist of several different types of processing machines, each 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 and to establish the potential for ginning to be the next frontier for the cotton industry.

Discussion

Gin Machinery Impact on Fiber Quality

Knowledge of the performance characteristics of gin machinery is the basis for controlling the gin process. Anthony (1991) developed performance characteristics of each type of gin cleaning machine 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):

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

The study also included three moisture levels (4.1, 5.5 and 8.4%) (Table 1) and three trash levels (3.0, 4.1 and 7.8% (not shown)) based on the Shirley Analyzer visible foreign matter.

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. The Cotton Testing Laboratory (CTL) at Stoneville (ASTM, 1985a; ASTM, 1985b; Shepherd, 1972), performed foreign matter and moisture analyses 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.

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 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 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 seedcoat fragments per 3 grams of lint (ASTM 1985c) was 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 4). The weight of seedcoat fragments was influenced significantly by moisture and machinery. Means were significantly higher for the high moisture level (33.8 fragments) than for the other two moistures (28.5 fragments). Machinery strongly influenced fragment weight (Figure 4), with seed cotton cleaners having no effect but lint cleaners decreasing the weight dramatically. The mote number and weight was 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 5). He also reported that neps decreased by 15% and 42%, respectively, when one and two stages of lint cleaning were bypassed.

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 dryers, and three lint cleaners as directed by a computer (Anthony, 1990). Initially, an infrared moisture meter and a High Volume Instrument (HVI) colour 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 used in the three-dimensional decision matrices containing machinery decisions based on measurements of moisture, colour, 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 been evaluated. Note that Figure 1 approximates the cross-sectional view of each gin machine.

Fiber Improvement by Process Control

Control of the cotton ginning process minimizes machinery usage as well as drying (Anthony 1996b). Obvious benefits result in both monetary rewards and fiber quality. Control of fiber moisture will: 1) increase length about 4%, 2) reduce short fibers about 47%, 3) increase seedcoat fragment size about 18%, improving removability at the textile mill, 4) decrease the number of seedcoat 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 seedcoat 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 seedcoat 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 improvements in fiber quality. Process control designed to maximize farmer monetary returns also minimizes fiber damage.

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 probably too low for current raw cotton and market conditions (Anthony *et al.*, 1995; Anthony and Byler 1995, 1996, and 1997). Greene (1998) reported farmer profit increases of over $40 per bale. He also reported dramatic improvements in fiber quality based on HVI measurements. Mill processing experiences with the cotton produced from gins equipped with the IntelliGin have been exceptionally good with higher quality yarn produced at lower costs.

Experience

The gin process control system developed at the Stoneville Ginning Lab has operated successfully for several years. 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. Components of the CGPCS were initially field tested at Burdette Gin near Leland, MS, in 1989. After successful validation, the components were installed at Westlake Gin, Stratford, CA (Anthony *et al.*, 1995) and Servico Gin, Courtland, AL (Anthony *et al.*, 1996). Excellent results have been achieved at Westlake since 1992. The Servico system processed about 40,000 bales successfully in 1994 and improved monetary returns to the farmer as well as provided cotton of a higher spinning quality. It also helped identify several additional opportunities for improvements during the gin process. The CGPCS at Servico was improved and operated in 1995, yielding even better results for the farmer and spinner. Based on the successes in 1994 and 1995, Zellweger Uster licensed several USDA patents to enable them to make the CGPCS available to the cotton industry. In 1996, the CGPCS at Servico was upgraded with Zellweger Uster cameras. Again, the upgraded CGPCS was very successful. New Zellweger Uster manufactured sampling stations, flash cameras, FM data transmission equipment and other improvements were installed at Servico prior to the 1997 season. The new system essentially operated on “automatic pilot” during the 1997 season. Experiences with the cotton from Servico at one textile mill have been exceptionally farmable. The same mill has purchased the entire gin production for 1998 (Greene, 1998). New beta sites were also installed prior to the 1997 season at Marianna and Dumas, AR, and were Zellweger Uster’s first installations. Additional CGPCSs are being installed for the 1998 season. Thus, this new technology is now available to the cotton industry on a limited basis.

Future

Rapid expansion of automated and intelligent process control systems for cotton gins will vastly improve the quality of cotton. The capability to rapidly determine the essential fiber quality features of cotton and to consider the ability of individual cotton machines to modify those fiber quality characteristics every few seconds, and to make those measurements at multiple locations in the ginning process and refine the machinery selection is the basis for a new frontier in cotton ginning. Armed with a full spectrum of knowledge concerning the fiber qualities of cotton online during processing and the capabilities of gin machines to influence those fiber qualities, this new frontier will represent many future opportunities for improved ginning processes. It will also serve as a platform for major advancements in gin machinery, in fact, some are already in the patent process. New, less aggressive and less damaging machines can be developed and integrated into existing gin systems that can now monitor the performance of those machines. Ginners will now be able to achieve the desired fiber qualities based upon guidance from the farmer or textile mill within constraints of initial fiber quality characteristics. Farmers, ginners, gin managers, and the textile industry now have access to instantaneous online measurements of cotton quality. Interactive, responsive processing at the gin can now be controlled remotely by the buyer of the cotton. Enormous opportunities exist for re-engineering the post harvest processing of cotton to deliver textile mills precise products that meet their specifications. With control of the cotton fiber quality characteristics comes the opportunity for improvements in the textile industry. The stage is now set for ginning to be the next new frontier in cotton processing.

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Table 1. Moisture and machine main effect means for the dependent variables, (means for trash levels are not shown).

Variables	Lint moisture %	Lint turnout, %	Lint foreign matter %		Length	HVI				
			Visible	Total	in	Rd	+ b	Trash	Strength g/tex	Uniformity index
Moisture, %										
Low	4.14c	33.92a	3.86c	5.54c	1.10c	70.9a	7.7a	4.8c	28.0c	81.9c
Medium	5.49b	34.00b	4.75b	6.28b	1.11b	70.4b	7.6b	5.1b	28.6b	82.2b
High	8.37a	33.78c	6.22a	7.52a	1.12a	69.2c	7.6b	5.6a	29.2a	82.8a
Machines										
Gin stand[2]	6.27ab	35.18a	7.41a	9.08a	1.12a	67.9e	7.4d	6.0a	28.7ab	82.8ab
Cylinder	6.16ab	35.01ab	6.72b	8.40b	1.12a	68.5de	7.5c	5.9a	28.6ab	82.9a
cleaner[3]	6.07b	34.95b	6.64bc	8.21b	1.12a	68.3de	7.5cd	6.0a	28.9a	82.8ab
Stick machine[3]	6.31a	34.89b	6.50cd	c	1.12a	68.3de	7.6c	5.6b	28.5abc	82.6b
Trash master[3]	6.13ab	34.83b	6.40d	8.28b	1.12a	68.8d	7.5c	5.8b	28.6ab	82.8ab
Impact[3]	5.86c	33.27c	3.84e	c	1.10b	71.3c	7.7b	4.9c	28.5bc	81.9c
One LC[3, 4]	5.74c	32.57d	2.73f	8.07c	1.10bc	72.3b	7.8a	4.3d	28.5bc	81.8cd
Two LC[3, 4]	5.70c	32.04f	2.03h	5.25d	1.10d	73.1a	7.9a	3.9e	28.2c	81.4e
Three LC[3, 4]	5.79c	32.35e	2.22g	4.07e	1.10cd	72.9ab	7.8a	4.0e	28.7ab	81.7ad
Standards[5]				3.27f						
				3.41f						

[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 mg /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. Typical schematic of a ginning system with video trash cameras installed at the feed control, after the gin stand, and condenser.

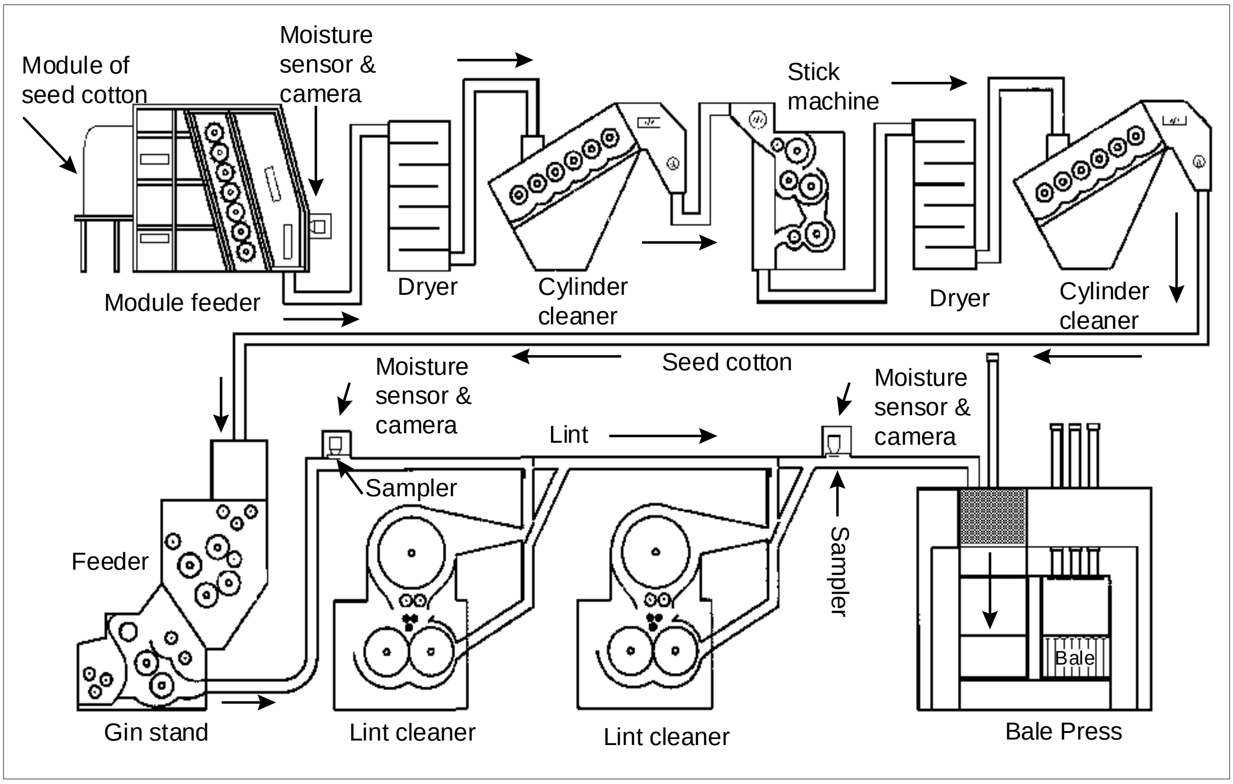


Figure 2. Visible lint foreign matter as a function of gin machinery.

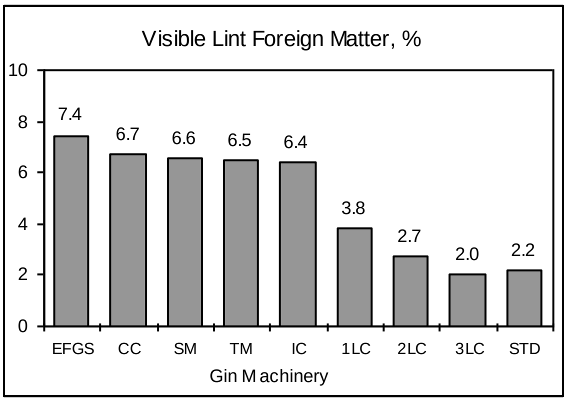


Figure 3. Short fiber content as a function of gin machinery.

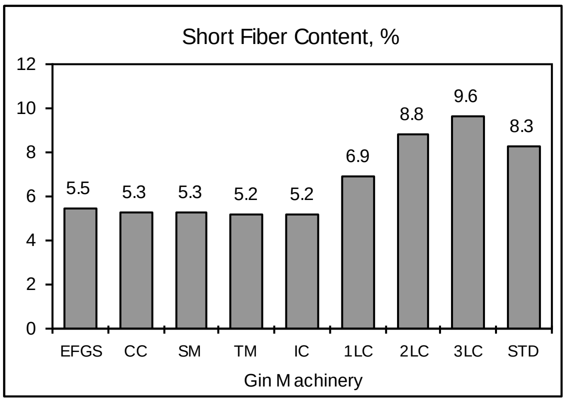


Figure 4. Neps averaged across moisture levels as a function of gin machinery.

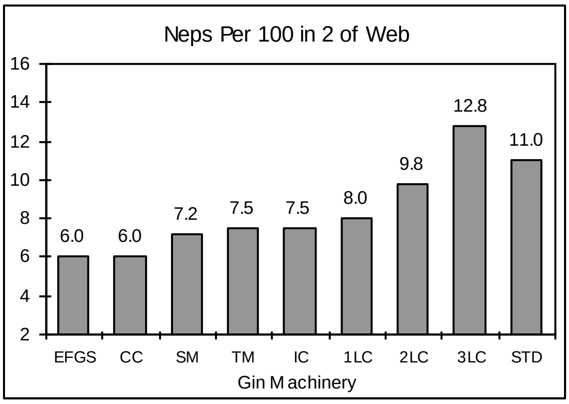
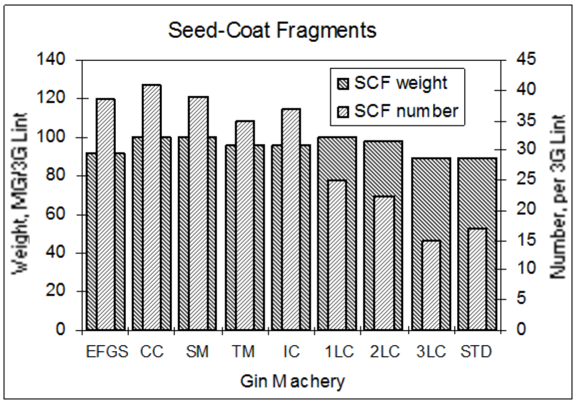


Figure 5. Seed-coat fragment weight and number as a function of gin machinery.



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.