EVALUATING A DEVICE FOR PNEUMATIC LINT CLEANING

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Abstract

Research exploring innovative techniques to clean ginned lint while reducing short fiber and neps has led to evaluations of a pneumatic fractionator. This device is typically used to determine foreign matter content of seed cotton at the USDA cotton ginning research laboratories. No modifications were made to the device, but the operational parameters of pneumatic air pressure and processing time were varied from 40 to 70 psi and 10 to 75 s, respectively. The overall results were not conclusive. The fractionator cleaned ginned lint about as well as a typical saw-type lint cleaner, but no differences in measures of fiber damage – such as fiber length, short fiber content, and nep count – between the fractionator and saw-type lint cleaner were detected. Compared to the saw-type lint cleaner, the fractionator did remove less fiber with the foreign matter during cleaning and that fiber was shorter. The results brought to the forefront questions about 1) the effects of cultivar physical properties on susceptibility to fiber damage during ginning and 2) the effects of undetectable differences in raw fiber quality parameters on spinning performance. Answering these questions will require further investigation.

Introduction

Recent concern about the short fiber content and neps in US cotton and the tendency of international markets to consider leaf grade 4 as a discount cotton, though it is the base grade for the U.S. loan chart (Laws, 2006), has spurned new efforts to improve cotton quality to keep US cotton competitive on the international markets.

In a modern gin plant, foreign matter removal is accomplished with seed-cotton cleaning machines (i.e. inclined cleaners and stick machines) prior to ginning (Baker et al., 1994) and lint cleaners (i.e. air-type and saw-type lint cleaners) after ginning (Mangialardi et al., 1994). Lint cleaning research, for the most part, has concentrated on saw-type cleaners with grid bars (Mangialardi and Anthony, 2003). This type of lint cleaner is efficient at removing foreign material, but reduces fiber length and increases short fiber content and nep counts.

Based on discussions at a research summit to address lint cleaning issues, researchers from Cotton Incorporated, the USDA-ARS Ginning Labs, and Texas A&M University established the following goal:

> To clean fiber and maintain fiber quality as well as or better than current technology, and reduce neps and short fiber content.

To work towards this goal, a lint cleaning research program was initiated at the USDA-ARS Southwestern Cotton Ginning Research Laboratory (SWCGRL) in Mesilla Park, NM in cooperation with Cotton Incorporated and researchers from the other USDA-ARS Ginning Labs.

For years, the USDA-ARS Ginning Labs have used a pneumatic fractionator as a standard method to separate foreign matter from seed cotton to measure trash or foreign matter levels (Shepherd, 1972). The fractionator consists of a rectangular chamber about 18-in. high × 24-in. wide × 8-in. deep with rounded ends at the top and bottom and is split and hinged in the middle (Figure 1). A pre-weighed sample is placed in the chamber, the chamber is closed, and compressed air from 8 jets across the back of the chamber cause the cotton to tumble and flow around the perimeter of the chamber. The tumbling action and rubbing action on 3/16-in. slots across the front of the chamber cause small trash and dust to be dislodged from the cotton. The foreign matter exits the chamber through the slots, aided by a slight flow of air pulled from the chamber, and collects on two 8-in. diameter sieves (Tyler No. 6 [0.13-in. opening] and No. 200 [0.0029-in. opening]).

Brashears (1983) modified the fractionator to collect fine bur cotton material. Optimum line pressure and fractionation time for this application were 40 psi and 30 seconds. Work at the SWCGRL explored using the fractionator as a faster means of determining foreign matter content in classer's samplers than the Shirley Analyzer

(Chapman, W.E. and J.V. Martinez. 1972. Unpublished report. Mesilla Park, NM: USDA-ARS SW Cotton Ginning Res. Lab). The results from the tests showed a positive and highly significant correlation between the fractionator and Shirley Analyzer foreign matter measurements. The time required to process a sample averaged 4 minutes for the fractionator and 20 minutes for the Shirley. In a previous test to evaluate the fractionator as a lint cleaning device, Whitelock et al. (2008) used the standard device with compressed air pressure set to 40 psi instead of 70 psi. Seven lint cleaning treatments after normal saw ginning were used: no lint cleaning, one standard saw-type lint cleaner, and cleaning with the fractionator for 5, 10, 15, 20, and 30 seconds. They found that while maintaining fiber quality parameters such as length, short fiber content, and nep count at levels similar to those of lint not subjected to lint cleaning, the fractionator cleaned lint and produced color measurements similar to one saw-type lint cleaner. Also, varying the fractionator processing time had little effect on the results.

The objective of this research was to further evaluate the USDA-ARS fractionator as a lint cleaning device over a wide range of operating conditions.

Figure 1. USDA-ARS Pneumatic Fractionator.

Materials and Methods

The gin facilities and fractionator at the SWCGRL were used for the tests. Upland seed cotton (FiberMax 989) was processed through the Lab's gin with a typical three seed-cotton cleaner (3SC) machine sequence – cylinder cleaner, stick machine, cylinder cleaner, feeder, gin stand – and with no seed-cotton precleaning (noSC) – feeder and gin stand only. The two seed-cotton cleaning treatments were conducted in random order within five replications. During processing of each seed-cotton cleaning treatment, ginned lint samples were collected for three lint cleaning treatments: before the lint cleaner for the 1) no-lint-cleaning (noLC) and 2) air-lint-cleaning with the fractionator treatments, and after the saw-type lint cleaner for the 3) saw-lint-cleaner (sLC) treatment.

Two treatment levels for the fractionator compressed air pressure (40 and 70 psig) and three levels for processing time (10, 30, 75 s) were combined for a total of six fractionator air-lint-cleaning treatments. The higher pressure forced more compressed air to flow through the jets causing more aggressive agitation of the cotton sample in the fractionator. The order of the fractionator treatments was randomized within each of five replications.

Initial weight of lint samples processed in the fractionator was approximately 50 g or 0.11 lb. After processing, final weights were recorded for the cleaned lint remaining in the fractionator chamber, the material captured on the No. 6

sieve, and the material captured on the No. 200 sieve. For this test, the waste removed from the lint during cleaning (lint cleaner waste [LCW]) was analyzed for foreign matter content and fiber properties. In order to obtain enough LCW for these analyses, each fractionator treatment was run about 20 times for each replication and the LCW combined.

Cleaned lint samples were sent to the USDA-AMS Classing Office for official classing. Lint samples were also analyzed with the Advance Fiber Information System (AFIS, Uster Technologies, Charlotte, NC) and Micro Dust and Trash Analyzer III (MDTA3, Uster Technologies, Charlotte, NC). The LCW was analyzed for foreign matter content using the Shirley Analyzer (ASTM, 2007) and the lint portion was also analyzed with the AFIS.

Data were analyzed to evaluate differences in fiber quality among the lint cleaning treatments using GLM procedures in SAS (Ver. 9.2, SAS Institute, Inc., Cary, N.C.).

Results and Discussion

The results for this report are focused on the noLC and sLC treatments, and the most and least aggressive air-lint-cleaning fractionator treatments: 70 psig/75 s (70-75) and 40 psi/10 s (40-10). One concern about using the fractionator for cleaning lint was that the action of the compressed air jets tumbled the lint without the combining effect of the saw-type lint cleaner. As a result, the fiber may appear tangled and receive prep calls from the classer (Figure 2). USDA classing data showed that about 10% of the 40-10 samples had prep calls, but this was not significantly different from the noLC and sLC treatments with no prep calls. All the 70-75 samples were called for prep.

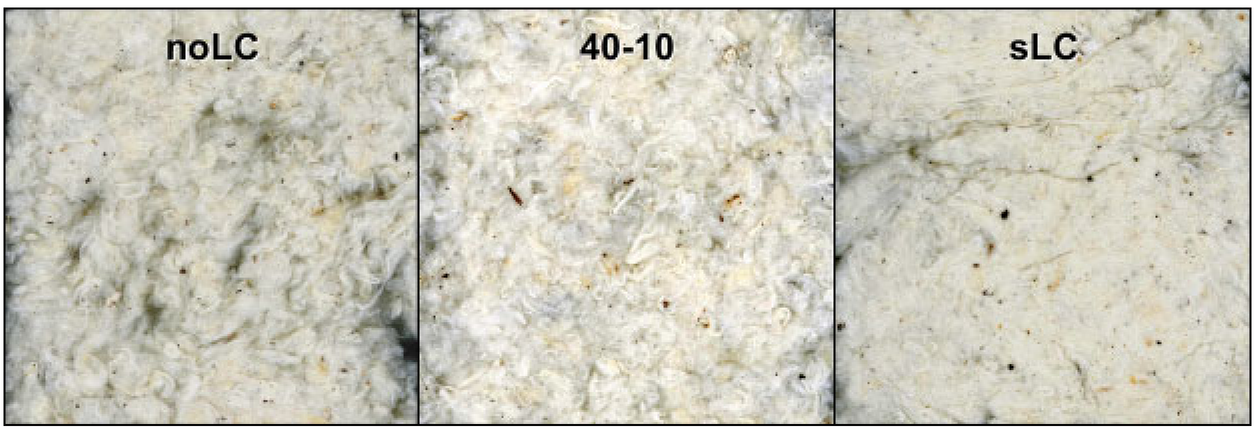

Figure 2. Photograph of lint samples with no lint cleaning (noLC), fractionator air-lint-cleaning with 40 psi for 10s (40-10), and one saw-type cleaner (sLC).

For comparison of the lint cleaning effectiveness of the fractionator, average color and foreign matter measurements are shown in Figure 3. Average color grade, shown in Figure 3 as Old Code (105 = 11 color, 104 = 21 color, 100 = 31 color), was not different among the two fractionator lint cleaning treatments (40-10 and 70-75) and the sLC. The average leaf grade for 40-10 was not significantly different from the sLC. While, the 70-75 lint samples received a 1.0 leaf grade that was significantly better than all the other lint cleaning treatments. AFIS visible foreign matter for 40-10 was significantly better than noLC, but higher than sLC that was higher still than 70-75. MDTA3 trash content of the lint samples followed the same trend as the visible foreign matter. These measurements indicated that the air-lint-cleaning fractionator treatments cleaned the ginned lint about as well as the sLC or better in the case of the 70-75 fractionator treatment.

The seed-cotton cleaning by lint cleaning treatment interactions were statistically significant only for the lint foreign matter measurements. In general, for all the foreign matter measures, foreign matter content decreased with the level of seed-cotton cleaning (noSC, 3SC) and with level of lint cleaning (noLC, 40-10, sLC, 70-75). Figure 4 shows an example of this general trend for classer leaf grade.

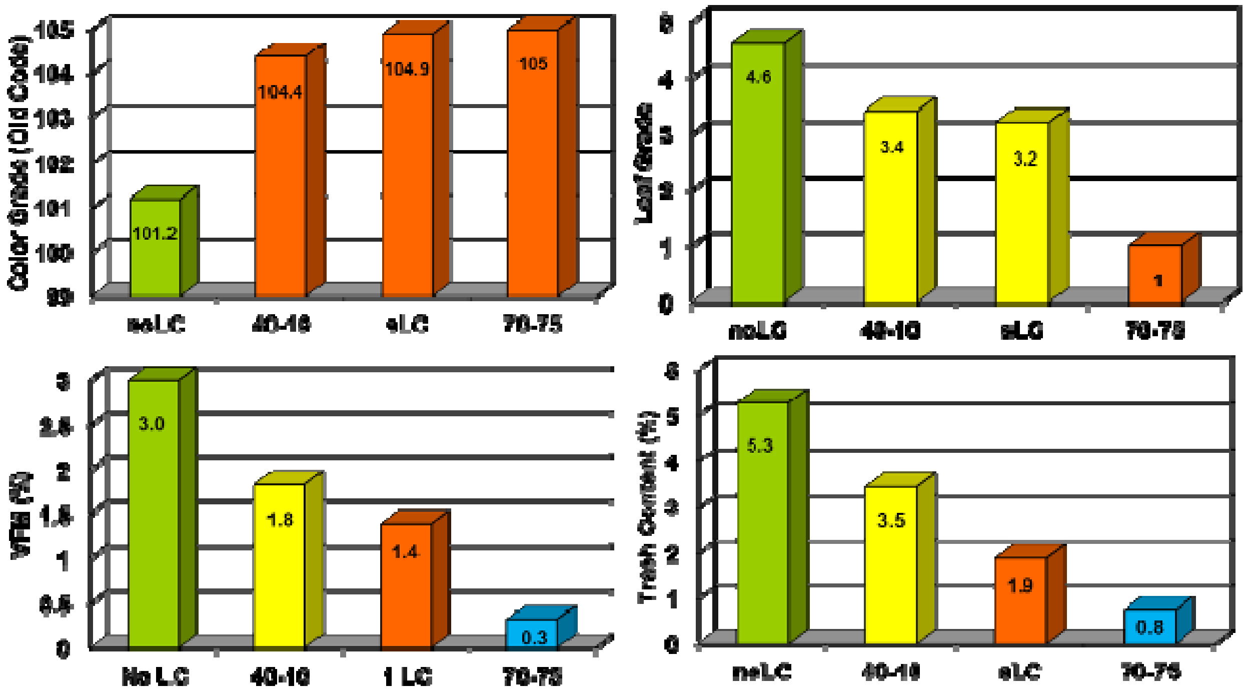

Figure 3. Color code (Old Code: 105 = 11 color, 104 = 21 color, 100 = 31 color), Classer leaf grade, AFIS visible foreign matter (VFM), and MDTA3 trash content for ginned lint with no lint cleaning (noLC), fractionator air-lint-cleaning with 40 psi for 10s (40-10) and 70 psi for 75 s (70-75), and one saw-type cleaner (sLC). Bars that contain the same color are not significantly different (based on Tukey's multiple comparisons test with α ≤ 0.05).

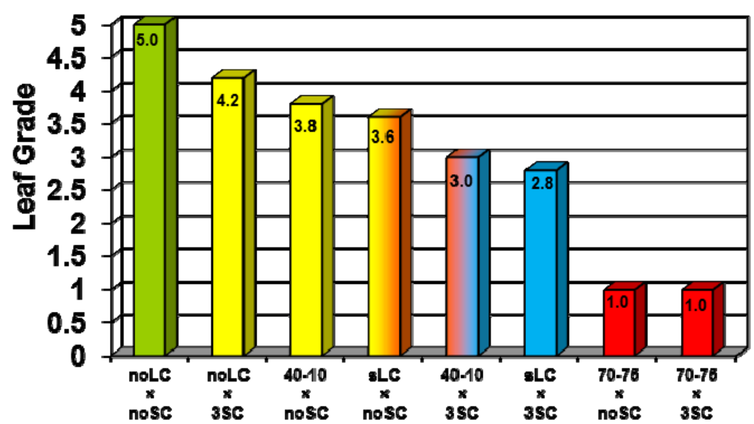

Figure 4. Classer leaf grade for ginned lint with seed-cotton cleaning by lint cleaning treatment combinations: noSC = no seed-cotton cleaning, 3SC = three seed-cotton cleaners; noLC = no lint cleaning, 40-10 = fractionator air-lint-cleaning with 40 psi for 10s (40-10) and 70-75 = 70 psi for 75 s, and sLC = one saw-type cleaner. Bars that contain the same color are not significantly different (based on Tukey's multiple comparisons test with α ≤ 0.05).

Comparisons of the selected length measurements are shown in Figure 5. Staple length of the 40-10 fractionator treatment was not different from noLC, but was also not longer than sLC. The 70-75 fractionator treatment had the shortest average staple length fiber. The average AFIS length by weight measurements for noLC, 40-10, and sLC were not significantly different and were all longer than the 70-75 treatment. These length measurements indicated that air-lint-cleaning with the fractionator did not maintain fiber length better than sLC. However, at least as measured by AFIS length by weight, lint cleaning (air or saw) did not significantly affect fiber length, except for the most aggressive fractionator treatment.

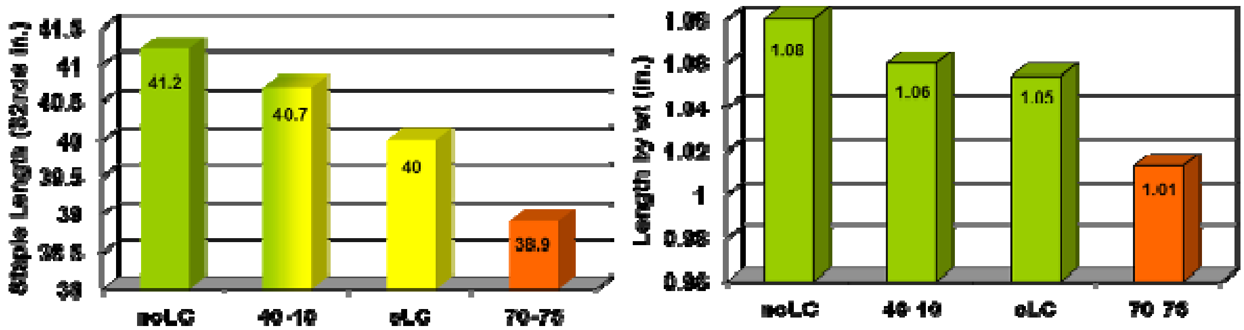

Figure 5. Staple length and AFIS length by weight for ginned lint with no lint cleaning (noLC), fractionator air-lint-cleaning with 40 psi for 10s (40-10) and 70 psi for 75 s (70-75), and one saw-type cleaner (sLC). Bars that contain the same color (including two-tone bars) are not significantly different (based on Tukey's multiple comparisons test with $\alpha \leq 0.05$).

Two quality measurements of particular interest, AFIS short fiber content and nep count, are shown in Figure 6. There were no significant differences in average short fiber content among the lint cleaning treatments. Also, the short fiber content of the 40-10 and sLC lint cleaning treatments were not different from noLC, but the 70-75 short fiber content was greater than noLC. All lint cleaning treatments had significantly higher average nep counts than noLC and there was no difference between the nep counts of 40-10 and sLC. These measurements also indicated that air-lint-cleaning with the fractionator did not maintain fiber length better than sLC. The 40-10 fractionator treatment produced about the same number of fiber entanglements (neps) as the sLC treatment.

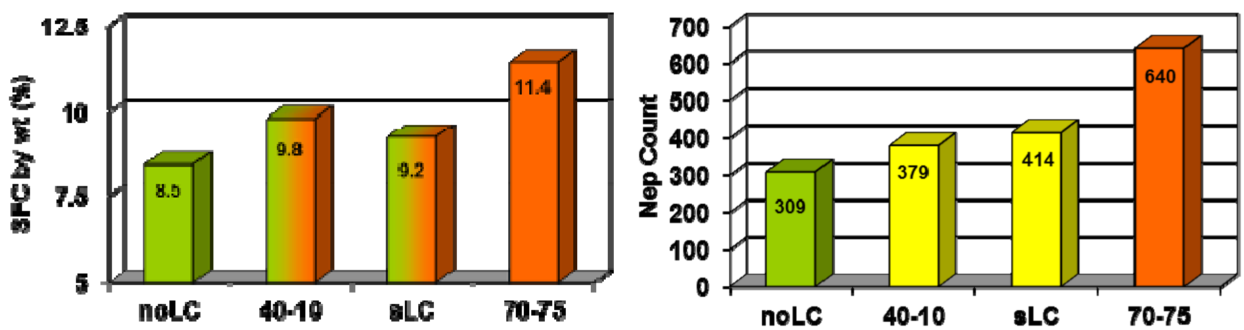

Figure 6. AFIS short fiber content (SFC) by weight and nep count per gram for ginned lint with no lint cleaning (noLC), fractionator air-lint-cleaning with 40 psi for 10s (40-10) and 70 psi for 75 s (70-75), and one saw-type cleaner (sLC). Bars that contain the same color (including two-tone bars) are not significantly different (based on Tukey's multiple comparisons test with $\alpha \leq 0.05$).

Select measurements from the lint cleaner waste analyses are shown in Figure 7. The 40-10 fractionator treatment removed significantly less lint cleaner waste during cleaning and that waste proportionately had a higher amount of foreign matter (trash content), and less fiber, than the other two treatments, sLC and 70-75. Analyses showed that the fiber in the lint cleaner waste from air-lint-cleaning fractionator treatments was shorter and contained more short fiber than the sLC treatment. This result indicated that the 40-10 treatment removed less fiber waste from each bale ginned and the fiber removed tended to be shorter.

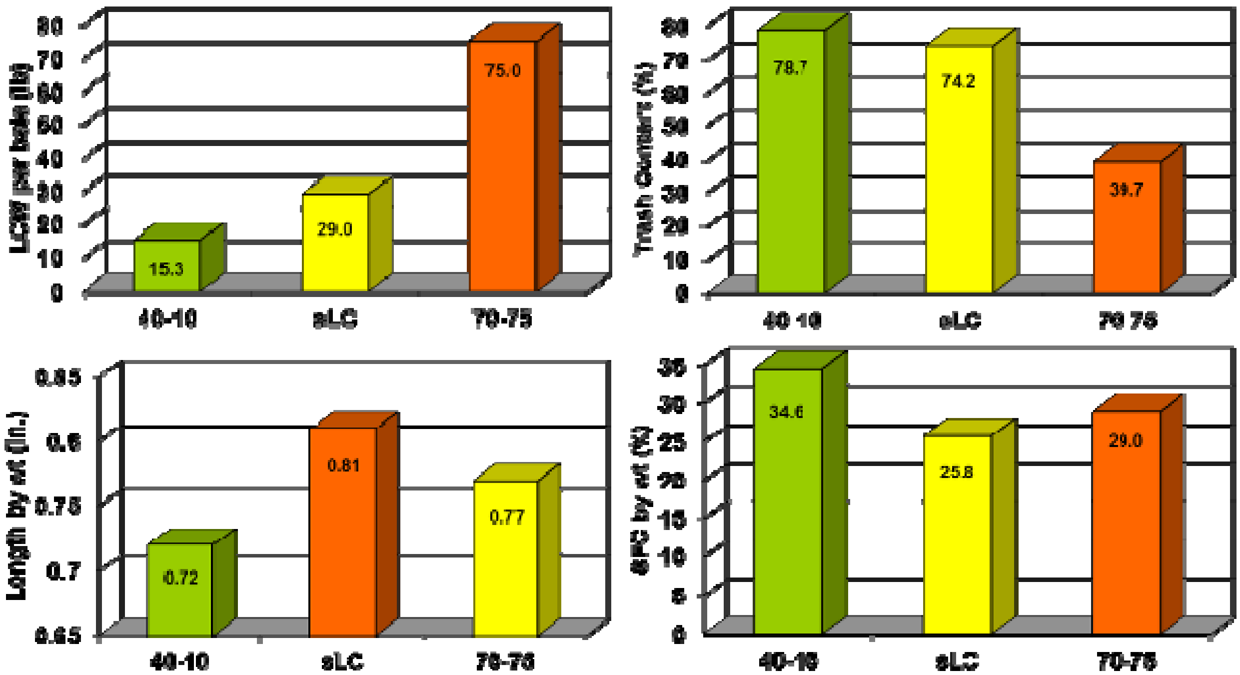

Figure 7. Lint cleaner waste (LCW) produced per bale, LCW trash content, and AFIS length by weight and short fiber content (SFC) of LCW fiber for LCW produced from lint cleaning ginned lint with fractionator air-lint-cleaning with 40 psi for 10s (40-10) and 70 psi for 75 s (70-75), and one saw-type cleaner (sLC). Bars that contain the same color are not significantly different (based on Tukey's multiple comparisons test with $\alpha \leq 0.05$).

The quality differences associated with fiber damage – length measures and nep count – between fractionator air-lint-cleaning and saw-type lint cleaning did not materialize in this test as it did in the earlier test by Whitelock et al. (2008). Also, many of the fiber length measurements (e.g., AFIS length and short fiber content) did not show any detrimental effects from lint cleaning. One explanation may be the differences in fiber properties of the cultivars used in the two tests. Average fiber staple length, strength, and micronaire before lint cleaning for the cultivar in the earlier test were about 37.8, 29.8 g/tex, and 4.3, respectively, while the same measurements for the cultivar in this test were about 41.2, 31.1 g/tex, and 3.3, respectively. These differences indicate that the cultivar in this test tended to be longer, stronger, and finer and may explain why it appeared less affected by lint cleaning than the cultivar in the earlier test. This hypothesis will require further testing in the future.

Ginned fiber quality differences were not detected, but significant differences in the characteristics of the lint cleaner waste and fiber contained in it were found. Namely, the less aggressive fractionator air-lint-cleaning treatment removed less fiber waste and the fiber removed was shorter than the saw-type lint cleaner. These results indicated that differences in fiber quality between fractionator air-lint-cleaning and saw-type lint cleaning, not detectable in the raw fiber for certain cultivars with current HVI and AFIS analyses, may be revealed with further processing at the spinning mill. Again, this hypothesis will require further testing in the future.

Conclusions

A pneumatic fractionator that utilizes compressed air to tumble and fluff seed cotton or lint and scrub it across a set of narrow slots multiple times to remove trash was evaluated as a lint cleaner. The fractionator cleaned ginned lint about as well as a typical saw-type lint cleaner. No differences in measures of fiber damage, such as fiber length, short fiber content, and nep count, were detected between the fractionator and saw-type lint cleaner. This may be attributed more to cultivar physical characteristics than lint cleaner aggressiveness. The fractionator did remove less fiber with the foreign matter during cleaning and that fiber was shorter. While the results were somewhat inconclusive, some questions about cultivar interactions and milling capabilities were raised that require further investigation.

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