THE IMPACT OF HISTORICAL GIN STAND TECHNOLOGIES ON COTTON FIBER AND SEED QUALITY

D. P. Whitelock, M. D. Buser, C. B. Armijo, S. E. Hughes

ABSTRACT. *The trend in modern gin stand designs to increase gin stand production rate in terms of bales/h was generally achieved by increased width, narrower saw spacing, and higher saw loading. This study examined fiber length reductions, short fiber content, fiber neps, and cottonseed damage associated with five saw gin stands of differing production rates, design, and manufacture that represent a range of gin technologies developed since the 1960s to identify technologies from those earlier designs that may guide future gin stand research. Based on rated ginning rate, the gin stands were classified in two general categories, lower capacity (LC, 5 bales/h and less) and higher capacity (HC, 7.5 bales/h and higher). Fiber from the LC gin stands contained fewer fiber neps, longer fibers, less short fiber, and less foreign matter than fiber from the HC gin stands. In addition, cottonseed from the gin stand with lowest capacity had the highest residual linters content and the lowest overall seed damage which aligned with the short fiber content data. Both the LC gin stands were older models and had wider saw spacing; the oldest of them was substantially different from the other designs with two saw mandrels pulling fiber from the same seed roll position. Study results indicate that there may be historical gin stand technologies and relationships between gin parameters such as ginning rate per saw, saw spacing, and seed roll density, and fiber and seed quality that need to be further investigated.*

Keywords. *Cottonseed quality, Cotton ginning, Fiber quality, Gin stand, Length, Neps, Short fiber content, Upland cotton.*

Cotton short fiber content (SFC) and neps from saw ginning have long been a topic of concern. The percentage of fibers less than 12.7 mm in length by weight or by number defines SFC (ASTM, 2012a; Uster Technologies, 2015). The SFC in cotton lint is inversely related to yarn strength and can directly affect the quality of a finished product (Anthony, 1985; Krifa et al., 2001). Neps are small knots of tangled fibers, which are created during boll development, harvesting, ginning, and yarn

manufacturing (Mangialardi et al., 1988). Neps may affect manufacturing, cause non-uniform dyeing, and affect the appearance of woven fabrics.

Several studies have focused on the formation of neps and SFC in gin stands. Early gin stands had about 90 saws set on 19-mm centers that turned at about 700 rpm. These stands had an optimum ginning rate of 327 to 435 kg (1.5 to 2 bales) of lint/h or about 4 kg/saw/h (Griffin, 1979). Higher capacity gin stands became readily available in the early 1960's. Some of these stands incorporated either larger diameter saws (410- or 460-mm diameter), redesigned roll boxes, reciprocating seed roll actions, or dual saw cylinders and achieved ginning rates of 762 to 1,524 kg (3.5 to 7 bales) of lint/h or about 12 kg/saw/h saw loading (Wilmot and Watson, 1966). Gin stand capacities have continued to increase and modern gin stand designs generally achieved increased gin stand production by increased width, narrower saw spacing, and higher saw loading and seed roll density (Mangialardi and Anthony, 2005; Hughes et al., 2017).

Griffin (1979) suggested that higher capacity gin stands do not create an abnormal quantity of SFC or fiber breakage when ginning at manufacturers' recommended rates of about 1,134 kg (5.2 bales) of lint/h. He further concluded that ginning at higher than recommended rates for a given gin stand (1,568 kg of lint/h or 7.2 bales/h) caused a significant increase in fiber breakage and thus, SFC.

Studies from the 1950's to the 1970's indicated that fiber neps increased with increasing seed roll density and can be

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The authors are **Derek P. Whitelock**, Research Leader, USDA-ARS Southwestern Cotton Ginning Research Laboratory, Mesilla Park, New Mexico; **Michael D. Buser**, National Program Leader, USDA-ARS Office of National Programs, Beltsville, Maryland; and **Carlos B. Armijo**, Textile Technologist and **S. Ed Hughes**, Retired, USDA-ARS Southwestern Cotton Ginning Research Laboratory, Mesilla Park, New Mexico. **Corresponding author:** Derek P. Whitelock, USDA-ARS Southwestern Cotton Ginning Research Laboratory, PO Box 578, Mesilla Park, NM 88047; phone: 575-526-6381; e-mail: derek.whitelock@ars.usda.gov.

affected by saw spacing, number of teeth per saw, and saw tooth condition. Early saw gin research indicated that seed roll density was a much more significant factor affecting fiber quality than saw speed (Bennett and Gerdes, 1936, 1937). Mangialardi (1985) evaluated nep formation at the gin and determined that gin stands were a major contributor to nepping during gin processing. In another study, ginning rates from 305 to 1,393 kg (1.4 to 6.4 bales) of lint/h did not significantly affect nep count for a gin stand rated at 1,043 kg (4.8 bales) of lint/h (Mangialardi et al., 1988). Holt and Laird (2007, 2008, 2010) conducted more recent studies on their patented powered roll gin stand to increase production and turnout without reducing fiber quality. The main operational components of the technology were the paddle roll that actively turned the seed roll and seed finger roll that presents unginned cottonseed back to the saw. While the powered roll gin stand did show improvements in production rates and fiber quality relative to conventional gin stands, it has not been widely adopted.

Seed damage studies have focused on the effects of pneumatic conveying, gin saw diameter, and ginning rate effects to find methods of reducing seed damage during the ginning process. Anthony (1985) reviewed several studies, which related increased seed damage to increased saw diameter and increased ginning rates. The review stated that seed damage consisting of slits and cracks parallel to the minor axis of the seed have been characterized as conveying damage, while slits and cuts parallel to the major axis of the seed have been defined as damage due to the gin stand. Reducing seed damage is important in terms of increasing germination, as well as improving fiber quality. Seed damage typically results in seed coat fragments (SCF), which can result in additional neps (fiber entangled around a SCF) and higher trash content.

The primary function and basic operating principle of the gin stand has not changed since its invention (Hughes and Holt, 2015). There have been design variations over the years, including huller fronts designed to remove hulls and feed seed cotton into the gin roll box; air or brush doffing systems to remove ginned lint from gin saw; seed tubes to convey seed from inside the seed roll without damage or seed roll agitators to aid in turning the seed roll and improve loading of lint on gin saws to increase capacity; the number of saw mandrels; and the diameter, number, and spacing of gin saws (Mangialardi and Anthony, 2005) (fig. 1). One of the main goals of gin machinery manufacturers over the years has been to increase gin stand capacity (fig. 2). Gin stands manufactured in the late 1950s and '60s averaged about 5 bales of lint/h utilizing about 100 saws. On the other hand, gin stands currently advertised have manufacturer-rated ginning rates as high as 6,532 kg (30 bales)/h and have more than 200 saws (Hughes et al., 2017). The various improvements mentioned earlier contributed to higher ginning rates, but the main drivers of capacity increases have been narrower saw spacing (11 to 14 mm), thus more saws per unit width, and wider gin stands. There is limited information available on how this evolution has affected fiber or seed quality, in particular nep formation and SFC.

The objective of this study was to evaluate gin stands with different configurations that represent levels of gin stand

Figure 1. Side view of typical gin stand.

technology developed since the 1960s and determine if the stands produced ginned lint and cottonseed of differing quality, specifically SFC, length, neps, and seed damage. The information obtained from this study could identify old technologies that may have been discontinued during the race for higher capacity, but may be used in future gin stand research to reduce SFC and fiber breakage, neps, and seed damage.

METHODS

The commercial-size ginning plant at the USDA-ARS Cotton Ginning Research Unit (CGRU) in Stoneville, Mississippi, was used in this study. The recommended seed cotton cleaning sequence for Mid-South spindle-picked cotton was used in this study (Baker et al., 1994). The standard sequence consisted of a 24-shelf tower drier, 6-cylinder incline cleaner, stick machine, 24-shelf tower drier, 6-cylinder inclined cleaner, and extractor-feeder. Five saw-type gin stands of different design in service at the CGRU were evaluated. A comparative list of the details of each gin stand, as supplied by the manufacturer, is shown in table 1.

The saw gin stands shown from left to right in table 1 represent ginning technologies developed by different manufacturers between the 1960s and 1990s. The gin stands listed in table 1 do not include the newest, widest, highest capacity gin stands that can be obtained from manufacturers today. However, Valco et al. (2018) showed that in 2016 the average rated capacity of gin facilities across the Cotton Belt was about 40 bales/h and the median total bales ginned was about 30,000. Because many of the active gin facilities in the United States are lower capacity and gin fewer bales, many of the earlier model gin stands, even from gin manufacturers that have gone out of business or have been merged into other companies, are maintained and remain active in the ginning industry today (Hughes et al., 2017).

Figure 2. Gin stand rated capacity trend from the 1950s to 2010s (Hughes et al., 2017).

Further information and descriptions of the gin stands in table 1 can be found in Hughes et al. (2017) and Mangialardi and Anthony (2005). Gin stand A was a Hardwicke-Etter Regal 178 (Hardwicke-Etter Company, Sherman, Tex.) that was introduced in 1962 and had 178 total saws spaced 19 mm apart on dual saw mandrels and rated capacity of 4.5 bales/h. Gin stand A increased capacity over single-man-

drel gin stands of the time by positioning an upper saw mandrel above and parallel with the lower mandrel to pull fiber from the same seed roll, thus plucking lint from unginned cotton in the seed roll where single saws did not. With the addition of the second saw mandrel, processing rate per saw was more on the order of earlier gin stands. The dual saw principle utilized more saws in the gin stand, but was designed to take up the same floor space as a 90-saw gin stand. Gin stand B was a 93-saw Continental Eagle (Continental Eagle Corporation, Prattville) from model year 1973 (Hughes et al., 2017). Gin stand B had similar capacity and power requirement as gin stand A, but used a single saw mandrel with larger 406-mm diameter saws spaced approximately 3 mm closer together. Gin stand C was a 1979 Continental 93-saw Double Eagle (Continental Eagle Corporation, Prattville, Ala.) and represented a higher capacity gin than gin stand B. This was accomplished through increased motor power and the addition of a seed tube in the center of the seed roll box that allowed a higher rate of seed discharge from the seed roll. Gin stand D was a Consolidated Horn 112 (Consolidated HGM Corporation, Lubbock, Tex.) from 1989. This stand had rated capacity one bale/h greater than gin stand C at the same power requirement. This was achieved mainly through more (112) and narrower spaced (12.7 mm) saws. Also, gin stand D had a powered agitator

Table 1. Gin stand details as specified by the manufacturer (Columbus et al., 1994; Mangialardi and Anthony, 2005; Hughes et al., 2017).

	Gin Stand				
	A ^[a]	B ^[a]	C ^[b]	D ^[b]	E ^[b]
Saw spacing, mm	19.0	15.9	15.9	12.7	12.7
Saw diameter, mm	298, 305	406	406	305	305
Saw speed, rpm	695, 650	625	615	841	850
No. of saws	178	93	93	112	116
No. of saw cylinders	2	1	1	1	1
Roll box width, m	1.73	1.60	1.60	1.65	1.68
Recommended ginning rate, bales/h	4-4.5	5	7.5	8.5	10
Recommended saw loading, kg/saw/h	4.9-5.5	11.7	17.6	16.6	18.8
Seed roll modification	No	No	Seed tube	Agitator	Agitator
Motor power, kW	37	37	56	56	75

^[a] Lower-capacity (LC) saw-type gin stand.

^[b] Higher-capacity (HC) saw-type gin stand.

cylinder in the roll box to aid rotation of the seed roll. Gin stand E was the newest model gin stand, a 1996 model year Lummus 116-saw Imperial III (Lummus Corporation, Savannah, Ga.). This gin stand, though narrower and with fewer saws than the very newest models offered by many manufacturers today, is still advertised by the manufacturer and represents modern gin stand technology featuring 12.7-mm saw spacing, hullerless front, and seed roll agitator. For the purpose of this study, the manufacturer of the individual machines is unimportant thus, the gin stands will simply be referred to as gin stands A-E from this point forward.

The gin stands in table 1 represent a range of gin technologies with similar widths, but different number of saws and capacities. Broadly speaking, they represent engineering to increase ginning efficiency by increasing gin stand production rate in terms of bales/hour/stand. There are a number of design differences between the gin stands but, with the exception of gin stand A, increased production was accomplished by decreasing gin saw spacing (putting more saws pulling fiber in the same space in the roll box) and increasing seed roll density to increase saw tooth loading. There were also differences between saw diameters and speeds, but the actual tip velocity of the saw teeth between the different gin stands was not greatly different. Gin stand A's saw tip speed was approximately 10.7 m/s for its two saws while the tip speeds of the other four gin stands ranged from 13.2 to

13.6 m/s. Referring to table 1, the five saw gin stands represent a broad span of saw gin production that follows the general trend of gin design since 1960 and can be expressed as individual saw loading in kg/saw/h (fig. 3). Evaluating the test ginning rates in terms of saw loading rates allows a more direct comparison of all five gins.

The target ginning rate for each gin stand was the manufacturer's recommended ginning rate. Gin stands A and B had lower recommended ginning rates (4.5-5 bales/h), lower capacity (LC), and gin stands C, D, and E had higher recommended ginning rates (7.5-10 bales/h), higher capacity (HC). However, due to differences in cotton cultivar and moisture content, some deviation from the target rates was expected. Prior to conducting the test, all five gin stands were inspected to determine the operational ginning rates, if the saws were dull and/or damaged, and shaft speeds. Necessary adjustments were made to bring the stands to the manufacturer's specifications. As part of these preliminary adjustments, approximately two bales of cotton (1,361 kg of seed cotton) were processed on each gin stand to evaluate their respective ginning rates. Gin stands A, B, and C processed the seed cotton slightly faster than the manufacturers' recommended rates, while stands D and E were approximately 10% below the manufacturers' recommended rates. The load on the gin stand motor can range up to about 110% before it is disengaged. The feed rate for gin stands D and E were set at approximately 60% to 70% of the full-capacity setting.

Figure 3. Gin stand saw loading trends from the 1950s to 2010s (Hughes et al., 2017). Darkened data markers with letters represent gin stands listed in table 1.

However, when either of these gin stands was pushed beyond these limits, their gin breasts disengaged, ceasing operation. The gin stand specifications were re-checked, the recommended rates were confirmed by the manufacturer, and although the ginning rates on gin stands D and E deviated from the manufacturer's recommended rate, the study was completed while maintaining the highest achievable ginning rate for the stands.

This study was conducted over two ginning seasons. The first ginning season test (Test 1) consisted of three replications, two cotton cultivars, and five gin stands for a total of 30 lots. Each lot consisted of 227 kg of seed cotton. By comparison, a 218-kg standard bale of cotton lint requires about 682 kg of seed cotton. The cotton cultivars used in Test 1 were Suregrow 125 and 501 (Delta and Pine Land Company, now part of Bayer Crop Science, Research Triangle Park, N.C.). The seed cotton was grown, spindle-harvested, and moduled near Leland, Mississippi.

Lot numbers were assigned to the Test 1 gin stand treatments in a randomized arrangement and blocked by cultivar, due to the difficulty of handling modules after the covers were removed and the module was partially ginned. To ensure that each gin stand was operating at normal steady-state conditions, approximately 227 kg of seed cotton was ginned prior to each lot, thus increasing the total number of bales required for Test 1 to 20. Furthermore, sample collection was performed after the gin stands reached the desired processing rate and before the rate declined to ensure that samples were collected at the target rates. Dryer temperature for Test 1 was 82°C at the top of the first dryer, while no heat was used in the second tower dryer.

For each lot, five lint samples were collected after the gin stands to determine fiber properties by the Advanced Fiber Information System (AFIS, Uster Technologies, Knoxville, Tenn.). Five lint samples were collected to determine fiber properties by the High Volume Instrument (HVI, Uster Technologies, Knoxville, Tenn.) at a USDA-AMS classing office. The unprocessed portion of the HVI samples (about 200 g) were returned from the classing office. These samples were then processed on the Shirley Analyzer to determine trash content (ASTM, 2012b). Three additional lint samples were used for moisture content determination by the oven-drying method (Shepherd, 1972). SCF, mote, and funiculi analysis and lint seed-content measurement were performed on another lint sample collected after the gin stand (ASTM, 1980). One cottonseed sample was used for residual linter measurements and five additional cottonseed samples were used for seed damage classification according to CGRU procedures summarized below.

The second ginning season test (Test 2) consisted of three replications, one cultivar, and five gin stands for a total of 15 lots. Each lot consisted of 682 kg of seed cotton. The cotton cultivar used in Test 2 was Stoneville 747 (Stoneville Cotton, now part of Bayer Crop Science, Research Triangle Park, N.C.). The seed cotton was grown, spindle-harvested, and moduled by the KLB Farms Partners in Leland, Mississippi.

Lot numbers were assigned to the Test 2 gin stand treatments in a randomized arrangement. Similar to Test 1, approximately 227 kg of seed cotton was ginned prior to each

lot. Sample collection was performed after the gin stands reached the desired rate and before the capacity declined. For Test 2, the dryer temperature was 65°C at the top of the first dryer and again, no heat was used in the second tower dryer.

Similar to Test 1, five lint samples were collected after the gin stands for AFIS measurements, five were collected for HVI measurements, three were collected for moisture content determination, and one was collected for SCF, mote, and funiculi analyses. Lint seed-content was not measured on Test 2 samples. Instead of using HVI samples returned from the classing office, five additional lint samples were collected for processing on the Shirley Analyzer to determine trash content. Three cottonseed samples collected from the seed-belt were used for residual linter measurements and five cottonseed samples were used for seed damage classification.

AFIS measurements for Test 1 were performed by Cotton Incorporated (Cary, N.C.). The HVI sample measurements for Tests 1 and 2 were completed by the USDA-AMS Cotton Classing Office in Dumas, Arkansas. Mid Continent Laboratory (Memphis, Tenn.) performed the linters measurements on the cottonseed samples from both tests. The Fiber Testing Laboratory at the CGRU completed the following measurements for this study: AFIS on lint samples from Test 2, and Shirley Analyzer lint trash measurements, lint SCF contents, moisture content determination, and seed damage classification on Tests 1 and 2.

Seed damage classification was conducted according to CGRU Fiber Testing Laboratory standard procedures. For the procedure, 200 fuzzy cottonseeds were collected from a cottonseed sample and acid delinted. After delinting, 100 seeds were randomly selected for visual mechanical damage inspection. Each seed was inspected and classified as either normal or abnormal. Abnormal cottonseeds were classified into three categories: 1) shriveled – small and usually curled; 2) Immature – full size seed, light in color, not fully developed inside and may have thin seed coats; or 3) damaged – shriveled and immature seed can also be damaged. In this procedure, the damage to the cottonseed can be further classified as pinhole damage – seeds with only one or two small (pinhole) punctures in seed coats; minor damage – seeds with seed coats cracked or cut, but not severely; or major damage – seeds with large cuts or ruptures in the seed coats, part of the seed coats missing, or damage to the radicle end of the seeds. For the types of damage, the number of cuts, the number of cuts parallel to the minor axis, the number of cuts parallel to the major axis, and the number of cracks on the seed can be determined.

Statistical data analyses were performed on the data from each test separately using the Mixed procedure in SAS (version 7, SAS Institute, Inc., Cary, N.C.) with a 5% level of significance used to identify differences. For Test 1, cultivar, gin stand, and their interaction were the main effects with replication*cultivar*gin stand as the random effect. For Test 2, only gin stand was the main effect with replication*gin stand as the random effect. Multiple comparison procedures were conducted on the means using the default LSD t-test ($p \leq 0.05$).

RESULTS

The saw loading and ginning rates achieved during testing are shown in table 2. During Test 1 of this study, gin stands A and B produced ginning rates that were higher than the manufacturers' recommended ginning rates. The ginning rates achieved by gin stands D and E were 24% and 35% lower than the recommended ginning rates, respectively, based on average rates across both cultivars. For Test 2, ginning rates achieved for gin stands A and B were slightly higher than the recommended rates, while gin stands D and E were 29% and 32% lower, respectively, than the manufacturer's recommended ginning rate.

The average seed cotton moisture content prior to ginning in Test 1 was 6.7% and 6.5% for Suregrow 125 and Suregrow 501, respectively. After ginning in Test 1, the lint moisture content averaged 3.9%. During Test 2 with Stoneville 747, the average seed cotton moisture content was 5.5% prior to ginning and lint moisture content was 3.7% after ginning. There were no significant differences in the before ginning seed cotton moisture content or after ginning lint moisture content among the five gin stand treatments for either Tests 1 or 2.

The gin stand×cultivar interaction was not found significant in the statistical analyses of the data from Test 1. Thus, fiber and cottonseed quality results for Test 1 are presented as averages across the two cultivars and statistical analyses consider only the gin stand main effect.

AFIS FIBER PROPERTIES

AFIS fiber properties for each gin stand treatment are shown in table 3 for Test 1 with the Suregrow 125 and Suregrow 501 cultivars and for Test 2 with the Stoneville 747 cultivar. In Test 1, gin stand A produced lint with the smaller-sized neps than the other four gin stands. Nep size was not different among gin stands in Test 2. It is important to note that nep size has little practical importance, while nep count has more influence on textile utility. Gin stand B produced lint with the fewest number of neps (209) among the stands in Test 1. Gin stand A had the next lowest average nep count (246), but was not significantly different than gin stands D and E. Average nep count was lowest in fiber produced by gin stand A for the Stoneville cultivar in Test 2, but this was only significantly different from stand D. In general, the LC gin stands (A and B) produced fewer and smaller neps than the HC gin stands (C, D, and E), but these differences were not always significantly different.

For both tests, fiber length by weight, L(w), and number, L(n), were different among gin stands and tended to be

Table 3. Tests 1 and 2 AFIS measurement means for gin stand treatments.

Measurement ^[b]	Gin Stand ^[a]				
	A ^[c]	B ^[c]	C ^[d]	D ^[d]	E ^[d]
Test 1					
Nep Size [μm]	744 a	765 c	752 b	753 b	763 c
Neps [count/g]	246 b	209 a	283 c	278 bc	264 bc
L(w) [mm]	26.1 d	25.9 cd	24.9 a	25.4 ab	25.5 bc
L(w) CV [%]	30.5 a	31.4 ab	32.8 b	32.0 ab	32.0 ab
UQL(w) [mm]	30.8 c	30.8 c	30.1 a	30.3 ab	30.5 b
SFC(w) [%]	5.6 a	6.3 a	7.7 b	6.8 ab	6.8 ab
L(n) [mm]	22.5 c	22.1 bc	21.0 a	21.6 ab	21.7 abc
L(n)CV [%]	39.9 a	41.2 ab	43.3 b	41.7 ab	41.7 ab
SFC(n) [%]	16.0 a	17.6 ab	20.7 b	18.4 ab	18.5 ab
L5%(n) [mm]	34.9 c	34.9 c	34.2 a	34.5 ab	34.6 bc
L2.5%(n) [mm]	37.3 d	37.3 cd	36.4 a	36.8 b	36.9 bc
Total [count/g]	164 a	540 c	224 b	169 c	235 b
Trash Size [μm]	399 ab	379 a	425 cd	436 d	406 bc
Dust [count/g]	128 a	435 c	174 b	130 a	185 b
Trash [count/g]	36 a	106 c	50 b	39 a	50 b
VFM [%]	0.8 a	2.6 d	1.3 c	1.0 b	1.2 bc
SCN Size [μm]	1014 ab	1003 a	1048 b	1017 ab	1019 ab
SCN [count/g]	13.1 a	24.5 b	16.6 a	20.2 a	25.4 b
Fineness [mTex]	172 a	173 ab	172 ab	172 ab	173 b
IFC [%]	5.7	5.6	5.8	5.9	5.7
Maturity Ratio	0.940	0.940	0.926	0.929	0.937
Test 2					
Nep Size [μm]	711	727	715	719	717
Neps per gram	150 a	159 a	156 a	174 b	158 a
L(w) [mm]	25.7 d	25.5 cd	25.2 ab	25.0 a	25.3 bc
L(w) CV [%]	30.3 a	31.5 b	31.9 b	32.5 c	31.8 b
UQL(w) [mm]	30.5	30.5	30.3	30.3	30.4
SFC(w) [%]	6.27 a	7.13 b	7.75 cd	8.13 d	7.47 bc
L(n) [mm]	21.5 d	21.1 c	20.6 ab	20.3 a	20.8 b
L(n)CV [%]	44.1 a	46.0 b	47.0 c	48.0 d	46.8 bc
SFC(n) [%]	20.0 a	22.1 b	23.5 c	24.5 d	23.0 bc
L5%(n) [mm]	34.0	34.1	33.7	33.8	34.0
L2.5%(n) [mm]	35.9	36.0	35.6	35.7	35.9
Total [count/gram]	304 a	391 b	384 ab	499 c	367 ab
Trash Size [μm]	318	309	305	311	303
Dust [count/gram]	257 a	337 a	333 a	427 b	318 a
Trash [count/gram]	47.4 a	54.6 a	50.7 a	72.5 b	48.3 a
VFM [%]	1.00 a	1.13 a	1.10 a	1.49 b	1.14 a
SCN Size [μm]	1151	1060	1143	1102	1122
SCN per gram	15.9 ab	23.2 c	14.3 a	22.7 c	18.2 b
Fineness [mTex]	185 b	181 a	182 a	180 a	182 a
IFC [%]	4.84 a	5.43 b	5.25 b	5.55 b	5.28 b
Maturity Ratio	0.92 b	0.90 a	0.91 ab	0.90 a	0.91 ab

[a] Means followed by different lower-case letters in each row are significantly different at the 0.05 level. Bold numbers in each row are more desirable.

[b] Descriptions of measurements are shown in the Appendix.

[c] Lower-capacity (LC) saw-type gin stand.

[d] Higher-capacity (HC) saw-type gin stand.

Table 2. Manufacturers recommended and actual saw loading and ginning rates for each cultivar in Test 1 and Test 2.

Gin Stand	Recommended Saw Loading (ginning rate) kg/saw/h (bales/h)	Actual Saw Loading (ginning rate), kg/saw/h (bales/h)			
		Test 1 ^[c]		Test 2 ^[c]	
		Suregrow 125	Suregrow 501	Mean	Stoneville 747
A ^[a]	4.9-5.5 (4.0 to 4.5)	6.1 (5.0) a	5.6 (4.6) a	5.9 (4.8) a	5.8 (4.7)
B ^[a]	11.7 (5.0)	14.8 (6.3) b	12.9 (5.5) b	13.8 (5.9) b	12.4 (5.3)
C ^[b]	17.6 (7.5)	19.5 (8.3) d	16.0 (6.8) c	17.6 (7.5) d	16.7 (7.1)
D ^[b]	16.6 (8.5)	14.2 (7.3) c	11.1 (5.7) b	12.7 (6.5) c	11.7 (6.0)
E ^[b]	18.8 (10.0)	13.7 (7.3) c	10.9 (5.8) b	12.2 (6.5) c	12.8 (6.8)

[a] Lower-capacity (LC) saw-type gin stand.

[b] Higher-capacity (HC) saw-type gin stand.

[c] Means in Test 1 followed by different lower-case letters in each column are significantly different at the 0.05 level. Not available in Test 2.

longer for cotton ginned on gin stands A and B. L(w) on gin stand A averaged 26.1 mm for Test 1 with Suregrow 125 and Suregrow 501 cultivars and 25.7 mm for Test 2 with Stoneville 747 cultivar. In both tests, average L(w) on gin stand B was longer than the HC stands, but not significantly different from gin stand E. L(n) averaged about 22.3 mm for stands A and B in Test 1. This was not significantly different from L(n) for stand E (21.7 mm). Both the LC gin stands produced lint in Test 2 with average L(n) values (21.5 and 21.1 mm for A and B, respectively) that were significantly longer than that from the HC gin stands.

AFIS upper quartile length by weight, UQL(w), and upper 5% and 2.5% length by number, L5%(n) and L2.5%(n), had similar trends to L(w) and L(n), but there were no significant differences in these measures among gin stands in Test 2. UQL(w) was different among gin stands with the Suregrow cultivars in Test 1 with gin stands A and B producing fiber with significantly better UQL(w) (30.8 mm) than gin stands C, D, or E (ranged from 30.1 to 30.5 mm). Also in Test 1, gin stands A and B both had L2.5%(n) and L5%(n) averages of 37.3 and 34.9 mm, respectively, that were significantly better than the values for HC gin stands C and D. With the single cultivar in Test 2, UQL(w) averaged 30.4 mm, L5%(n) averaged 33.9 mm, and L2.5%(n) averaged 35.9 mm. As stated above, none of these were different among the gin stands. Based on the overall AFIS length information, the lower ginning rate gin stands (LC stands A and B) on average produced longer fiber than the high ginning rate gin stands (HC stand C, D, and E) but, as with the nep measurements, these differences were often not significantly different.

In both tests, there were significant differences in short fiber content by weight and number, SFC(w) and SFC(n), and coefficient of variation of fiber length by weight and number, L(w)CV and L(n)CV, among gin stands. With the Suregrow cultivars, average SFC(w) and SFC(n) in Test 1 were lowest for gin stand A (5.63% and 16.0%), but these were only significantly different from stand C that had the highest values. On the other hand, in Test 2, average SFC(w) and SFC(n) from gin stand A (6.27 and 20.0%) were significantly better than all other stands and stand D had the highest average values with the Stoneville cultivar in Test 2. There were practically no differences in L(w)CV and L(n)CV among gin stands in Test 1, with only gin stand A having values significantly different from gin stand C. In Test 2, gin stand A had length CV values that were lowest (L(w)CV = 30.3% and L(n)CV = 44.1%) and significantly different from all other gin stands. Trends in these data show that LC gin stands (A and B) generally produced less short fiber and fiber with less length variability than the HC gin stands (D, C, and E), but there was too much variability in the data to conclude that many of the differences were significant.

Total count, trash count, dust count, and visible foreign matter (VFM) average values were lowest in fiber produced by gin stand A in both tests, but only total count and VFM in Test 1 for stand A were significantly different from all other stands. Total count per gram ranged from 164 (gin stand A) to 540 (gin stand B) in Test 1 with the Suregrow cultivars and 304 (gin stand A) to 499 (gin stand D) in Test 2

with the Stoneville 747 cultivar. VFM ranged from 0.8 (gin stand A) to 2.6% (gin stand B) in Test 1 and from 1.00 (gin stand A) to 1.49% (gin stand D) in Test 2.

There were no definitive differences in seed coat nep (SCN) size and SCN count between the LC and HC gin stands. SCN count in Test 1 ranged from 13.1 to 25.4 particles/g, with gin stand A having the lowest count and gin stand E having the highest count. SCN count in Test 2 was lowest for gin stand C (14.3 particles/g) and significantly different from the highest level of 23.2 particles/g for gin stand B. SCN size in Test 1 ranged from 1003 to 1048 μm for stands B and C, which were significantly different, but there was no difference among the other gin stands. No differences in SCN size were detected among any of the gin stands in Test 2.

There were few differences in fineness, immature fiber content (IFC), and maturity ratio among gin stands. Fineness averaged 173 mTex, IFC averaged 5.72, and maturity ratio averaged 0.93 for the Suregrow cultivars. With respect to the Stoneville cultivar, fineness averaged 182 mTex, IFC averaged 5.3, and maturity ratio averaged 0.91. In Test 2, fiber from gin stand A was significantly more mature, but less fine – although the values for all gin stands were “average” maturity and fineness. Fineness, immature fiber content, and maturity ratio are more dependent on the inherent properties of the cotton than on the gin stand treatment used, therefore the significant differences in these measurements are likely less a function of gin stand treatment and more a function of the cotton prior to ginning.

HVI FIBER PROPERTIES

HVI fiber properties for each gin stand treatment for Test 1 with the Suregrow 125 and Suregrow 501 cultivars and for Test 2 with the Stoneville 747 cultivar are shown in table 4. With the exception of reflectance, trash area, and length, none of the HVI fiber properties were significantly different among gin stands in Test 1. In Test 1, micronaire, strength, yellowness, and length uniformity averaged 45.3, 31.5 g/tex, 8.93 +b, and 83.8%, respectively. Gin stand A produced fiber with the best color reflectance (74.9 Rd), which was significantly different from all the other gin stands, but may also be attributed to lower trash levels. The longest fiber was also from gin stand A (29.1 mm), but it was only significantly different from gin stand D. Trash area was lowest for stand E at 3.80%, but this was not significantly different from either of the LC stands. There were no conclusive differences in the HVI measurements between the LC and HC gin stands in Test 2. Micronaire was not different among the gin stands and averaged 4.71. Fiber strength averaged 29.4 g/tex, was highest for fiber from gin stands B and E at 29.7 g/tex, and gin stands A and C had the lowest at 29.2 g/tex. Gin stands normally do not affect fiber strength, so differences noted may have been mostly due to small natural variation in the cotton. Reflectance ranged from 76.9 (gin stand D) to 78.5 Rd (gin stand A) and yellowness ranged from 9.0 (gin stand C) to 9.23 +b (gin stand B). Length was also not different among gin stands and averaged 29.0 mm. Although length uniformity was different among gin stands, it only ranged from 84.3 (gin stands C and D) to 84.8 (gin stand A).

Table 4. Test 1 and Test 2 HVI measurement means gin stand treatments.

Measurement ^[b]	Gin Stand ^[a]				
	A ^[c]	B ^[c]	C ^[d]	D ^[d]	E ^[d]
Test 1					
Micronaire [reading]	4.53	4.56	4.51	4.55	4.51
Strength [g/tex]	31.8	31.3	31.5	31.4	31.4
Reflectance [Rd]	74.9 b	73.8 a	74.1 a	73.8 a	74.0 a
Yellowness [+b]	8.84	8.92	8.92	9.01	8.97
Trash Area [%]	4.00 ab	3.93 a	4.63 c	4.53 bc	3.80 a
Length [mm]	29.1 b	28.9 ab	28.9 ab	28.8 a	29.0 ab
Length Uniformity [%]	83.6	83.8	83.8	83.7	83.8
Test 2					
Micronaire [reading]	4.73	4.71	4.71	4.73	4.69
Strength [g/tex]	29.2 a	29.7 b	29.2 a	29.5 ab	29.7 b
Reflectance [Rd]	78.5 b	77.2 ab	77.9 ab	76.9 a	78.0 ab
Yellowness [+b]	9.05 a	9.23 b	9.00 a	9.07 ab	9.02 a
Trash Area [%]	2.27 a	2.40 ab	2.73 ab	3.13 b	2.60 ab
Length [mm]	29.0	29.2	29.0	29.0	29.0
Length Uniformity [%]	84.8 b	84.5 ab	84.3 a	84.3 a	84.4 ab

^[a] Means followed by different lower-case letters in each row are significantly different at the 0.05 level. Bold numbers in each row are more desirable.

^[b] Descriptions of measurements are shown in the Appendix.

^[c] Lower-capacity (LC) saw-type gin stand.

^[d] Higher-capacity (HC) saw-type gin stand.

All micronaire readings were in the base range (4.3-4.9) and strength readings were in the premium range (≥ 27.5 g/tex) according to the CCC Loan Premium and Discount Schedule. Fiber length uniformity for all cultivars was in the “high” category (83%-85%) according to the classing office definition. Color grades associated with the average reflectance and yellowness values using an HVI color diagram for American Upland Cotton were 31 for gin stands A, D, and E and 41 for gin stands B and C in Test 1 and 21 for gin stands A, B, C, and E and 31 for gin stand D in Test 2.

LINT FOREIGN MATTER PROPERTIES

There were differences in Shirley Analyzer visible trash among individual gin stands, but there were no clear differences between the LC and HC stands (table 5). Visible trash ranged from 3.35 to 4.19 in Test 1. Gin stand A had the lowest value and was only significantly different from the highest value for gin stand D. In Test 2, gin stand D again had the highest average visible trash (3.23%), which was different from that of all other gin stands.

SEED COAT FRAGMENT, MOTE, FUNICULI ANALYSIS, AND LINT SEED-CONTENT

SCF, mote, and funiculi analysis and lint seed-content results for Tests 1 and 2 are shown in table 6. SCF properties had similar results as HVI and foreign matter properties above, in that there were no clear differences between the

Table 5. Test 1 and Test 2 Shirley visible trash means for gin stand treatments.

Measurement ^[b]	Gin Stand ^[a]			
	A ^[c]	B ^[c]	C ^[d]	D ^[d]
Test 1 visible trash [%]	3.35 a	3.54 ab	3.63 ab	4.19 b
Test 2 visible trash [%]	2.12 a	2.12 a	2.17 a	3.23 b

^[a] Means followed by different lower-case letters in each row are significantly different at the 0.05 level. Bold numbers in each row are more desirable.

^[b] Descriptions of measurements are shown in the Appendix.

^[c] Lower-capacity (LC) saw-type gin stand.

^[d] Higher-capacity (HC) saw-type gin stand.

Table 6. Test 1 and Test 2 SCF, mote, and funiculi analysis and lint seed-content measurement means for gin stand treatments.

Measurement ^[b]	Gin Stand ^[a]				
	A ^[c]	B ^[c]	C ^[d]	D ^[d]	E ^[d]
Test 1					
SCF(n) [count/ 5g]	44.2 a	79.0 b	56.0 ab	83.3 b	72.3 ab
SCF(w) [mg/5g]	26.6 a	46.2 ab	38.9 a	56.7 b	45.6 b
Mote(n) [count/ 5g]	8.2 a	5.5 a	7.3 a	11.8 b	7.0 a
Mote(w) [mg/5g]	56.8 cd	20.5 a	33.5 ab	72.1 d	44.2 bc
Funiculi(n) [count/ 5g]	15.8 a	19.5 ab	20.3 ab	24.7 b	24.5 b
Funiculi(w) [mg/5g]	3.9 a	4.2 a	5.5 ab	5.8 b	6.6 b
Seed in the Lint(n) [count/ 5g]	0	0.2	0	0.2	0
Seed in the Lint(w) [mg/5g]	0	10.2	0	18.5	0
Test 2					
SCF(n) [count/ 5g]	18.3	31.3	27.3	32.3	18.0
SCF(w) [mg/5g]	9.53 a	19.1 ab	16.0 a	33.0 b	14.8 a
Mote(n) [count/ 5g]	10.7 a	14.0 a	10.7 a	35.3 b	14.7 a
Mote(w) [mg/5g]	44.5	41.5	38.3	30.7	38.1
Funiculi(n) [count/ 5g]	14.3	25.7	22.3	29.0	21.0
Funiculi(w) [mg/5g]	6.37	10.7	6.97	7.00	7.77
Seed in the Lint (n) [count/ 5g]	- not measured -				
Seed in the Lint (w) [mg/5g]	- not measured -				

^[a] Means followed by different lower-case letters in each row are significantly different at the 0.05 level. Bold numbers in each row are more desirable.

^[b] Descriptions of measurements are shown in the Appendix.

^[c] Lower-capacity (LC) saw-type gin stand.

^[d] Higher-capacity (HC) saw-type gin stand.

LC and HC gin stands. In Test 1, gin stands A and B tended to have the lower average SCF property values but, in all cases, they were not significantly different from the values for several of the other gin stands. Gin stand A, which had the lowest ginning rate, had the fewest SCF by number, SCF(n), and was only different from gin stands B and D. SCF(n) ranged from 44.2 per 5 g of lint (gin stand A) to 83.3 per 5g (gin stand D). In Test 2, there were no significant difference in SCF(n) among gin stands and it ranged from 18 per 5g of lint (gin stand E) to 32.3 per 5 g (gin stand D). In both tests, gin stand D consistently produced lint with the largest count of fiber motes by number (11.8 and 35.3 per 5 g of lint for Tests 1 and 2, respectively), Mote(n), and that was significantly different from all the other gin stand averages. Fiber funiculi produced by gin stand A in Test 1 was lowest in number (15.8 particles per 5 g of lint) and weight (3.9 mg per 5 g sample of fiber). These numbers were significantly different than the same measurements for gin stands D and E, but not B and C. Fiber funiculi was not different among gin stands in Test 2 with the Stoneville 747 cultivar and averaged 22.5 particles and 7.76 mg per 5 g. Based on this information, the LC gins (which had the lowest ginning rate) generally produced fiber with the least amount of SCF, but the differences were not always statistically significant. There was no difference among gin stands in the amount of seed found in the lint from Test 1, where seed count averaged 0.1 and seed weight average 5.7 mg.

COTTONSEED PROPERTIES

Cottonseed properties for Tests 1 and 2 are shown in table 7. Seed damage was different among gin stands in both tests. Gin stand A had the lowest level of seed damage (3.1% and 2.0% in Tests 1 and 2, respectively). Interestingly, gin

Table 7. Tests 1 and 2 cottonseed property means for gin stand treatments.

Measurement ^[b]	Gin Stand ^[a]				
	A ^[c]	B ^[c]	C ^[d]	D ^[d]	E ^[d]
Test 1					
Seed Damage (%)	3.1 a	8.0 c	5.6 b	5.4 b	8.3 c
Linters (%)	13.7 c	12.3 ab	12.8 b	12.4 ab	11.9 a
Test 2					
Seed Damage (%)	2.00 a	4.44 b	3.22 ab	3.44 ab	4.22 b
Linters (%)	7.87	7.83	7.90	8.03	7.87

^[a] Means followed by different lower-case letters in each row are significantly different at the 0.05 level. Bold numbers in each row are more desirable.

^[b] Descriptions of measurements are shown in the Appendix.

^[c] Lower-capacity (LC) saw-type gin stand.

^[d] Higher-capacity (HC) saw-type gin stand.

stand B, the other low ginning rate gin stand with wider saw spacing had the largest amount of seed damage (Test 1 = 8.0% and Test 2 = 4.4%) and was not significantly different from gin stand E in Test 1 and not different from any of the HC gin stands in Test 2.

Linters content was different among gin stands with the Suregrow cultivars. Linters content ranged from 11.9% to 13.7%, was lowest for seed from gin stand E, and highest and significantly different from the other gin stands for gin stand A. Linters content was not different among gin stands with the Stoneville cultivar and averaged 7.9%.

DISCUSSION

Overall, these results revealed some general and consistent trends for the gin stands. Ginning rates for the LC gin stands A and B were slightly higher than the manufacturers recommended ginning rates, but considerably lower than the HC gin stands. Gin stands D and E operated at about 30% below the manufacturers recommended ginning rates possibly due to cotton cultivar characteristics (ginning rates were within 10% of the manufacturer's recommended ginning rate in a preliminary test with a different cultivar), or software calibration issues with the electronic feed control. Gin stand C with the highest actual saw loading and ginning rate for both tests operated nearly at the recommended rate during tests. The study was completed with the highest achievable ginning rates with the given cultivars. Though many of the differences in fiber and seed properties were not significantly different at the 5% significance level, there were obvious trends in the data when comparing LC and HC stands. As indicated by the bolded values in the tables, the LC stands, particularly stand A, had the more desirable average values for the majority of the fiber and cottonseed measurements in Tests 1 and 2. Conversely, the HC stands C and D had the majority of the least desirable fiber and seed measurement values in both tests. These trends may be related back to gin stand design characteristics shown in table 1. For example, gin stand A had two saw mandrels, wide saw spacing and roll box width and the lowest saw loading, while gin stands C and D had narrower saw spacing and higher saw loading. As the trend in modern gin stand designs is toward narrower saw spacing and higher saw loading, the influence of gin saw spacing, diameter, speed, and loading, and seed

roll density on fiber and seed quality warrant further controlled testing.

CONCLUSIONS

Tests were conducted on five different gin stands that represent a range of historical gin technologies with different widths, number of saws, and capacities to identify technologies from those earlier designs that may guide future gin stand research to improve fiber quality. Two of the stands had rated capacity lower than 5 bales/h (LC gin stands) and three had rated capacity of 7.5 bales/h or higher (HC gin stands). Seed cotton moisture content prior to ginning and lint moisture content after ginning were not different among gin stands. In general, the LC gin stands with lower ginning rate had wider saw spacing and lower saw loading (kg/saw/h) than the HC gin stands. These LC gin stands produced fewer neps, longer fiber, and less SFC in cotton ginned than the HC gin stands. The LC gin stand with lowest saw loading routinely produced fiber with less trash in the lint than the other gin stands. Fineness, immature fiber content, and maturity ratio were more dependent on cotton cultivar than on the gin stand treatment used. The AFIS measurements favored the LC stands and so did the HVI measurements, but to a lesser extent. The lowest ginning rate gin stand had higher residual linters content and lower seed damage than the other stands, which aligns with the short fiber content results.

In summary, although the differences in fiber and seed properties between the LC and HC gin stands were not always statistically significant at the 5% significance level, the fiber properties associated with the LC gin stands tended to be superior to the fiber properties associated with the HC gin stands. Both the LC gin stands were older models and had wider saw spacing; the oldest of them was substantially different from the other designs with two saw mandrels pulling fiber from the same seed roll position. These results indicate that there may be historical gin stand technologies and relationships between gin parameters such as saw loading, saw spacing, and seed roll density, and fiber and seed quality that need to be further investigated.

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APPENDIX

Definitions of measurements used in the gin stand comparison study.

Measurements	Definition
AFIS	
Nep size [μm]	The mean size of all neps (both fiber and seed coat neps) in the sample.
Neps per gram	The total nep count normalized per gram. This includes both fiber and seed coat neps.
L(w) [mm]	The average length of all the fibers in the sample computed on a weight basis.
L(w) CV [%]	The percentage of the coefficient of variation of the length by weight.
UQL(w) [mm]	Upper Quartile Length by weight. This is the length which is exceeded by 25% of the fibers by weight.
SFC(w) [%]	The short fiber content (<0.5 in.) of the sample (calculated by weight).
L(n) [mm]	The average length of all the fibers in the sample computed on a number basis.
L(n) CV [%]	The percentage of the coefficient of variation of the length by number.
SFC(n) [%]	The short fiber content (<0.5 in.) of the sample (actual fibers counted by number).
L5%(n) [mm]	Percent 1 - The length, calculated by number, that is exceeded by 5% of the fibers.
L2.5%(n) [mm]	Percent 2 - The length, calculated by number, that is exceeded by 2.5% of the fibers.
Total [count/gram]	Total count of trash particles measured by the Trash Module; this is the total of the trash and dust count per gram of the sample.
Trash Size [μm]	The mean size of all the trash particles in the sample.
Dust [count/gram]	The particles measured by the Trash Module that are less than 500 microns in size.
Trash [count/gram]	All foreign matter in cotton measured by the Trash Module that is larger than 500 microns in size.
VFM [%]	The percentage of Visible Foreign Matter (dust and trash) in the sample.
SCN size [μm]	The mean size of all seed coat neps in the sample.
SCN per gram	The seed coat nep count normalized per gram.
Fineness [mTex]	The mean fiber fineness (weight per unit length) in millitex. One thousand meters of fibers with a mass of 1 milligram equals 1 millitex.
IFC [%]	Immature Fiber Content is the percentage of fibers with less than 0.25 maturity. The lower the IFC%, the more suitable the fiber is for dyeing.
Maturity Ratio	The ratio of fibers with a 0.5 (or more) circularity ratio divided by the amount of fibers with a 0.25 (or less) circularity. The higher the maturity ratio, the more mature the fibers are and the better the fibers are for dyeing.
HVI	
Micronaire	Micronaire is a measure of fiber fineness and maturity.
Strength	Strength measurements are reported in terms of grams per tex. A tex unit is equal to the weight in grams of 1,000 m of fiber.
Reflectance and Yellowness	The color of cotton is determined by the degree of reflectance (Rd) and yellowness (+b). Reflectance indicates how bright or dull a sample is, and yellowness indicates the degree of color pigmentation.
Trash Area	Trash is a measure of the amount of non-lint materials in the cotton, such as leaf and bark from the cotton plant. The surface of the cotton sample is scanned by a video camera and the percentage of the surface area occupied by trash particles is calculated.
Length [mm]	Fiber length is the average length of the longer one-half of the fibers (upper half mean length). It is officially reported in 32nds of an inch.
Length Uniformity [%]	The ratio between the mean length and the upper half mean length of the fibers and is expressed as a percentage.
Shirley Visible Trash [%]	Percent of visible trash, by weight, from the Shirley Analyzer.
SCF (n)	The number of seed coat fragments in a 5 g sample of lint.
SCF (w)	The weight of seed coat fragments in a 5 g sample of lint.
Mote (n)	The number of motes in a 5 g sample of lint.
Mote (w)	The weight of motes in a 5 g sample of lint.
Funiculi (n)	The number of funiculi in a 5 g sample of lint.
Funiculi (w)	The weight of funiculi in a 5 g sample of lint.
Seed in the Lint (n)	The number of cottonseed in a 5 g sample of lint.
Seed in the Lint (w)	The weight of cottonseed in a 5 g sample of lint.
Linters [%]	Measurement of the percent of lint on the cottonseed, by weight, after ginning.