TRACKING COTTON FIBER QUALITY THROUGHOUT A STRIPPER HARVESTER: PART II

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Abstract

Cotton fiber quality begins to degrade naturally with the opening of the boll and mechanical harvesting processes are perceived to exacerbate fiber degradation. Previous research indicates that stripper harvested cotton generally has lower fiber quality and higher foreign matter content than picker harvested cotton. The main objective of this project was to track cotton fiber quality and foreign matter content throughout the harvesting units and conveying/cleaning systems on a brush-roll stripper harvester. During 2011 seed cotton samples were collected at six locations including: 1) hand-picked from the field, 2) just after the brush rolls in the row unit, 3) just after the row units, 4) from the separation duct after the cotton was conveyed by the cross auger, 5) from the basket with the field cleaner by-passed, and 6) from the basket after the cotton was processed through the field cleaner. During 2012 the second location (just after the stripper rolls in the row unit) were eliminated from the collections. Seed cotton samples collected at each location were analyzed for foreign matter content and ginned to produce fiber for HVI and AFIS fiber analyses. Results independent of year effect were very similar from 2011 and 2012. Results show that the row unit augers and field cleaner are the most effective systems on a cotton stripper for removing foreign material. AFIS and HVI results indicate that the harvesting, conveying, and cleaning systems on a stripper harvester have a minimal effect on fiber length characteristics and the formation and size of neps. Leaf grade increased between the harvesting units and the field cleaner due to the breakup of foreign material caused by mechanical action in the conveying system. The field cleaner helped to reduce leaf grade back to the level observed at the stripper rolls. It is very important to note that independent of year effect the results presented in this paper show very similar trends between two harvest seasons. Thus the data represented is of high accuracy and the integrity was preserved between the two years. The results of this work indicate that the cross auger and pneumatic conveying systems on stripper harvesters could be redesigned to help improve seed cotton cleanliness while helping to preserve fiber quality.

Introduction

Cotton fiber quality begins to degrade with the opening of the boll (ICAC 2001). Mechanical harvesting processes increase the amount of foreign material contained in seed cotton at the gin and influences the quality of ginned lint. Stripper harvested seed cotton contains more foreign matter than picker harvested cotton (Kerby et al., 1986; Baker et al., 1994; Faulkner et al., 2011a), and the quality of stripper harvested fiber is often lower than that of picker harvested lint (Faulkner et al., 2011b). Unlike picker harvesters, which use spindles to remove seed cotton from open bolls, stripper harvesters use brushes and bats to indiscriminately remove seed cotton, bolls, leaves, and other plant parts from the stem of the plant. The harvesting efficiency of a picker is lower than that of a stripper harvester. Thus for a particular cotton crop, a picker harvests a different subset of the total fiber population than a stripper harvester. The difference in fiber quality between picker and stripper harvested cotton is dependent upon fiber maturity (Faulkner et al., 2011b). Micronaire and fiber length parameter differences between harvest methods are greater when fibers are immature and favor picker harvesting. When fibers are mature, fiber quality differences tend to be less between harvest methods.

Stripper harvesting is predominately confined to the Southern High Plains of the US due to several factors including: low humidity levels during daily harvest intervals, tight boll conformations and compact plant structures adapted to withstand harsh weather during the harvest season, and reduced yield potential due to limited rainfall and irrigation capacity. Cotton strippers typically cost about one-third the price of cotton pickers and have harvesting efficiencies in the range of 95 – 99% making them ideal for lower yielding cotton conditions (Williford et al., 1994). Approximately 50% of the total number of cotton bales produced in the U.S. recently came from Texas and Oklahoma (USDA, 2011). A majority of the cotton harvested in these two states is done so with stripper harvesters.

Many studies have investigated the overall quality of stripper harvested cotton, quality of stripper harvested cotton versus picker harvested cotton, and a cost comparison of the two harvest methods (Faulkner et al., 2011b and c; Kerby et al. 1986; Nelson et al. 2006.). Several studies focused on the use of field cleaners and their effectiveness at removing foreign material (Brashears, 2005; Smith and Dumas, 1982; Wanjura and Baker, 1979; Wanjura and Brashears, 1983; Wanjura et al., 2011). All of these studies show that a field cleaner is an effective system for removing foreign material from stripper harvested cotton; however these studies do not address any other components of the stripper harvester. Brashears (1994) observed that attaching pieces of square key stock to the outer edge of the conveyor auger flights on a cotton stripper increased the amount of foreign material removed from harvested seed cotton but the influence of these modifications on fiber quality was not reported. To our knowledge, only the previous work by Porter et al. (2011) addresses the influence of the individual harvesting and conveying systems of a stripper harvester on fiber quality. Thus, the objective of this work was to document cotton quality and foreign matter content at several sequential locations on a stripper harvester. The overall goal of this effort is to identify components and systems on the stripper that if redesigned, could help to improve the cleanliness and better preserve the quality of stripper harvested cotton.

Materials and Methods

In this study, the term location refers to a location on the harvester, not a location from within the actual field the fiber was collected from. The data collection for this project occurred at the Texas A&M Research and Extension Center north of Lubbock, TX. Two years of harvest data were collected including 2011 and 2012. During 2011, five locations on the harvester and a hand-collected field stand of cotton were identified as points of interest from the fiber quality standpoint to begin the collection process. One location was eliminated during 2012 due to excessive dirt and debris incorporated into the machine and the excellent job performed by the row unit augers at removing this foreign matter. The same two varieties were harvested for this project in both years, FiberMax 9170 B2F, and Stoneville 5458 B2F. Two varieties were used only because they are common in the Southern High Plains for stripper harvested cotton. This study did not explore the varietal differences from the perspective of variety performance, only from machine effects on the fiber. One hundred rows of each variety were planted in a row-irrigated field that was 775 feet long. The cotton was stripper harvested using a four row wide John Deere 7460, thus the collections for each replication occurred from within one 4-row wide 775 feet long strip. A total of eight 4-row wide passes were harvested from each variety: 5 passes for the machine location and hand harvested sample collections and three additional full length passes used to measure yield (Figures 2 and 3).

The six locations of interest were cotton handpicked from the field (1), after brush rolls (2) (removed for the 2012 harvest), after the row unit/before the cross auger (3), after the cross auger (4), before the field cleaner (5), and from the basket (after field cleaner) (6) of the stripper after the cotton has been field cleaned (Table 1 (2011) and, Figures 1 and 4).

Table 1. Abbreviated equivalent of the machine locations used for fiber collection in 2011.

Machine Location	Abbreviated Equivalent
Hand Harvested	HH
After Brush Rolls (Removed in 2012)	ASR
After Row Unit	ARU
After Cross Auger	ACA
Before Field Cleaner	BFC
After Field Cleaner	AFC

Figure 1. Locations cotton lint samples were collected from.

A total of five replications were conducted for each sampling location per variety as shown in Figures 2 and 3. Figures 2 and 3 are oriented in cardinal direction with North to the top, and represent the harvested strips and approximate field locations of the collection areas. For each replication, approximately 20-lb. of seed cotton was collected from each sampling location. In order to collect an adequate sample amount from the after brush roll, after row unit, and after cross auger locations, it was necessary to stop the harvester several times in the field. Only one replication per variety was collected from the after stripper roll location because with the row unit augers disabled the row unit filled with dirt and debris too quickly. Due to the excessive dirt and debris this collection area was eliminated from the 2012 machine collection locations. The row unit augers did an excellent job at removing the foreign matter introduced by the stripper rolls.

Variety	Replication	Approximate Collection Areas			
Stoneville	Yield Pass				
Stoneville	Rep 5	BFC/AFC	HH	ARU/ACA	
Stoneville	Rep 4	BFC/AFC	HH	ARU/ACA	
Stoneville	Rep 3	BFC/AFC	HH	ARU/ACA	
Stoneville	Yield Pass				
Stoneville	Rep 2	BFC/AFC	HH	ARU/ACA	
Stoneville	Rep 1	BFC/AFC	HH	ARU/ACA	ASR
Stoneville	Yield Pass				
FiberMax	Yield Pass				
FiberMax	Rep 1	BFC/AFC	HH	ARU/ACA	ASR
FiberMax	Rep 2	BFC/AFC	HH	ARU/ACA	
FiberMax	Yield Pass				
FiberMax	Rep 3	BFC/AFC	HH	ARU/ACA	
FiberMax	Rep 4	BFC/AFC	HH	ARU/ACA	
FiberMax	Yield Pass				
FiberMax	Rep 5	BFC/AFC	HH	ARU/ACA	

Figure 2. Field and variety layout for the collection strips 2011.

Variety	Replication	Approximate Collection Areas		
Stoneville	Rep 1	BFC/AFC	HH	ARU/ACA
Stoneville	Yield Pass			
Stoneville	Rep 2	BFC/AFC	HH	ARU/ACA
Stoneville	Yield Pass			
Stoneville	Rep 3	BFC/AFC	HH	ARU/ACA
Stoneville	Rep 4	BFC/AFC		ARU/ACA
Stoneville	Yield Pass			
Stoneville	Rep 5	BFC/AFC		ARU/ACA
FiberMax	Rep 1	BFC/AFC	HH	ARU/ACA
FiberMax	Rep 2	BFC/AFC	HH	ARU/ACA
FiberMax	Yield Pass			
FiberMax	Rep 3	BFC/AFC	HH	ARU/ACA
FiberMax	Rep 4	BFC/AFC		ARU/ACA
FiberMax	Yield Pass			
FiberMax	Rep 5	BFC/AFC		ARU/ACA
FiberMax	Yield Pass			

Figure 3. Field and variety layout for the collection strips 2012.

Figure 4. Clockwise from top left to bottom left are pictures representing the sampling locations: Before Field Cleaner, After Field Cleaner, Hand Harvested, After Brush Rolls, After Cross Auger, and After Row Unit.

Simultaneous sampling of the harvested seed cotton at each location on the harvester was problematic from a safety and feasibility standpoint. Therefore, all samples from one location were collected from both varieties prior to collecting samples from the other locations. The following sequence of events was conducted to collect the seed cotton samples from each location for each rep:

1. Before field cleaner sample collection: The machine was operated at full load into the un-harvested cotton with the field cleaner bypassed so that the harvested cotton flowed directly into the basket and not through the field cleaner. After the machine traveled approximately 150 ft into the field, the harvester was stopped and a 20-lb. sample of seed cotton was collected in the basket. The remaining seed cotton in the basket was moved so that there was an empty location in the basket for the next sample to fall into.
2. After field cleaner sample collection: The bypass lever on the field cleaner was switched to allow the cotton to pass through the field cleaner before entering the basket. The harvester was operated at full load into the un-harvested cotton in the same rep as in step 1 for approximately 150 ft. The harvester was stopped and a 20-lb. sample of seed cotton was collected from the field cleaned cotton in the basket. The stripper basket was emptied and moved to the next replication. Steps 1 and 2 were completed for all reps in both varieties before samples were collected from other machine locations.
3. Hand harvested sample collection: a 20-lb. sample of seed cotton was hand harvested from each replication in both varieties after step 2.
4. After row unit and after cross auger sample collection: The right-hand section of the cross auger was removed from the header allowing the two right-hand row units to empty directly into the open auger trough. A large sack was connected to the bottom of the main cotton conveying duct to collect the cotton moved to the center of the header by the remaining left-hand section of the cross auger. With the main conveying fan disengaged and the row units and cross auger running, the stripper proceeded into the un-harvested cotton located after the hand harvested collection area. The machine was operated until the cross auger trough behind the right hand row units was full at which time the cotton was removed from the open auger trough and placed in a collection bag. This process was repeated until approximately 20 lb. of seed cotton was collected from the open right-hand auger trough (after row unit sample) and in the large sack attached to the base of the main cotton conveying duct (after cross auger sample). Step 4 was conducted for all replications in both varieties before step 5.
5. After stripper roll sample collection: The drive gears used to operate the two row unit augers in each row unit were removed from the harvester. The stripper was operated at full engine speed into the un-harvested cotton and stopped when the row unit auger troughs were full of harvested material. The material was removed from the row units and placed in a collection bag and this process was repeated until a total of 20-lb. of harvested material was collected. Step 5 was only conducted for one replication in each variety due to the excessive accumulation of soil and debris. As stated earlier this collection location was removed from the 2012 harvest season, so this step was not followed.

Cotton samples were hand collected from the field for gravimetric moisture analysis each time a collection replication occurred. In conjunction with each sample stop throughout the entire process, air temperature and relative humidity were recorded. Cotton samples collected from the field were transported back to the USDA-ARS Gin Lab at Lubbock for ginning. The samples were separated by variety and location, and then weighed. Once the samples were weighed they were transported to the top of the extractor-feeder/gin stand. Prior to ginning two hand fractionation samples were pulled from each of the samples during 2011 and one sample was pulled during 2012. A moisture sample was collected from the extractor-feeder apron during ginning of each sample. Analysis of the hand fractionation samples and the moisture content samples were performed based on standard procedures outlined by USDA (Shepherd 1972). Each of the cotton samples collected in the field was processed through an extractor-feeder, 16-saw gin stand, and one stage of saw-type lint cleaning. The cleaned lint was weighed to obtain lint turnout. The trash collected from the extractor-feeder and seeds from the gin stand were collected and weighed. Two samples of the cleaned cotton lint from each sample were collected and sent to the Texas Tech University, Fiber and Biopolymer Research Institute in Lubbock, TX for HVI and AFIS fiber analysis. The Analysis of Variance (ANOVA) was performed using the Statistical Analysis System 9.3 program (SAS Institute Inc. Cary, NC). Least Squared Difference (Tukey $\alpha = 0.10$) were calculated for all of the parameters reported from the ginning and fiber quality data results.

Results and Discussion

Foreign Matter Content

Analysis of the ginning data showed a trend of increasing gin turnout and decreasing seed cotton trash content as the cotton was sampled on the harvester. A significant difference was not seen between varieties for the results of the gin data, thus all data presented represents both the Stoneville and FiberMax varieties. In the graphical and tabular representations of the data the machine location was assigned a numerical value to make it easier for analysis. Table 1 gives the numerical equivalent of the name.

Gin turnout was highest for the hand harvested location with an average of approximately 37%. This was expected since only fiber and seed was intentionally removed from the plants. There was minimal trash incorporated into the hand harvested fiber. The second location which occurred after the brush rolls had removed the cotton from the plants had the lowest gin turnout, with an average of about 12%. The row unit augers were disabled during this data collection, and a large amount of dirt, dust, and debris was picked up by the row units and conveyed into the row unit auger troughs. It was very easy to see the amount of debris removal that occurs at the row unit. Once the cotton had entered the cross auger trough, gin turnout increased to near double that of the after brush roll location, or about 25%. The difference in turnout between locations 2 and 3 indicates that the row unit augers are quite effective at removing debris. At the cross auger collection area, a 1-2% drop occurs in the average gin turnout. The mechanical conveyance occurring from the cross auger is affecting the gin turnout of the cotton over that of the cotton collected from the cross auger trough. However, from locations 3 to 5 there is very little change. At the fifth location, the cotton was allowed to flow up the separation duct, by pass the field cleaner and then was collected. An average 5% increase is seen in the gin turnout when the cotton is allowed to pass through the field cleaner. Thus, the field cleaner is the only point on the machine that significantly influences the turnout after the row unit augers. Therefore, there is potential for machine redesign somewhere between these locations 3 to 5 to increase gin turn out and reduce overall trash content. The field cleaner is effective in achieving a gin turnout level statistically equivalent to that of hand harvested cotton. If the overall turnout could be increased earlier in the machine the field cleaner would have the opportunity to increase the level to that of hand harvested cotton.

Percent trash and gin turnout, based on total sample weight, is shown in figures 5 for 2011 and figure 6 for 2012. The trash was collected from the extractor feeder before the gin stand. The hand harvested and field cleaned cotton has the lowest percent trash. Again the row unit auger collection area had the highest percentage of trash in 2011.

Figure 5 below is the statistical groupings based on machine location. It can be seen that use of the field cleaner made it is possible to obtain statistically similar gin turnouts and lower trash contents to that of hand harvested cotton. The non-field cleaned, cross auger, and after brush roll cotton had statistically similar gin turnouts and trash contents. The cotton collected from the row unit was in its own statistical group having a very high trash content and low gin turnout. No varietal differences were observed in the data collected from ginning the fiber samples. Even though statistical analysis has not been performed on the 2012 data the trends are very similar to those observed during 2011.

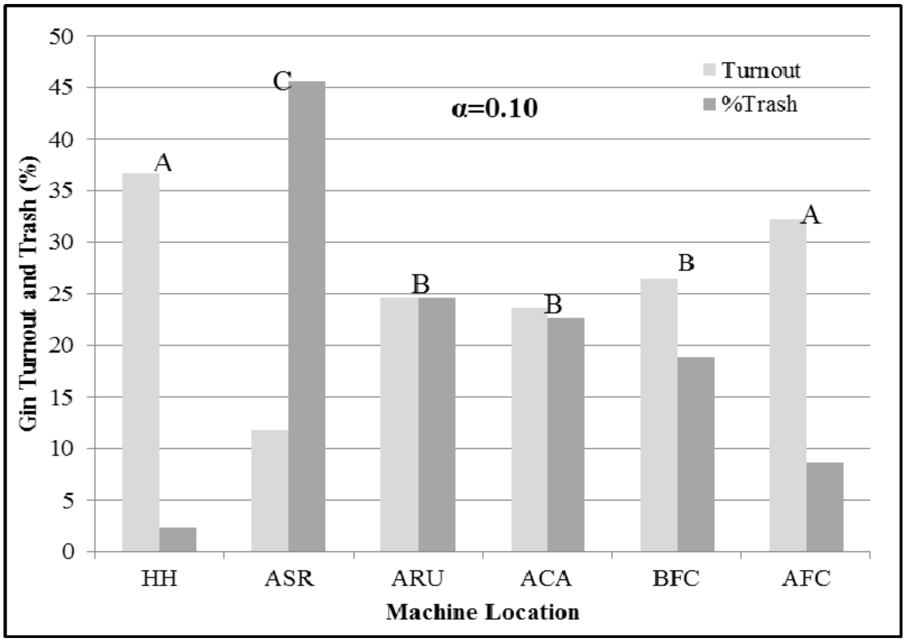

Figure 5. Statistical groupings of 2011 gin data as reported from gin turnout and trash weight.

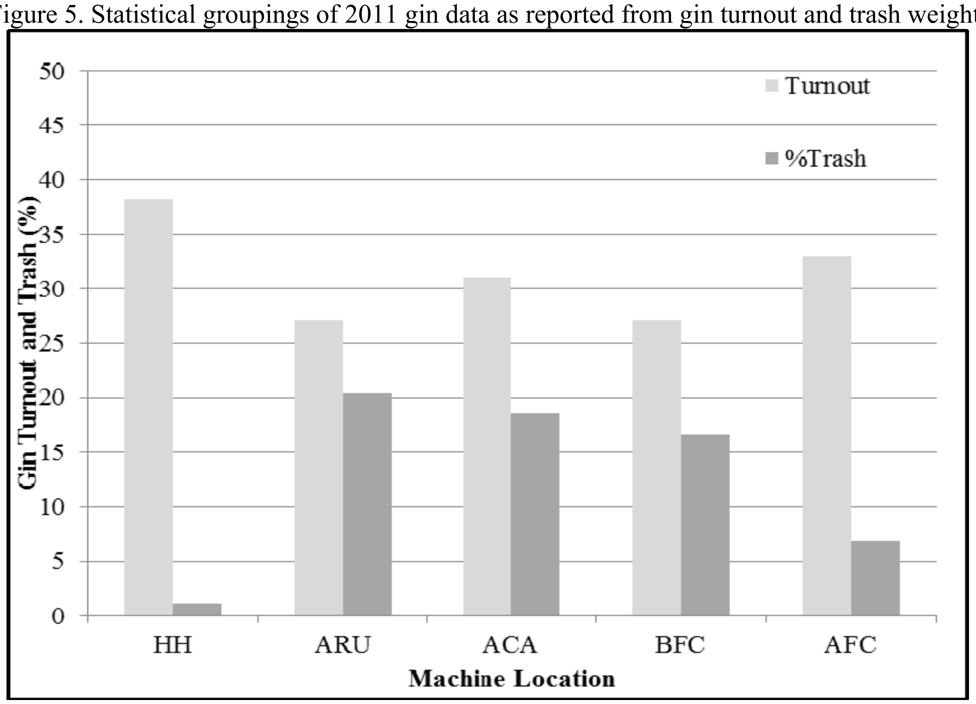

Figure 6. 2012 gin data as reported from gin turnout and trash weight.

The results of hand fractionation analysis on samples collected at each location are shown in Figures 7 and 8 (2011 and 2012 respectively). The bars in the figures represent the total percentage of trash and the contribution from each type of foreign material is illustrated in each bar. Consistent with the rest of the gin data, total trash was reduced throughout the machine. It is apparent that the row unit augers do a very good job of reducing fine trash in the cotton. Once past the row units, burs consistently make up the highest percentage of trash with fine trash falling at a close second. The data shown in Figure 7 indicate that the field cleaner performs well at removing total trash and even in removing fine trash and burrs from the samples. The data represented in this graphs shows that an effort to remove burrs and fine trash is most important since they compose the highest amount of the total trash collected from the fiber samples. The main difference between the data from 2011 and 2012 is in the shift from the secondary percentage of foreign matter being fine trash in 2011 to being mainly burrs in 2012. There was a very large dust storm one day before harvest in 2011 causing the fiber to have an abnormally high amount of fine trash. This was not the case in 2012.

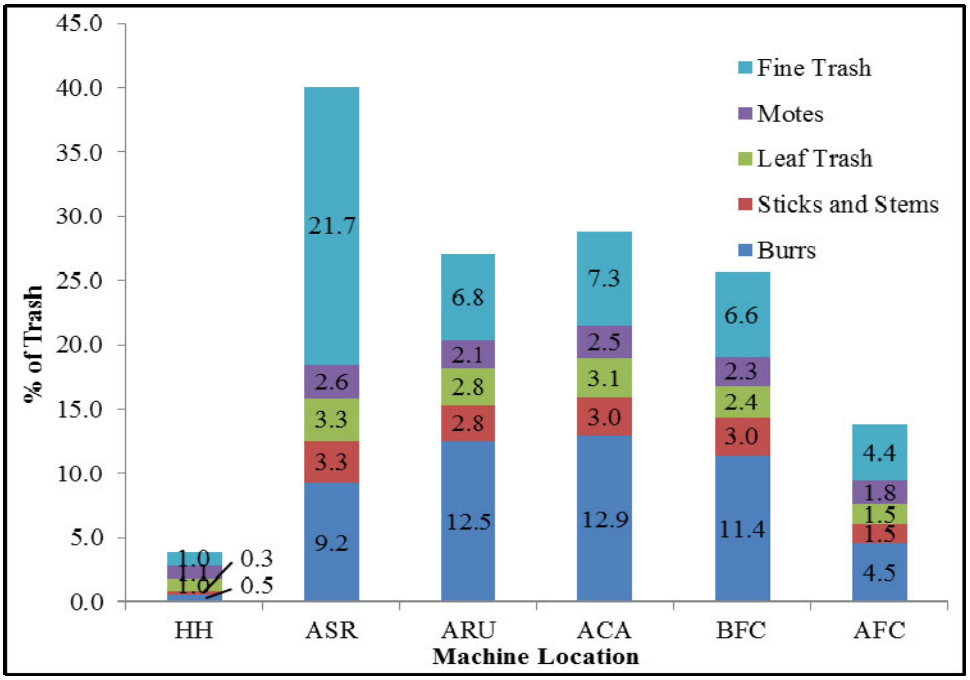

Figure 7. Hand fractionation results 2011.

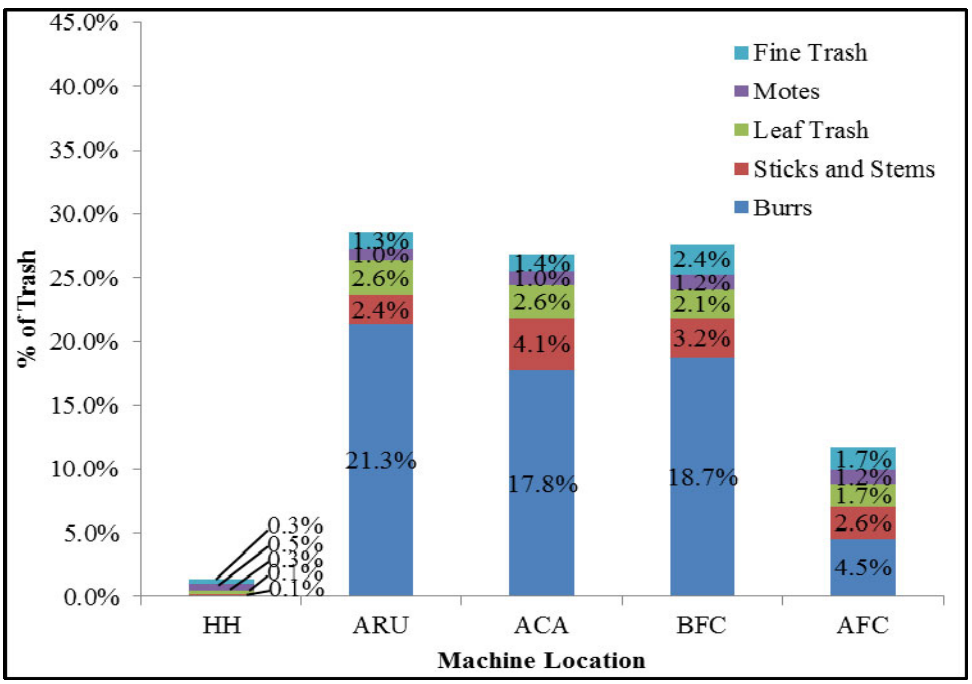

Figure 8. Hand fractionation results 2012.

The Stoneville variety had and average micronaire of approximately 5.2 while the FiberMax had an average micronaire of approximately 4.3 in 2011. In 2012 the Stoneville variety had an average micronaire of 4.0 and the FiberMax had an average of 3.7. Independent of year effect and the varietal differences there is no significant difference in fiber micronaire between machine locations. Micronaire is an estimate of maturity and fineness thus should not be significantly affected by mechanical handling. Therefore the micronaire results are consistent with what is expected.

Leaf grade increased throughout sampling locations HH through ACA because the mechanical action imparted on the cotton during harvesting and conveying causes leaf trash and other foreign material to be broken up and further mixed into the fiber (Figures 9 and 10). The field cleaner removed some of the foreign material contained in the seed cotton and helped to reduce leaf grade. However the final grade of the field cleaned cotton was double that of hand harvested cotton and equivalent to the cotton fiber collected from the row units. The fiber collected from the row units has not been mechanically conveyed through the rest of the machine, thus the leaf trash was not mechanically incorporated into it.

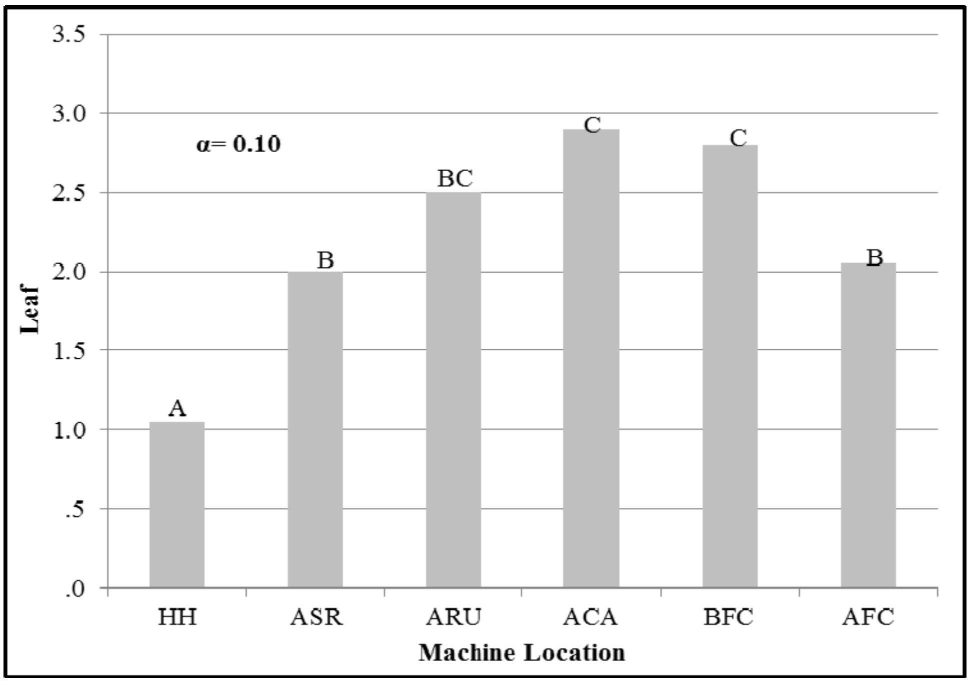

Figure 9. Leaf grade represented by sampling location 2011.

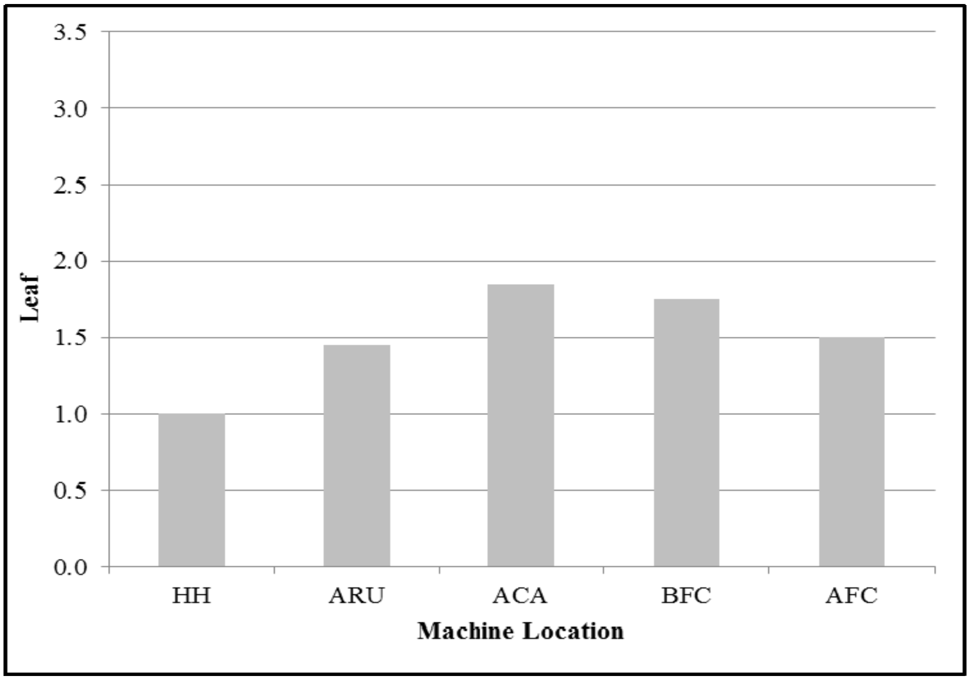

Figure 10. Leaf grade represented by sampling location 2012.

AFIS trash and dust content (Figures 11 and 12) follow similar trends to each other throughout the machine. The levels have a general increase throughout sample locations until the cotton is pneumatically conveyed and then passed through the field cleaner. The pneumatic conveyance of the cotton through the separation duct allows for some of the dust and larger/heavier trash to fall out. The removal of the larger/heavier trash means the green boll separator is doing its designed job function. Even more of the trash and dust was removed when the cotton passed through the field cleaner. However, enough trash and dust was not removed by the field cleaner to lower it back to the level of hand harvested cotton.

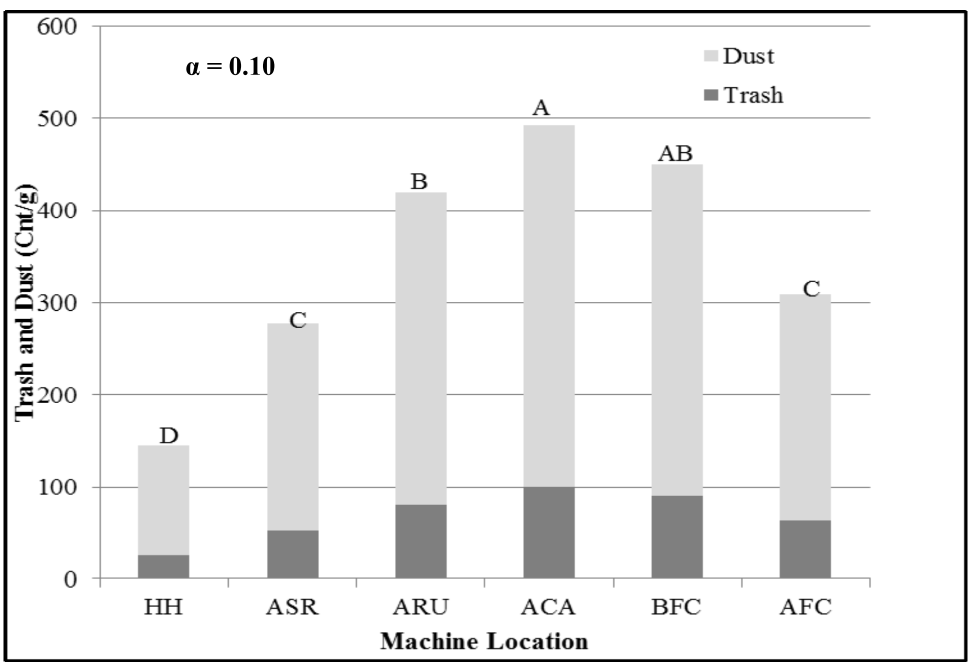

Figure 11. Trash and dust content 2011.

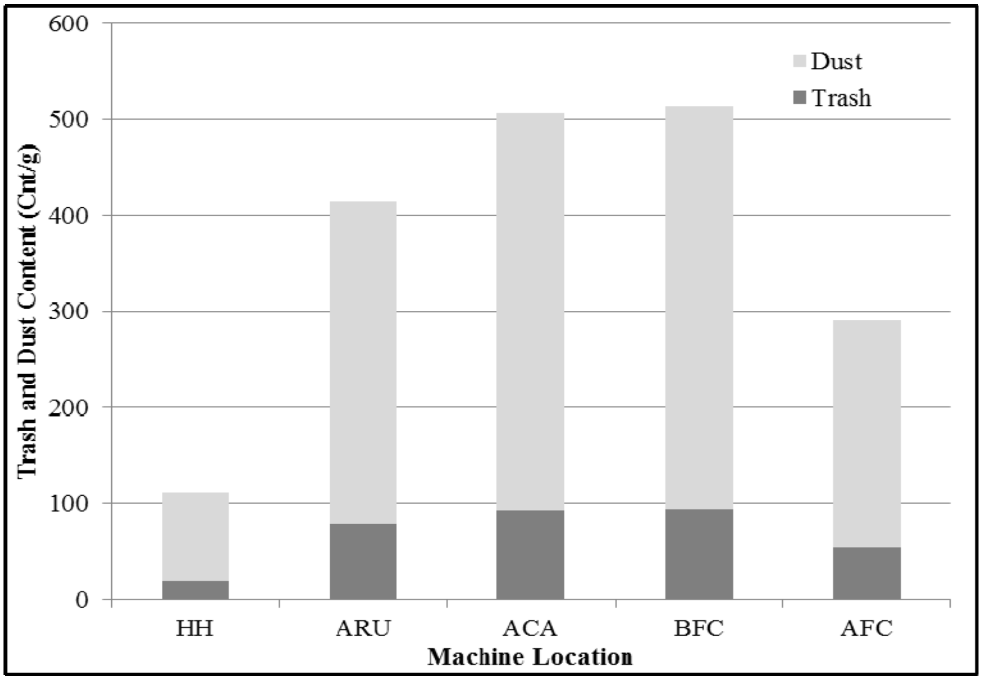

Figure 12. Trash and dust content 2012.

Fiber Quality as Affected by Harvesting

Two parameters that would seem to have been affected by mechanical handling of cotton fiber are nep size and nep content. However, even though visible differences can be observed, no clear statistical correlations with sampling location were observed in either harvest year for the nep size or nep content data.

Fiber length as reported by the HVI has no statistically significant correlation with the machine sample location. The fiber lengths are equally distributed across each of the sample locations with small varietal differences. There were insignificant year effects observed in the fiber length data.

Differences among sample locations were observed for length uniformity (Figures 13 and 14) and strength. There was some variation observed in uniformity between sampling locations. The uniformity tended to increase at later sampling locations, but is not really consistent across locations or years. The uniformity was significantly lower in 2012 and the general trend through the sampling locations was slightly different than that observed in 2011.

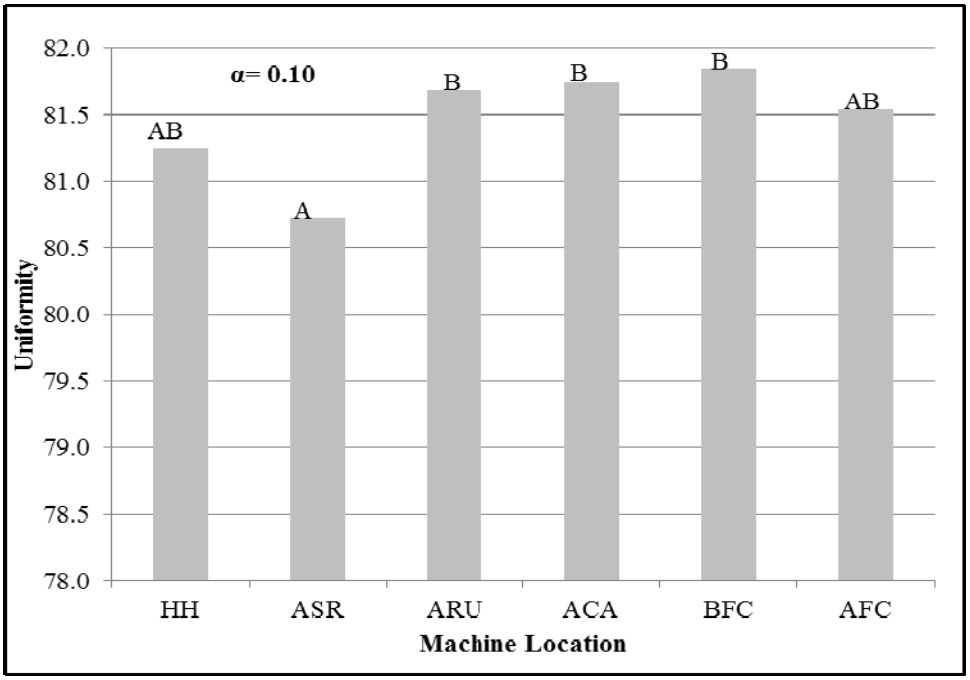

Figure 13. Fiber uniformity 2011.

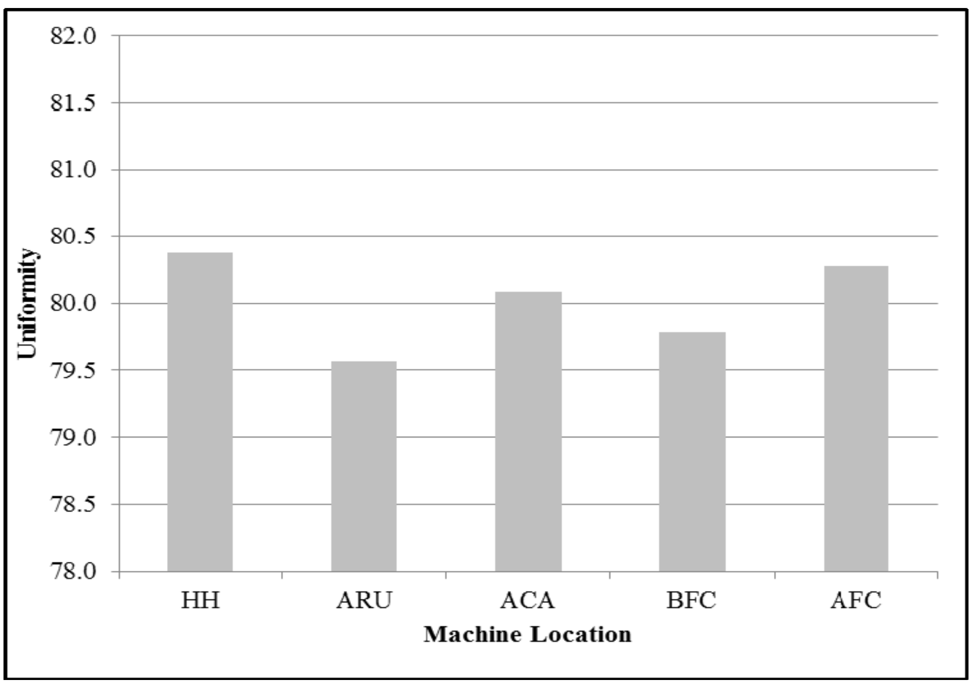

Figure 14. Fiber uniformity 2012.

Natural variations were observed in the fiber strength as the fiber was conveyed throughout the harvester. The trend does not follow an expected trend where fiber strength would be hypothesized to decrease as the fiber is exposed to more mechanical handling. However, the data show that the fiber strength increases as the fiber is handled until the fiber is moved through the conveyance duct and into the field cleaner. The use of the field cleaner seems to reduce the fiber strength but not back to that observed in the hand harvested samples. One possible explanation for the variation of fiber strength observed is mechanical handling of the fiber is breaking or destroying the weak points in the fibers as seen in the cotton boll. The remaining fibers then have a higher overall strength since the weaker fibers have been removed from the sample at the tested machine locations. The mechanical action of the field cleaner appears to damage and weaken some of the fibers as they are allowed to pass through it. However, this is not confirmed, the differences observed could just be natural variation in the fiber.

Differences were observed among sampling locations for AFIS short fiber content (SFC) by weight (Figures 15 and 16). It was observed that the SFC was higher during the 2012 harvest season. However, it is not assumed that the observed differences in SFC are due to machine conveyance and fiber interactions. The variances observed in SFC can be attributed to natural variations in cotton fiber length. The abnormally high level of SFC at machine location two can be attributed to the reduced number of samples collected at this area. It was expected that short fiber content would increase throughout the harvest process as the fibers are handled and exposed to additional mechanical action; however, this trend was not observed.

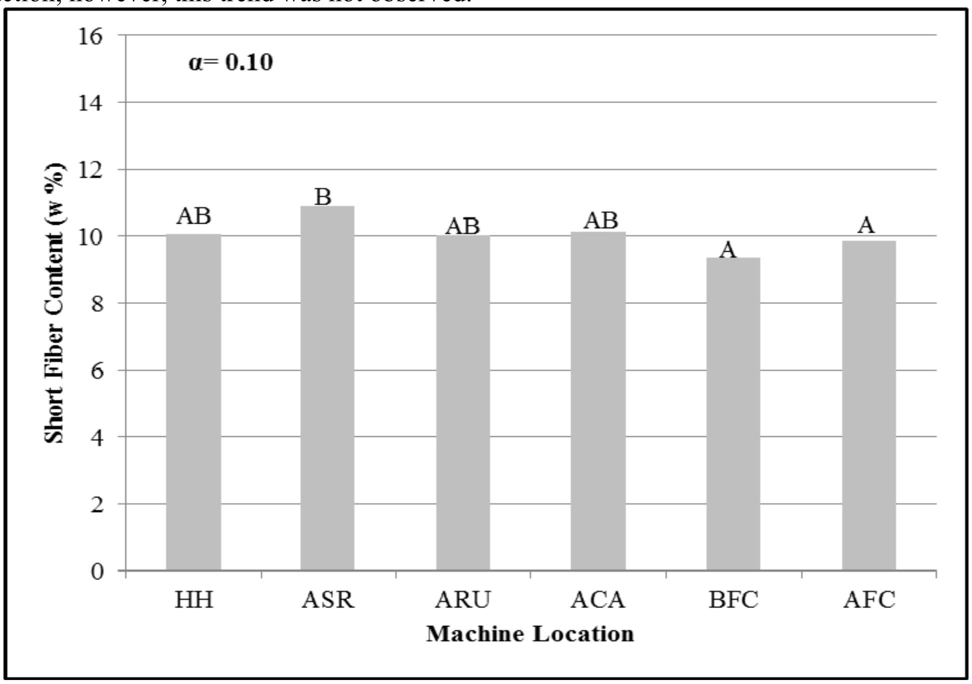

Figure 15. Short Fiber Content 2011.

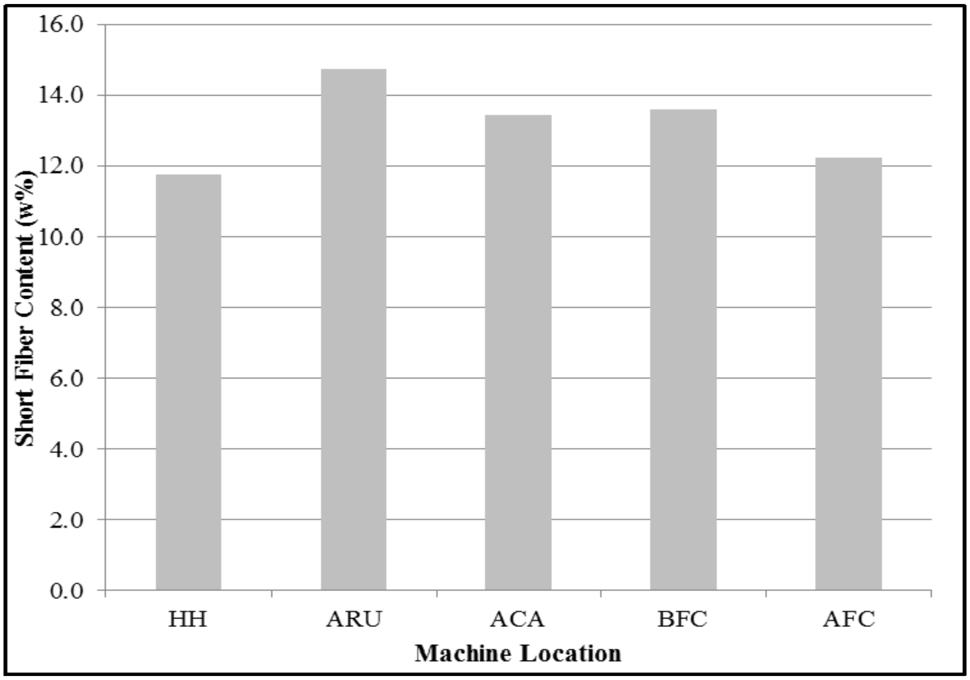

Figure 16. Short Fiber Content 2012.

Summary

The goal of this work was to identify individual components and systems on a cotton stripper harvester that, if redesigned, could improve seed cotton cleanliness and better preserve fiber quality. Two harvest seasons were collected and analyzed for relevant fiber quality parameters. This data has given a very good and accurate foundation for fiber quality and foreign matter content throughout individual cleaning and conveying components on a stripper harvester. Seed cotton samples were hand harvested in the field and collected at five sequential locations on a cotton stripper harvester. The samples were analyzed for foreign matter content and HVI and AFIS fiber quality. Seed cotton total foreign matter content was highest after the stripper rolls before the cotton was conveyed out of the row units by the row unit augers. The row unit augers decreased total foreign matter content in the seed cotton by removing a substantial amount of fine trash comprised mostly of soil and small plant parts. Total foreign matter content remained at a consistent level during conveyance in the cross auger until the harvested seed cotton was processed through the field cleaner. The field cleaner decreased total foreign matter content by removing burs and some fine trash. Leaf grade and AFIS trash and dust content measurements follow similar trends where parameter levels increase on the stripper from the stripper rolls until the inlet to the field cleaner. Leaf grade, AFIS trash, and AFIS dust content were decreased by the field cleaner back to levels observed just after the stripper rolls. HVI and AFIS fiber analysis results indicated that the harvesting and conveying systems on the cotton stripper did not have a detrimental impact on fiber length characteristics or on the formation or size of neps. Year effect was observed between the 2011 and 2012 harvest seasons. However, independent of the year effect very similar trends were observed in a majority of the fiber quality parameters reported in this document, meaning consistency of data collection and analysis is represented. Thus valid conclusions can be drawn about each of the individual components of the machine selected for fiber sampling.

The results of this work indicate that a location between the row units and field cleaner could be selected for potential redesign. Specifically the cross auger and pneumatic conveying system on the stripper could be redesigned to provide additional seed cotton cleaning and fiber quality preservation on the harvester. Pneumatic conveyance of seed cotton requires a substantial amount of engine power that could be reduced if mechanical conveyors were implemented.

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Disclaimer

Mention of trade names or commercial products in this manuscript is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

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