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ENGINEERING AND GINNING

How Current Cotton Ginning Practices Affect Fiber Length Uniformity Index

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ABSTRACT

There is a need to develop cotton ginning methods that better preserve length uniformity, a fiber characteristic that is critical with newer, more efficient air-jet spinning technology. This report summarizes results of harvesting and ginning studies within the past fifteen years that included High Volume Instrument (HVI) fiber length uniformity index (uniformity). The studies concluded that cultivar was an important determining factor and some production practices, such as early defoliation and stripper harvesting, could also reduce uniformity. Uniformity was not adversely affected by seed cotton cleaning machinery (cylinder cleaners and stick machines). Saw ginning reduced uniformity more than did roller ginning, from 0.8 to 2.0%. Uniformity was negatively affected by the saw-type lint cleaner, from 0.4 to 1.1% per stage. Moisture restoration before lint cleaning partially mitigated (0.5%) lint cleaning's decrease in uniformity. Studies reviewed in this report suggest that most of the decrease in uniformity occurs at the saw-type lint cleaner feed bar. Although uniformity was not affected by lint cleaner grid bars, faster lint cleaner saw cylinder speeds did reduce uniformity. Roller gin-type lint cleaners reduced uniformity 0.2 to 0.8%, which was less than the reduction caused by saw-type lint cleaners.

The United States (U.S.) exported 71% of its 2015/16 cotton crop (Cotton Incorporated, 2017). During 2015/16, countries with larger mill-use than the U.S. included China, India, Pakistan, Bangladesh, Turkey, and Vietnam (Cotton Incorporated, 2017). Overseas, ring spinning is the predominant method for manufacturing yarns. Ring spinning is an old and well-established technology. Ring spinning produces strong and fine yarns, but it is a slow and expensive process. The most important raw material quality factor for ring spinning is fiber length.

Air-jet or Vortex spinning is a relatively new, more efficient spinning technology. Air-jet spinning produces spun yarn on a large-scale finished package directly from sliver, eliminating the need for roving and winding which saves space, labor, and time. The production rate of air-jet spinning, up to 500 m/min, is three times higher than rotor spinning and 20 times that of ring spinning. As with ring spinning, it requires a fiber that is long, but air-jet spinning also requires a uniform length and few short fibers. Currently, air-jet spinning predominantly uses synthetic fibers and blends, mainly due to the lower cost of man-made fiber, but also because the synthetic fiber manufacturing industry can supply a fiber of suitable length and length uniformity index. Providing the textile industry with a longer and more uniform cotton fiber to manufacture yarns more efficiently with newer technologies, such as air-jet spinning, could give cotton a competitive edge, increasing demand for cotton and expanding cotton's market share.

High Volume Instrument (HVI) length uniformity index (hereafter referred to as "uniformity") is defined as the ratio of mean fiber length and upper half mean fiber length expressed as a percentage (Cotton Incorporated, 2013). Uniformity is categorically divided into the following: very high (above 85%); high (83-85%); intermediate (80-82%); low (77-79%); and very low (below 77%). A small numerical improvement results in significant gains in efficiency during spinning. Although genetic characteristics overwhelmingly dictate a particular cultivar's uniformity, and weather plays a significant role, production and ginning practices also affect uniformity. The goal of producers and ginners is to minimize decreases in uniformity from harvesting and ginning, both to provide a higher financial return to the producer and to provide a better fiber for yarn manufacturing.

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Figure 1 gives a perspective of the past and current levels of uniformity in regions of the U.S. (Cotton Incorporated, 2000 and 2015). Uniformity can vary within a short time period due to the introduction of new cultivars, or adverse production events such as weather, pests or disease. Uniformity in the Far West has decreased from 81.7 to 81.0% over the past 15 years. Uniformity has increased over this time period in other regions, with the Mid-South seeing the largest increase (81.3 to 82.4%). In general, uniformity lies within the "intermediate" range of 80 to 82% across the U.S.

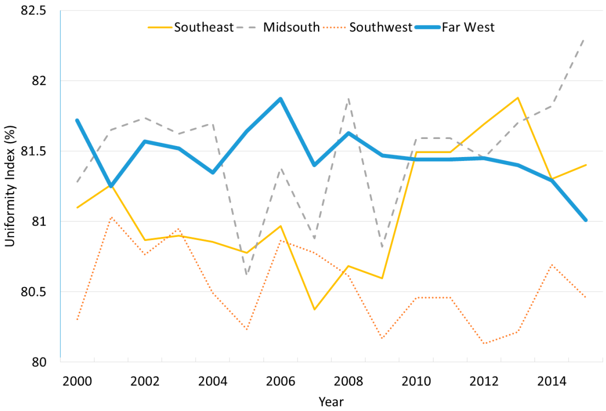

Figure 1. Fiber length uniformity (%) by region.

The purpose of this report is to summarize and document how current cotton ginning practices affect HVI uniformity. This report will mainly focus on ginning of Upland cotton, the predominant type of cotton grown in the U.S. (Pima, an extra-long-staple cotton, comprises only 3-5% of the U.S. crop and is roller ginned, not saw ginned). This report will focus only on studies from the last 15 years. This report will also present potential ginning research that may improve fiber length uniformity.

DISCUSSION

The cotton ginning process can be divided into the following sub processes: seed cotton unloading; seed cotton drying; seed cotton cleaning and extracting; ginning (saw- or roller-type gin stands); lint cleaning (saw- or roller-type lint cleaners); lint moisture restoration; and lint cotton packaging. Seed cotton unloading, and lint cotton packaging do not have much potential to affect uniformity. However, the remaining processes do have potential to affect uniformity and are the subject of this study.

In the reviewed studies, the cultivars were diverse, and represented cottons throughout all of the growing regions of the U.S. Although uniformity was different among cultivars, uniformity did not have a cross product effect with treatment*cultivar in all the studies reviewed, so this discussion will center on ginning treatment effects. Not all studies included sampling after lint cleaning.

Drying Effects and Moisture Control

Table 1 shows results of a three-year study by Byler et al. (2014), that examined the influence of early and late defoliation on fiber maturity using two Mid-South cultivars. Four ginning treatments were nested within each defoliation level: (1) no heat used with seed cotton cleaning, and no lint cleaning used, (2) no heat used with seed cotton cleaning, and one saw-type lint cleaner used, (3) no heat used with seed cotton cleaning, and three saw-type lint cleaners used, and (4) heat used with seed cotton cleaning, and one saw-type lint cleaner used which is a combination typically used in commercial ginning. All of the treatments used the same amount of seed cotton cleaning as follows: tower dryer, cylinder cleaner, stick machine, tower dryer, cylinder, and extractor feeder. The treatments that applied heat to the seed cotton used a moderate amount of heat: 93° C (200°F) on the first dryer, and 65° C (150°F) on the second dryer. Results showed that lint moisture content (taken at the end of gin processing) was different among gin treatments; treatments one thru four averaged 5.4, 5.2, 4.9, and 4.5%, respectively. Uniformity was different between defoliation times; uniformity averaged 82.5 and 83.1% for early and late defoliation, respectively. Uniformity was also different among gin treatments, and it is interesting to note that uniformity on all four ginning treatments of the late defoliation was higher than any of the early defoliation ginning treatments. Compared to no lint cleaning, uniformity was reduced 0.1 percentage points with one saw-type lint cleaner when defoliated early, and it was reduced 0.3-0.5 percentage points with one saw-type lint cleaner on cotton defoliated late. Again, compared to no lint cleaning, uniformity was 0.5 percentage points lower when using three saw-type lint cleaners; this occurred with both early and late defoliation times. Treatments two and four used the same amount of lint cleaning (one lint cleaner), but different levels of heat in the dryers. On cotton that was defoliated early, uniformity was 82.6% on both treatments two and four. On cotton that was defoliated late, uniformity was 0.2 percentage points better when no heat was used (83.1% versus 82.9% with heat).

Table 1. Uniformity results of a maturity and processing study by Byler et al. (2014)[Z]

Treatment	Uniformity (%)
Defoliated Early	
No heat, no lint cleaning	82.7 bc
No heat, 1 saw-type lint cleaner	82.6 c
No heat, 3 saw-type lint cleaners	82.2 d
Heat, 1 saw-type lint cleaner*	82.6 c
Defoliated Late	
No heat, no lint cleaning	83.4 a
No heat, 1 saw-type lint cleaner	83.1 ab
No heat, 3 saw-type lint cleaners	82.9 bc
Heat, 1 saw-type lint cleaner*	82.9 bc

[Z] Means followed by the same letter are not different (P≤0.05).

Table 2 shows results of a two-year study by Le (2007) that examined fiber quality properties produced by a saw-type lint cleaner in response to low and high levels of feed rate, saw speed, combing ratio and lint moisture. Two Mid-South cultivars were used (hairy and smooth leaf). In this study, lint moisture content was the only treatment that had a significant effect on uniformity. In the first year of the study, uniformity averaged 80.6 and 81.2% at 4 and 6% lint moisture content, respectively. This equated to a 0.6 percentage point increase in uniformity due to 2% higher lint moisture content. Similar results were found in the second year: a 0.4 percentage point increase in uniformity resulted from an increase of 2% lint moisture content. This study also showed that hairy leaf cultivars had 0.6 percentage points better uniformity than smooth leaf cultivars.

Table 3 is the results of a study by Byler (2005) that added a modest amount of moisture to seed cotton during pre-cleaning to determine the impact on fiber properties. One treatment included conditioning the seed cotton with warm dry air in the second tower dryer, and a second treatment conditioned the seed cotton with warm moist air (moisture restoration). Two Mid-South cultivars were used in the study. Samples were taken before and after lint cleaning. Although uniformity was not measured directly, Advanced Fiber Information System (AFIS) fiber length, fiber length CV, and short fiber content (by weight) were different between treatments. After ginning, but before lint cleaning, fiber length averaged 24.3 and 24.7 mm with warm dry air and warm moist air, respectively. After lint cleaning, fiber length averaged 23.8 and 24.2 mm with warm dry air and warm moist air, respectively. In other words, fiber length was better preserved by 0.3-0.4 mm with added moisture, but lint cleaning reduced fiber length by 0.5 mm. Fiber length CV and short fiber content followed the same trend. Before lint cleaning, fiber length CV averaged 32.9 and 32.5% with warm dry air and warm moist air, respectively. After lint cleaning, fiber length CV averaged 33.8 and 33.2% with warm dry air and warm moist air, respectively (a lower fiber length CV is more favorable). Before lint cleaning, short fiber content averaged 8.7 and 8.0% with warm dry air and warm moist air, respectively. After lint cleaning, short fiber content averaged 9.6 and 8.9% with warm dry air and warm moist air, respectively. In other words, short fiber content was better (lower) by 0.7 percentage points with added moisture, but lint cleaning increased short fiber content by 0.9 percentage points.

Table 2. Uniformity results of a lint cleaner study that included moisture content by Le (2007) [Z]

Treatment	Uniformity (%)	
	2003 Study	2004 Study
Saw Speed (rpm)		
877	81.0 a	81.6 a
115	80.9 a	81.4 a
Feed Rate (kg/m/h)		
447	80.8 a	81.5 a
745	81.0 a	81.4 a
Combing Ratio		
25	80.9 a	81.6 a
50	81.0 a	81.4 a
Cultivar		
Hairy Leaf	82.1 a	82.7 a
Smooth leaf	79.7 b	80.3 b
Lint Moisture (%)		
4	80.6 a	81.3 a
6	81.2 b	81.7 b

[Z] Means followed by the same letter in each column under a treatment heading are not different (P≤0.05).

Table 3. AFIS Fiber length and short fiber content (by weight) of a seed cotton moisture addition study by Byler (2005) [Z]

Treatment	Fiber Length (mm)		Fiber Length CV (%)		Short Fiber (%)	
	Before L.C.	After L.C.	Before L.C.	After L.C.	Before L.C.	After L.C.
Drying Only	24.3 a	23.8 a	32.9 a	33.8 a	8.7 a	9.6 a
Seed Cotton Moisture Restore	24.7 b	24.2 b	32.5 b	33.2 b	8.0 b	8.9 b

[Z] **Means followed by the same letter in each column are not different (P≤0.05).**

Byler (2006) provided a historical review on the effect of adding moisture to seed cotton during precleaning (before ginning) on fiber length. The review covered studies from the 1940's to the 1990's which are earlier time periods than this report comments on. Studies documented the decrease in fiber length quality when ginning at moisture contents below 5%. One study gave a possible explanation of why this occurs: the ratio of the force required to remove the fiber from the seed to the strength of the fiber decreases with increasing moisture content. The consensus of the studies supported ginning at moisture content levels above 6% to preserve fiber length quality.

Seed Cotton Cleaning and Extracting

Table 4 shows results of a study by Wanjura et al. (2012) that investigated the influence of harvest method, the number of seed-cotton extractor cleaners (stick machines) used during pre-cleaning, and seed cotton cleaning rate on fiber and yarn quality. The study included two cultivars grown in the Texas High Plains. Harvest methods included spindle picker or brush-roll stripper with field cleaner. Seed cotton cleaning included either one or two stick machines. The levels of seed cotton cleaning rate were labeled as low, medium, and high, and averaged 7.1, 8.8, and 10.1 bales per hour per meter of width, respectively. Results showed that uniformity was significantly better with the picker harvester, averaging 81.2% compared to the stripper harvester which averaged 80.9%. The difference may be ascribed to the selective nature of spindle picking which can only access fiber from mature bolls that are open. Stripper harvesters gather everything, including partially opened and closed bolls containing immature fiber. Significant to this study, uniformity was not different between seed cotton cleaning level or among seed cotton cleaning rates and averaged 81.1 %, respectively.

Table 5 is the results of a study by Armijo et al. (2009) that determined the impact of spindle harvester configuration and seed cotton cleaning level on fiber quality (seed coat fragmentation in particular). Three harvester treatments examined spindle diameter and speed and included: (1) 13 mm at 2000 rpm, (2) 14 mm at 1500 rpm, and (3) 14 mm at 2400 rpm. Three levels of seed cotton cleaning were used: (1) no cleaning, (2) three cleaners in series (six-cylinder incline, stick machine, six-cylinder incline), and (3) six cleaners in series (six-cylinder incline, stick machine, six-cylinder incline, stick machine, stick machine, six-cylinder incline). The study used a cultivar known to have fragile seed coats. Results showed uniformity was not different among harvester treatments (83.1%) or among seed cotton cleaning levels (83.2%).

Table 4. Uniformity results of a harvesting and gin cleaning study by Wanjura et al. (2012)[Z]

Treatment	Uniformity (%)
Harvesting	
Picked	81.2 a
Stripped	80.9 b
Seed Cotton Cleaning	
One Stick Machine	81.1 a
Two Stick Machines	81.1 a
Seed Cotton Cleaning Rate	
High	81.1 a
Medium	81.1 a
Low	81.1 a

[Z] **Means followed by the same letter under a treatment heading are not different (P≤0.05).**

Table 5. Uniformity results of a harvesting and seed cotton cleaning study by Armijo et al. (2009) [Z]

Treatment	Uniformity (%)
Harvester	
13-mm spindle (most common)	83.0 a
14-mm spindle	83.3 a
14-mm spindle running fast	83.1 a
Gin (seed cotton cleaning)	
No Cleaning	83.2 a
Incline, Stick, Incline	83.3 a
Incline, Stick, Incline, Stick, Stick, Incline	83.0 a

[Z] **Means followed by the same letter under a treatment heading are not different (P≤0.05).**

Hardin and Byler (2013) reported on a two-year study that evaluated processing rates of cylinder cleaners and stick machines that were higher than the manufacturers recommended rate, which is 4.9 to 8.2 bales per hour per meter of width. The study examined five processing rates between 6.56 and 19.7 bales per hour per meter of width. Cottons from 2008 included three cultivars from the Mid-South (smooth leaf and intermediate leaf pubescence) and one stripper-harvested cultivar from the Texas High Plains. The 2009 cottons included two cultivars from the Mid-South (smooth and hairy leaf), and two considerably different moisture levels (about 6 and 11% w.b.). Although uniformity data was not reported, it was stated that fiber quality, including uniformity, was not affected by processing rate of the seed cotton cleaning machinery.

Saw Ginning

Table 6 is the results of a study by Armijo et al. (2006a) that examined the impact of spindle harvester configuration and type of seed roll box (seed roll density) on fiber quality (seed coat fragmentation in particular). Three harvester treatments examined spindle diameter and speed and included: (1) 13 mm at 2000 rpm, (2) 16 mm at 2000 rpm, and (3) 16 mm at 2900 rpm. Four ginning treatments were tested: (1) traditional seed roll box (the seed roll is turned by the gin saws), (2) conveyor tube seed roll box (the tube assists in turning the seed roll and provides an alternate discharge for ginned seed), (3) conveyor tube seed roll box running at slow speed, and (4) a Power Roll gin stand (no conveyor tube but a powered paddle assists in turning the seed roll and the seed box contains a seed finger roll that returns “not fully ginned seed” back to the gin saws). The study included a cultivar known to have fragile seed coats. Results showed that uniformity was different among harvester treatments and ranged from 83.3 to 83.7%. The 16-mm spindle running at 2000 rpm had the lowest uniformity. Other fiber qualities such as AFIS length, short fiber, and seed coat neps also did not favor the 2000 rpm, 16-mm spindle. Results showed that uniformity was not different among seed roll boxes and averaged 83.6%.

Table 7 is the results of a study by Holt and Laird (2008) that focused solely on Power Roll gin stands (see description in previous paragraph). The Power Roll gin stand was compared to three different makes of commercial gin stands (Continental, Lummus, and Consolidated) in three different states (Arkansas, California, and Texas). Results showed that uniformity was not different between the Power Roll gin stand and any of the conventional gin stands at the three commercial gins. These results are based on samples taken before lint cleaning. At the Arkansas gin, uniformity averaged 83.7% on the Power Roll gin stand and one Continental Golden Eagle 161 gin stand. At the California gin, uniformity averaged 84.2% on the Power Roll gin stand and two Lummus 158 gin stands. And at the Texas gin, uniformity averaged 84.1 % on the Power Roll gin stand and four Consolidated 164 gin stands.

Table 6. Uniformity results of a harvesting and saw gin seed roll box study by Armijo et al. (2006a) ^{Z}

Treatment	Uniformity (%)
Harvester	
13-mm spindle	83.7 ab
16-mm spindle	83.3 b
16-mm spindle, fast	83.7 a
Seed Roll Box	
Traditional (seed roll turned by gin saws)	83.7 a
Conveyor tube (assists turning seed roll)	83.6 a
Conveyor tube, slow speed	83.6 a
Paddle Roll (assists turning seed roll)	83.3 a

^{Z} Means followed by the same letter under a treatment heading are not different (P≤0.05).

Table 7. Uniformity results of a power roll gin stand study by Holt and Laird (2008) ^{Z}

Gin Location/Gin Stand Type	Uniformity (%)
Arkansas	
Power Roll 161 saw	83.9 a
Continental Golden Eagle 161 saw	83.4 a
California	
Power Roll 158 saw	84.4 a
Lummus 158 saw	84.3 a
Lummus 158 saw	84.0 a
Texas	
Power Roll 164 saw	84.2 a
Consolidated 164 saw	84.4 a
Consolidated 164 saw	83.7 a
Consolidated 164 saw	84.2 a
Consolidated 164 saw	83.8 a

^{Z} Means followed by the same letter at a gin location are not different (P≤0.05).

Table 8 is the results of a study by Hughs and Armijo (2015) that examined different gin saw tooth designs and evaluated their effects on fiber quality, ginning performance parameters, and textile processing quality. The test involved five different styles of gin saws. The saws were all 0.4-m diameter, but differed in tooth shape and tooth number depending upon which saw manufacturer supplied the saw. Gin saw treatments were assigned according to the number of saw teeth as follows: (1) 328 teeth per saw, (2) 352 teeth per saw, (3) 352 teeth per saw, (4) 330 teeth per saw, and (5) 352 teeth per saw. The gin saw from treatment 2 was supplied from the same manufacturer as the gin stand. Gin saw motor load was kept constant to observe how ginning rate (kg of seed cotton per minute) varied among gin saw tooth designs. One cultivar, grown in New Mexico, was used in the study and samples were taken before and after lint cleaning. Results showed that for samples taken before lint cleaning (gin stand effects only), uniformity was not different among saw tooth designs and averaged 81.2%. However, for samples taken after lint cleaning, uniformity was different among treatments and ranged from 79.6 to 80.3%. The results indicated that saw-tooth shape had a more significant effect on seed cotton ginning rate than saw-tooth number. They also highlight the detrimental effects that lint cleaning causes on fiber length.

Table 8. Uniformity results of a gin saw tooth design study by Hughs and Armijo (2015) [Z]

Treatment (teeth/saw)	Gin Rate (kg/min)	Uniformity (%)	
		Before Lint Cleaning	**After Lint Cleaning**
328	**89.8 a**	**81.2 a**	**80.3 a**
352 (original equipment)	**81.0 b**	**81.1 a**	**79.6 b**
352	**80.2 b**	**81.0 a**	**80.3 a**
330	**71.5 c**	**81.1 a**	**80.1 ab**
352	**67.0 d**	**81.6 a**	**80.0 ab**

[Z] **Means followed by the same letter in each column are not different (P≤0.05).**

Roller Ginning

Table 9 is the results of a study by Joy et al. (2012) that compared saw ginning and roller ginning with various cultivars. The saw ginning treatment included a saw gin stand followed by one saw-type lint cleaner. The roller ginning treatment included a high-speed roller gin stand followed by two mill type beater/air-jet lint cleaners. Two experimental extra-long-staple (ELS) upland cultivars, one conventional upland cultivar, and one conventional Pima cultivar were used in the study. Results showed that across all cultivars, uniformity was different between gin types; uniformity averaged 84.2 and 82.8% (a difference of 1.4 percentage points) for the roller and saw ginning treatment, respectively.

Table 9. Uniformity results of a saw and roller ginning study by Joy et al. (2012) [Z]

Treatment	Uniformity (%)
Roller Gin, High Speed	**84.2 a**
Saw Gin	**82.8 b**

[Z] **Means followed by the same letter are not different (P≤0.05).**

Table 10 is the results of a study by Armijo et al. (2013) that compared high-speed roller ginning, conventional roller ginning, and saw ginning. The roller ginning treatments included (1) no lint cleaning, (2) mill-type lint cleaner with one beater-cylinder/air-jet lint cleaner, and (3) mill-type lint cleaner with one pin-cylinder/air-jet lint cleaner. The pin-cylinder/air-jet lint cleaner is similar to the commercial Lummus Guardian lint cleaner. The saw ginning treatments included (1) no lint cleaning, (2) one saw-type lint cleaner, and (3) two saw-type lint cleaners. Three diverse cultivars, one of them stripper-harvested, were used in the study. Results showed that uniformity was different among ginning processes (which included lint cleaning); uniformity averaged 83.7% with roller ginning (high speed and conventional) and 81.7% with saw ginning. Results also showed that uniformity was different among lint cleaner types. Uniformity was highest when no lint cleaning was used and averaged 84.2, 83.7, and 82.4% for the high-speed roller gin with no lint cleaning, the conventional roller gin with no lint cleaning, and the saw gin with no lint cleaning, respectively. Uniformity was reduced on the high-speed roller gin with beater-cylinder lint cleaning and pin-cylinder lint cleaning by 0.2 and 0.8 percentage points, respectively. Uniformity was reduced on the saw gin with one saw-type lint cleaner and the saw gin with two saw-type lint cleaners by 0.7 and 1.3 percentage points, respectively. There were no interactions between gin process, lint cleaner type, and cultivar.

Table 10. Uniformity results of a saw and roller-ginning/lint-cleaning study by Armijo et al. (2013) [Z]

Gin and Lint Cleaner Treatments	Uniformity (%)
Gin Stand Type Treatment	
Roller Gin, High Speed	83.9 a
Roller Gin, Conventional	83.5 a
Saw Gin	81.7 b
Gin and Lint Cleaner Treatment	
Roller Gin, High Speed, No Lint Cleaning	84.2 a
" , Beater Lint Cleaner	84.0 ab
" , Pin Cylinder Cleaner	83.4 bc
Roller Gin, Conventional, No Lint Cleaning	83.7 abc
" , Beater Lint Cleaner	83.9 ab
" , Pin Cylinder Cleaner	83.1 c
Saw Gin, No Lint Cleaning	82.4 d
" , One Saw-Type Cleaner	81.7 e
" , Two Saw-Type Cleaners	81.1 e

[Z] **Means followed by the same letter under a treatment heading are not different (P≤0.05).**

Table 11 is the results of a roller ginning study by Byler and Delhom (2017) that used three different types of lint cleaners. A saw gin with one saw-type lint cleaner was also included in the study for comparison. The four treatments included (1) roller ginning with a pin-cylinder/air-jet lint cleaner (similar to the commercial Lummus Guardian lint cleaner), (2) roller ginning with an experimental cylinder-type seed cotton cleaner that was coupled to a saw-type lint cleaner without the normal feed works, (3) roller ginning with a saw-type lint cleaner, and (4) saw ginning with one saw-type lint cleaner. Four Mid-South cultivars were used in the study. Results showed that uniformity was different among ginning treatments. Roller ginning with the pin-cylinder lint cleaner had the highest uniformity of 84.3% followed by roller ginning with the experimental cylinder cleaner at 83.9%. The saw ginning treatment (with one saw-type lint cleaner) had the lowest uniformity at 82.8%. Uniformity on the roller gin with the saw-type lint cleaner was 83.6%; this was 0.7 percentage points lower than roller ginning with the pin-cylinder lint cleaner, but 0.8 percentage points higher than the saw gin with one saw-type lint cleaner.

Table 11. Uniformity results of a saw and roller-ginning/lint-cleaning study by Byler and Delhom (2017) [Z]

Treatment	Uniformity (%)
Roller Gin, Pin Cylinder Cleaner	84.3 a
Roller Gin, Experimental Cleaner	83.9 ab
Roller Gin, Saw-Type Cleaner	83.6 b
Saw Gin, Saw-Type Cleaner	82.8 c

[Z] **Means followed by the same letter are not different (P≤0.05).**

Lint Cleaning

Table 12 is the results of a two-year field study by Whitelock et al. (2011) that assessed changes in cotton quality at different stages of the ginning process. The study that included many different cultivars ginned throughout the season at many gins across the cotton belt was conducted to establish a baseline for cotton quality before and after saw-type lint cleaning for future research efforts to improve fiber quality. The study included many different cultivars. At gins that had only one stage of lint cleaning, uniformity was different within the stage and averaged 81.9 and 81.1% before and after lint cleaning, respectively. This equated to a drop in uniformity of 0.8 percentage points. At gins that had two lint cleaning stages, uniformity was different among stages and averaged 82.3% before lint cleaning, 81.7% after one stage of lint cleaning, and 81.3% after two stages of lint cleaning. This was a 0.6 percentage point decrease after one stage of cleaning, and a total 1.0 percentage point decrease after two stages. Fiber quality results summarized by growing region were similar to results summarized across the entire cotton belt, but relative differences among regions emphasized the impact of regional cultivars and environmental factors.

Table 12. Uniformity results of a Beltwide cotton quality study by Whitelock et al. (2011) [Z]

Gin Type/Treatment	Uniformity (%)
Gins using 1 lint cleaner	
Before Lint Cleaning	81.9 a
After One Lint Cleaning	81.1 b
Gins using 2 lint cleaners	
Before Lint Cleaning	82.3 a
After One Lint Cleaner	81.7 b
After Two Lint Cleaners	81.3 c

[Z] **Means followed by the same letter under a Gin Type are not different (P≤0.05).**

Table 13 is the results of a study by Delhom et al. (2008) that determined the effects of individual components of a saw-type lint cleaner on fiber quality. The lint cleaner was modified to allow isolating the feed works section of the cleaner from the grid bars section. The lint cleaner treatments were as follows: (1) no lint cleaning (control), (2) processing ginned fiber thru the feed works section only (no grid bars), (3) processing fiber thru the feed works and one grid bar, (4) processing fiber thru the feed works and two grid bars, and (5) processing fiber thru the feed works and five grid bars. Three Mid-South cultivars (hairy leaf, smooth leaf, and semi-smooth leaf) were used in the study. Results showed that uniformity for the no lint cleaning treatment was 82.2% and significantly different from all of the other treatments that averaged 81.6%. These results show that the feed works reduced uniformity by 0.6 percentage points, but the grid bars did not reduce uniformity any further.

Table 13. Uniformity results of a lint cleaner feed works and grid bar study by Delhom et al. (2008) z

Treatment	Uniformity (%)
By-Pass Lint Cleaning	82.2 a
No grid bars	81.5 b
1 Grid Bar	81.5 b
2 Grid Bars	81.6 b
5 Grid Bars	81.6 b

z Means followed by the same letter are not different (P≤0.05).

Table 14 is the results of a study by Delhom and Byler (2009) that determined the effects of lint cleaner saw speed on fiber quality. A variable frequency drive allowed varying the speed of the saw cylinder without altering other settings of the lint cleaner including the feed works. Four saw speed treatments were included in the test: (1) 605 rpm, (2) 870 rpm, (3) 1135 rpm, and (4) 1400 rpm. The normal saw speed in this test was 870 rpm. Three Mid-South cultivars (hairy leaf, smooth leaf, and semi-smooth leaf) were used in the study. Results showed that uniformity was different among saw speed treatments with uniformity decreasing from 82.0 to 81.3% when saw speed was increased from 605 to 1400 rpm.

Table 14. Uniformity results of a lint cleaner saw speed study by Delhom and Byler (2009) z

L.C. Saw Speed (rpm)	Uniformity (%)
605	82.0 a
870	81.8 ab
1135	81.6 b
1400	81.3 cc

z Means followed by the same letter in each column are not different (P≤0.05).

Table 15 is the results of a field study by Rutherford et al. (2004) that compared fiber quality from side-by-side installations of conventional Lummus Model 108 controlled-batt saw-type lint cleaners and Lummus Sentinel lint cleaners at three commercial gins. A conventional saw-type lint cleaner collects ginned fiber on a slow moving condenser drum and forms a batt of lint. The batt then travels thru a feed works assembly and feed plate where the lint is set onto the moving saw. The Sentinel lint cleaner, developed in 1999, uses a high-speed perforated separator cylinder to feed individual tufts to the saw, eliminating the feed works assembly but retaining the feed plate. Three commercial gin plants were used in the study: two in Texas and one in Australia. Cultivar varied by gin plant and growing area. Samples were taken before and after lint cleaning. Results show that uniformity at Gin A was 83.4% before lint cleaning and 82.9% after lint cleaning with the Sentinel lint cleaner (0.6% reduction in uniformity), and 84.0% before lint cleaning and 82.8% after lint cleaning with the Model 108 lint cleaner (1.4% reduction in uniformity). At Gin B, uniformity was reduced by 0.7% with the Sentinel lint cleaner, and uniformity was reduced by 0.5% with the Model 108 lint cleaner. At Gin C, uniformity was reduced by only 0.02% with the Sentinel lint cleaner and reduced by 1.41% with the Model 108 lint cleaner. The results from Gins A and C indicate that the absence of the feed works and batt formation in the Sentinel reduce uniformity by a lesser amount. However, a formal statistical analysis was not performed.

Table 15. Uniformity results of a study with the Lummus Sentinel lint cleaner by Rutherford et al. (2004)

Gin Facility/Lint Cleaner Type	Uniformity (%)
Gin A	
Before Sentinel	83.4
After Sentinel	82.9
Percentage point change	-0.60%
Before Model 108	84.0
After Model 108	82.8
Percentage point change	-1.43%
Gin B	
Before Sentinel	81.7
After Sentinel	81.1
Percentage point change	-0.71%
Before Model 108	81.0
After Model 108	80.6
Percentage point change	-0.48%
Gin C	
Before Sentinel	81.5
After Sentinel	81.4
Percentage point change	-0.02%
Before Model 108	81.8
After Model 108	80.7
Percentage point change	-1.41%

Table 16 is the results of a study by Hughs et al. (2013) that determined how the length distribution of a medium staple upland cotton was affected by saw-type lint cleaning treatments. The test included four saw ginning/lint-cleaning treatments: a saw gin with zero, one, two, or three saw-type lint cleaners and a roller gin with two beater/air-jet (mill-type) cleaners for comparison. Although uniformity was not reported, Sutter-Webb upper quartile length and mean length were reported. Results showed that both upper quartile length and mean length were different among ginning/lint-cleaning treatments. Of the saw ginning treatments, no lint cleaning resulted in the best fiber upper quartile and mean length at 29.5 and 22.4 mm, respectively. Fiber lengths among the saw ginning treatments got shorter as more lint cleaning was used. One lint cleaner reduced mean length by 2.68% (0.6 mm) from saw ginning with no lint cleaning. Interestingly, mean length was not reduced by adding a second lint cleaner; both one and two lint cleaner treatments had 21.8-mm mean length. Mean length was further reduced by 5.5% and averaged 20.6 mm when a third saw-type lint cleaner was used. This equated to 1.2 mm, or nearly two staple lengths shorter, when using three lint cleaners compared to one or two lint cleaners. The roller ginning treatment had the best upper quartile and mean length at 30.5 and 24.1 mm, respectively. Comparing roller ginning with mill-type lint cleaning to saw ginning with one saw-type lint cleaner, mean length was reduced by 2.3 mm, or three staple lengths, with the saw ginning treatment

SUMMARY

Table 17 summarizes the results for the research reviewed. Uniformity was different among cultivars in the studies cited. The cultivars were diverse, and represented cottons from many growing regions. In all of the studies with multiple cultivars, cultivar did not have a cross effect with ginning treatments on the uniformity response. In other words, ginning treatments impact on uniformity was independent of cultivar.

Uniformity was reduced by stripper harvesting when compared to picker harvesting. Seed cotton cleaning machinery (cylinder cleaners and stick machines) did not affect uniformity. Uniformity was reduced when processing cotton at lower moisture contents.

Interestingly, uniformity was not affected by the configuration of the seed roll on the saw gin stand. Roller ginning preserved uniformity better than saw ginning. This is not surprising as roller ginning is a gentler process.

Roller gin lint cleaning reduced uniformity, but to a lesser degree than saw-type lint cleaning. Saw-type lint cleaning reduced uniformity, and multiple stages reduced it more than one stage. Uniformity was not affected by the grid bars on saw-type lint cleaning. Faster saw speeds reduced uniformity, but more importantly, studies reviewed for this report confirmed findings from older studies (over 10 years) that showed that the feed works was the machine part within the saw-type lint cleaner that causes the most damage. Although the Lummus Sentinel lint cleaner eliminates the condenser batt and feed rollers in the feed works, it still retains a feed plate to place the fiber on the saw. Some of the field tests with the Sentinel lint cleaner showed better uniformity than the standard lint cleaner, but further controlled experiments are needed to confirm this.

Table 16. Suter-Webb upper quartile length and mean length of a roller/saw ginning and lint cleaning study by Hughs et al. (2013) ^{Z}

Treatment	Upper Quartile Length (mm)	Mean length (mm)
Roller Gin, Two Mill-Type Lint Cleaners	**30.5 a**	**24.1 a**
Saw Gin, No lint Cleaning	**29.5 b**	**22.4 b**
Saw Gin, One Saw-Type Lint Cleaner	**29.0 c**	**21.8 c**
Saw Gin, Two Saw-Type Lint Cleaners	**28.7 c**	**21.8 c**
Saw Gin, Three Saw-Type Lint Cleaners	**27.4 d**	**20.6 d**

^{Z} Means followed by the same letter in each column are not different (P≤0.05).

Table 17. Summary of change in uniformity reported in above studies sorted by process stage and ranked by impact

Process	Variable	Level	Level	Change in Uniformity (percentage points)	Table (no.)
Production	**Defoliation Timing**	**Late**	**Early**	**-0.60%**	**1**
	Picker Spindle Speed	**2900 rpm**	**2000 rpm**	**-0.40%**	**6**
	Harvest Method	**Picker**	**Stripper**	**-0.30%**	**4**
Moisture Restoration	**Lint Moisture Year 1**	**6%**	**4%**	**-0.60%**	**2**
	Lint Moisture Year 2	**6%**	**4%**	**-0.40%**	**2**
Ginning	**Type of Gin Stand**	**Roller**	**Saw Gin**	**-1.40%**	**9**
	Type of Gin Stand	**Roller**	**Saw Gin**	**-1.00%**	**10**
	Type of Gin Stand	**Roller**	**Saw Gin**	**-0.80%**	**11**
Lint Cleaning	**Saw-Type, 2 stages**	**No**	**Two**	**-1.30%**	**10**
	Saw-Type, 2 stages	**No**	**Two**	**-1.00%**	**12**
	Saw-Type, 1 stage	**No**	**Yes**	**-1.20%**	**8**
	Saw-Type, 1 stage	**No**	**Yes**	**-0.80%**	**12**
	Saw-Type, 1 stage	**No**	**Yes**	**-0.70%**	**10**
	Saw-Type Cylinder Speed	**605 rpm**	**1400 rpm**	**-0.70%**	**14**
	Saw-Type Feed Works	**No**	**Yes**	**-0.60%**	**13**
	Saw-Type, Second Stage	**One**	**Two**	**-0.40%**	**12**
	Pin-Type Lint Cleaner	**No**	**Yes**	**-0.80%**	**10**
	Battless Lint Cleaner[z]	**Sentinel**	**Lummus 108**	**-0.67%**	**15**
	Beater-Type Lint Cleaner	**No**	**Yes**	**-0.20%**	**10**

[z] **No statistics**

FUTURE WORK

Areas of future research that have the potential to preserve uniformity in the ginning process include:

- **Re-evaluate the "coupled lint cleaner concept" with current cultivars.** The coupled lint cleaner concept connects the gin stand directly to the lint cleaner (Gillum et al., 1986). This eliminates the need for the feed works (condenser batt, feed rollers, and feed plate) on the lint cleaner. It also reduces pneumatic conveying-related energy consumption and particulate emissions. The Lummus Sentinel lint cleaner is based on the coupled lint cleaner concept, but it is not connected directly to the gin stand. Previous evaluations of the coupled lint cleaner concept were done more than 15 years ago (Hughs et al., 1990 and Gillum et al, 1999). Cultivars have changed considerably over the last quarter-century. Re-evaluations would include both saw and roller ginning with coupled lint cleaning.
- **Evaluate the performance of feed plate modifications on the saw-type lint cleaner.** The feed plate sets the fiber on the saw, but the fiber is jerked around the nose of the feed plate as it changes directions drastically while being grabbed by the saw. Past research has shown that this drastic change in direction over the sharp feed plate nose causes most of the reduction in fiber length uniformity. Some work evaluated feed plate modification for lint cleaning in saw and roller gin applications (Kirk and Leonard, 1977 and Mangialardi, 1995), but this work also needs evaluation with current cultivars.
- **Evaluate "saw-tooth pitch angle" on the saw-type lint cleaner.** Past research has investigated saw tooth density (Columbus, 1985), but not pitch angle. A less aggressive pitch angle may cause less damage, particularly where the fiber is abruptly placed onto the saw at the feed plate.
- **Resume studies on differential ginning.** This is a type of roller ginning that limits the proximity and time that fiber is exposed to the ginning point, thereby removing only the longer fibers. Preliminary research has shown that differential ginning has the potential to preserve fiber length (Armijo, et al., 2006b and Armijo et al., 2010).

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DISCLAIMER

Mention of trade names or commercial products in this publication is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture. USDA is an equal opportunity provider and employer.

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