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TEXTILE TECHNOLOGY

Effect of Instrumental Leaf Grade On HVI Micronaire Measurement In Commercial Cotton Bales

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ABSTRACT

The high volume instrument (HVI^{TM}) instrumental leaf grade index has been accepted in both domestic and international cotton fiber trading. There is interest in how trash content in cotton samples impact the HVI measurements. In this investigation, HVI micronaire attribute was measured on commercial cotton bales representing instrumental leaf grade categories one to six, pre- and post- Shirley Analyzer (SA) cleaning process. The SA system was used since it is a traditional gravimetric cotton trash reference method, and also plays a role as a small-scale cotton trash cleaner. This study first examined the variations of five repeated HVI micronaire measurements within one pre-SA or post-SA cleaned cotton, and it revealed an insignificant effect of trash presence in high instrumental leaf grade cottons on HVI micronaire measurement repeatability. A comparison of HVI micronaire between pre-SA and post-SA cleaned cottons indicated a good agreement, suggesting minimal effect of cotton trash presence in commercial cottons on their HVI micronaire determination. Meanwhile, higher instrumental leaf grade cottons were observed to show lower micronaire values.

Every bale of cotton produced in the United States (U.S.) has been classed by the U.S. Department of Agriculture's (USDA's) Agricultural Marketing Service (AMS) using the standardized high volume instrument (HVI^{TM}) protocol (ASTM, 2012a). At a relatively high speed, the HVI system provides multiple cotton fiber quality attributes, including micronaire, strength, length, uniformity, color (reflectance, Rd and yellowness, +b), and trash index (particle count, percentage area, and instrumental leaf grade).

The HVI trash module counts the number of dark spots, or non-lint particles (particle count) and estimates the surface area covered by these particles (percentage area). In 2012, the AMS revised the cotton classification protocol for determining cotton leaf grade by replacing the classer's visual leaf determination with instrumental leaf grades that are calculated from HVI particle count and HVI percentage area data (USDA, 2012). The HVI instrumental leaf grades are discrete values one through six and differ from HVI particle count and HVI percentage area readings.

Presence of non-lint materials (or botanic trash) within commercial cotton bales degrades their market value, requires further cleaning process, and compromises the finished product quality. An earlier study revealed that HVI percentage area (HVI_{area}) trash values were not the same as classer's leaf grade but there was a positive correlation between the two indices (Wakelyn et al., 2007). After averaging the Shirley Analyzer visible trash ($SA_{visible}$) values for samples having identical HVI_{area} or HVI particle count (HVI_{count}), a better correlation relating HVI_{area} or HVI_{count} to $SA_{visible}$ in lower-trash cottons compared to higher-trash cottons was reported (Liu et al., 2012). More recently, HVI instrumental leaf grade was reported to increase with percent trash content determined by gravimetric instruments such as the Micro Dust and Trash Analyzer III (MDTA 3) (Whitelock et al., 2016) and Shirley Analyzer (SA) (Liu and Delhom, 2018).

From the perspective of commercial fiber quality testing, there is an interest in determining if trash content can impact the HVI micronaire measurement. Cotton micronaire is one of the most essential fiber characteristics and reflects fiber maturity (degree of secondary cell wall development) and fineness (weight per unit length) com-

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bined (Lord, 1956), and has been increasingly and routinely utilized in the cotton and textile industry from cotton breeding programs to textile quality control (Frydrych and Thibodeaux, 2010; Kelly et al., 2012; Kim, et al., 2014; Paudel et al., 2013). To determine the micronaire value, conditioned fiber samples with standard weight (approximately 10.0 g) are compressed to a known volume and then measured by the drop in pressure of air flow passing through the fiber samples. Since HVI micronaire measurement is an air flow test, the presence of trash in raw cotton lint may impact HVI micronaire readings because trash will take up space in compressed samples and trash particles (depending on their size) could disturb the airflow during the measurement.

MATERIALS AND METHODS

Cotton Samples and Official Instrumental Leaf Grade Readings. A total of 90 commercial cotton bale lint samples (15 samples / leaf grade x 6 leaf grades) and their official instrumental leaf grade one through six assignments were provided by a collaborator. These fibes were part of an earlier report demonstrating the potential of visible and near infrared (NIR) spectroscopy in the determination of instrumental leaf grade (Liu and Foulk, 2013), but they were different from those 150 samples used to explore the relationship between instrumental leaf grade and Shirley Analyzer trash content (Liu and Delhom, 2018). All cotton samples and SA resultant clean fibers were conditioned at a constant relative humidity of 65 ± 2% and temperature of 21 ± 1°C for at least 24 h, prior to routine SA and HVI micronaire measurement.

Shirley Analyzer Cleaning and Trash Content Determination. Gravimetric cotton trash content (percent by mass) was measured by the use of the Shirley Analyzer (Shirley Developments, Ltd., Stockport, UK) (ASTM, 2012b). Briefly, 100 g of lint cotton was placed onto a feed tray to cover as much of the tray as possible. The sample then was moved slowly by a rotating feed roll to a rapidly rotating saw tooth cylinder. Separated visible trash and cleaned lint were fed through a second time, then collected and weighted respectively. As observed before (Montalvo and Mangialardi, 1983), lint fiber mingles in with visible trash in retained trash remains. Using known percentage contents of SA visible trash ($SA_{visible}$, %) and clean fiber (SA_{fiber}, %), SA total trash (SA_{total}, %) and SA invisible trash ($SA_{invisible}$, %) contents were indirectly calculated from respective equations of $SA_{total} = 100 - SA_{fiber}$ and $SA_{invisible} = 100 - SA_{visible} - SA_{fiber}$. Due to the limited quantity of lint sample available, only one Shirley Analyzer trash measurement from each individual cotton sample was taken.

HVI Micronaire Measurement. Average micronaire values were obtained from five replicates on each sample (pre- and post- SA cleaning) by an Uster® HVI™ 1000 (Uster Technologies Inc., Knoxville, TN). All measurements were performed at the Southern Regional Research Center of USDA's Agricultural Research Service (USDA-ARS-SRRC).

Statistical Analysis. Statistical analyses using the Minitab 17 (Minitab, Inc. State College, PA) were performed to run the analysis of variance (ANOVA) and Pearson Correlation. ANOVA was executed using the general linear model and Pearson correlations were carried out using the correlation function.

RESULTS AND DISCUSSION

Shirley Analyzer Total Trash Contents and Instrumental Leaf Grade. Table 1 summarizes the range, mean, and standard deviation (STDEV) of SA_{total} trash content (%) for six instrumental leaf grade cottons, in which 30 and 15 samples were selected randomly from a set of 50 cotton lint samples and tested by Shirley Analyzer in 2016 (Liu and Delhom, 2018) and 2017, respectively. Like SA_{total} trash content increased from 3.41 to 6.64 % in 2016 (Liu and Delhom, 2018), SA_{total} trash content increased from 4.68 to 8.20 % with instrumental leaf grade in 2017. Notably, SA_{total} trash of 15 samples in 2017 measurement is about 1.2 ~ 2.4 % higher than that of 30 samples in the 2016 test. The difference could suggest that gravimetric SA_{total} trash and instrumental leaf grade correlates in general but is not specific. This reflects the nature of nonhomogeneous and unexpected distribution of trash type and size from one sample to another.

Table 1. Range, mean, and standard deviation (STDEV) of SA_{total} trash content (%) in 6 instrumental leaf grade.[z]

		SA_{total} Trash, 2016	SA_{total} Trash, 2017
Leaf grade 1	Range	2.0-6.2	2.9-7.6
	Mean	3.41	4.68
	STDEV	1.10	1.31
Leaf grade 2	Range	1.9-3.5	3.3-8.4
	Mean	2.81	4.85
	STDEV	0.46	1.40
Leaf grade 3	Range	2.4-4.4	4.9-7.0
	Mean	3.31	5.78
	STDEV	0.52	0.68
Leaf grade 4	Range	3.5-5.4	5.4-9.0
	Mean	4.39	6.79
	STDEV	0.49	0.93
Leaf grade 5	Range	4.5-7.7	5.1-9.5
	Mean	5.37	7.31
	STDEV	0.64	1.20
Leaf grade 6	Range	4.8-8.3	7.8-11.3
	Mean	6.64	8.20
	STDEV	0.83	3.08

[z] Leaf grades are discrete values 1-8, of which 1-6 were represented in this work. 30 and 15 samples were selected randomly and tested in 2016 (Liu and Delhom, 2018) and 2017, respectively.

Variations of HVI Micronaire Measurement within Pre-SA and Post-SA Cleaning Cottons. STDEV values of five repeated HVI micronaire measurements on individual pre- and post- SA cleaning sample are depicted in Figure 1 for comparison. There were three pre-cleaning samples and two post-cleaning samples whose STDEV values are greater than a threshold of 0.10 (USDA stated precision on HVI testing of micronaire (Cotton Incorporated, 2013)). These three pre-cleaning samples were identified as high leaf grade cottons (No. 68 in leaf grade five category and No. 82 and 89 in leaf grade six category), while the two post-cleaning samples were recognized as low leaf grade cottons (No. 13 in leaf grade one category and No. 42 in leaf grade three category). Besides these five outlier samples, there are 69 and 18 out of 87 pre-SA cleaning samples exhibiting respective STDEV value of less than 0.05 and between 0.05 and 0.10, and there are 87 and 1 out of 88 post-SA cleaning samples showing respective STDEV value of less than 0.05 and between 0.05 and 0.10. Statistical analysis on the STDEV against leaf grade shows differences in Pearson correlation (r) and p-value of correlation between pre-SA cleaning fibers (r = 0.302 and p = 0.004) and post-SA cleaning samples (r = -0.134 and p = 0.209). It indicates that non-lint content present in pre-SA cleaning samples does impact micronaire repeatability, and the STDEV among pre-SA cleaning samples is greater for higher leaf grade samples. Although the higher leaf grade samples are more variable than lower leaf grade samples, all STDEV but one sample (No. 68), are within AMS tolerance or within instrument repeatability expectations (± 0.10 is the normal standard repeatability for micronaire measurement on the HVI).

Complementary to Figure 1, Figure 2 compares the STDEV values against HVI micronaire on individual pre- and post- SA cleaning sample. Statistical analysis on the STDEV against HVI micronaire shows no differences between pre-SA cleaning fibers (r = -0.045 and p = 0.673) and post-SA cleaning samples (r = -0.049 and p = 0.649). It suggests that STDEV is independent of cotton fiber micronaire between pre- and post- SA cleaning fibers.

Figure 3 shows the comparison of mean STDEV between pre-SA and post-SA cleaning cottons against instrumental leaf grade, after excluding five outlier samples. In the line with expectation, STDEV is greater among pre-SA cleaning cottons than among post-SA cleaning cottons, mostly because SA cleaning process has modified and better-blended cotton fibers, causing them to be more uniform and fluffier. The STDEV increases gradually with instrumental leaf grade among pre-SA cleaning cottons, while the STDEV is nearly unchanged among post-SA cleaning cottons. Despite the disparity between pre-SA and post-SA cleaning cottons in Figure 3, it should not be a concern when determining HVI micronaire attribute on high instrumental leaf grade cottons when considering the known precision of this test.

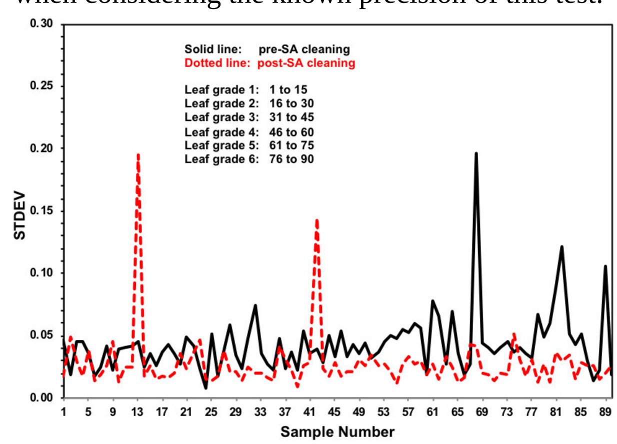

Fig. 1. Comparison of STDEV values of 5 repeated HVI micronaire measurements between pre-SA (solid line) and post-SA (dotted) cleaning process against individual sample.

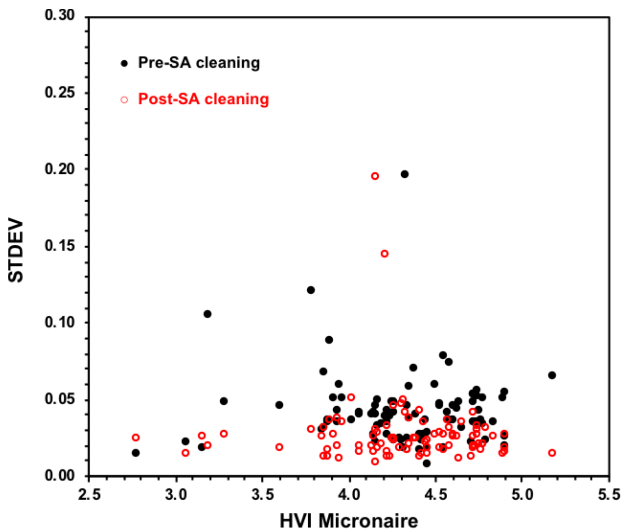

Fig. 2. Comparison of STDEV values of 5 repeated HVI micronaire measurements between pre-SA (solid line) and post-SA (dotted) cleaning process against HVI micronaire.

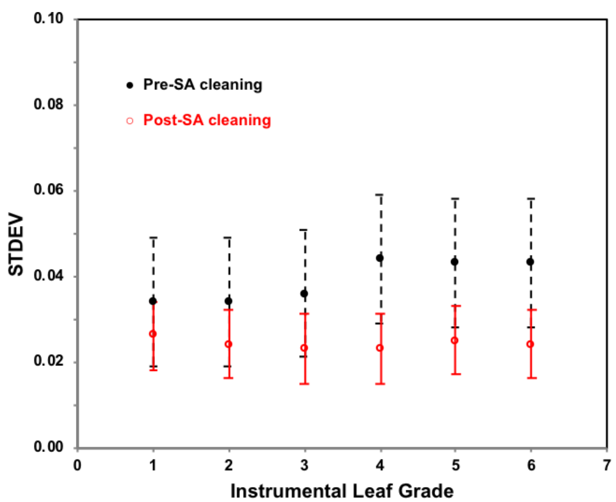

Fig. 3. Comparison of mean STDEV between pre-SA (●) and post-SA (○) cleaning cottons against instrumental leaf grade, after excluding 5 outlier samples.

Correlation of HVI Micronaire between pre-SA and post-SA Cleaning Cottons.

Figure 4 compares HVI micronaire readings of 90 cottons representing instrumental leaf grade one to six between pre- and post- cleaning process. A linear correlation ($R^2 = 0.986$) suggests good agreement in HVI micronaire measurement between pre-SA and post-SA cleaning cottons, implying that the effect of cotton trash presence on HVI micronaire is minimal and insignificant when testing raw cottons . The instrumental leaf grade six cotton set has the smallest HVI micronaire of 3.63 in average, compared to a HVI micronaire range of 4.24 to 4.70 for instrumental leaf grade one to five cottons. This observation echoes a previous study that "the finer the cotton the greater the amount of waste removed" (Rusca et al., 1964). It is likely that the low micronaire cottons are immature and, due to agronomic conditions, are higher in trash content during harvesting, therefore they are harder to clean up at the gin than the higher micronaire (coarser and more mature) cottons.

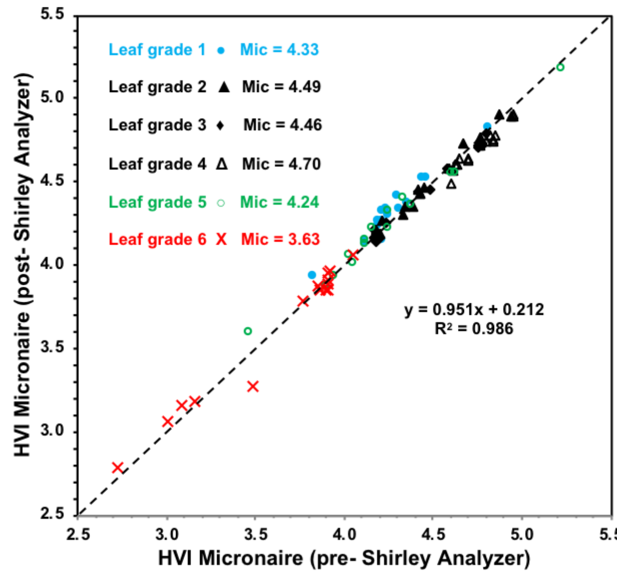

Fig. 4. Comparison of mean HVI micronaire readings against instrumental leaf grade between pre-SA and post-SA cleaning cottons.

Figure 5 shows the difference in HVI micronaire between pre-SA and post-SA cleaning process. Among 90 cotton lint samples examined, 84 (93.3%) indicate a micronaire difference of less than 0.10 absolute value. For six samples with a difference greater than 0.10 absolute value, three samples (No. 2, 5 and 6) were located in the leaf grade one group, one sample (No. 58) was observed in leaf grade four pool, one1 sample (No. 73) was classified in leaf grade five class and one sample (No. 79) was included in leaf grade six assignment. None of these 6 samples with large micronaire difference in Figure 5 is identified as the one having great STDEV in Figure 1. Hence, the presence of trash in high leaf grade cottons does not appear to impact the accuracy of HVI micronaire measurement.

The differences in HVI micronaire between pre-SA and post-SA cleaning process against instrumental leaf grade are plotted in Figure 5. In general, the differences in values tended to decrease from leaf grade one to four and then to increase slightly from leaf grade four to six, in which the average differences for leaf grades one to six are 0.06, 0.00, -0.01, -0.05, 0.01, and 0.00, respectively. ANOVA of the differences vs. leaf grade results with a P-vale of < 0.001. However, this trend is difficult to interpret because the harvest history or production region of each of these fiber samples is unknown. The pattern in Figure 5 is similar to a previous report (Liu and Delhom, 2018), in which the first principal component (PC1) scores from principal component analysis (PCA) of near infrared (NIR) spectra of SA visible trash remains representing six leaf grade samples were related to leaf grade.

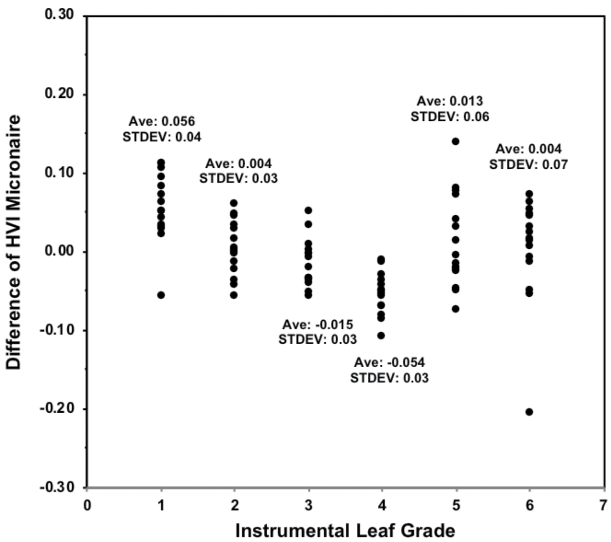

Fig. 5. Comparison of the difference in HVI micronaire between pre-SA and post-SA cleaning process against instrumental leaf grade. Averages and STDEV for each leaf grade category are inserted.

CONCLUSION

With the wide use of HVI system in both domestic and international cotton trading, there could be a concern that trash occurrence in cotton fibers might impact the HVI micronaire measurement. Variations of HVI micronaire measurements within either pre-SA or post-SA cleaning cottons revealed an insignificant effect of trash presence in high instrumental leaf grade cottons on HVI micronaire measurement repeatability. Further, good agreement in HVI micronaire between pre-SA and post-SA cleaning cottons implied a minimal effect, if any, of cotton trash on accurate HVI micronaire determination. The conclusions in this study would not hold true on research samples and in particular on breeder samples as they often contain much more trash than commercial bales. At times, breeders may want to clean the samples prior to micronaire readings.

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DISCLAIMER

Mention of a product or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

REFERENCES

American Society for Testing and Materials (ASTM). 2012a. Standard test method for measurement of physical properties of cotton fibers by high volume instruments (D5867). *In* Annual Book of ASTM Standards. ASTM International, West Conshohocken, PA.

American Society for Testing and Materials (ASTM). 2012b. Standard test method for non-lint content of cotton (D2812). *In* Annual Book of ASTM Standards. ASTM International, West Conshohocken, PA.

Cotton Incorporated. 2013. The classification of cotton. Available at http://www.cottoninc.com/fiber/quality/Classification-Of-Cotton/Classing-booklet.pdf (Accessed June 7, 2016)

Frydrych, I., and D. Thibodeaux. 2010. Fiber quality evaluation – current and future trends/intrinsic value of fiber quality in cotton. p. 251–295. *In* P.J. Wakelyn, and M.R. Chaudhry (eds.). Cotton: technology for the 21st century. International Cotton Advisory Committee, Washington DC.

Kelly, C., E. Hequet, and J. Dever. 2012. Interpretation of AFIS and HVI fiber property measurements in breeding for cotton fiber quality improvement. J. Cotton Sci. 16: 1–16.

Kim, H.J., J. Rodgers, C. Delhom, and X. Cui. 2014. Comparisons of methods measuring fiber maturity and fineness of Upland cotton fibers containing different degrees of fiber cell wall development. Text. Res. J. 84: 1622–1633.

Liu Y., D. Thibodeaux, and G.R. Gamble. 2012. Relationship between three cotton trash measurements and near infrared spectral response. J. Cotton Sci. 16: 272–281.

Liu, Y., and J. Foulk. 2013. Potential of visible and near infrared spectroscopy in the determination of instrumental leaf grade in lint cottons. Text. Res. J. 83: 928-936.

Liu, Y., and C.D. Delhom. 2018. The relationship between instrumental leaf grade and Shirley Analyzer trash content in cotton lint. Text. Res. J. 88: 1091-1098.

Lord, E. 1956. Air flow through plugs of textile fibers part II. The micronaire test for cotton. J. Text. Inst. 47: T16–T47.

Montalvo Jr. J. G., and G.J. Mangialardi. 1983. Systems errors in Shirley Analyzer measurements. Text. Res. J. 53: 408-414.

Paudel, D., E. Hequet, and A. Noureddine. 2013. Evaluation of cotton fiber maturity measurements. Ind. Crop Prod. 45: 435–441.

Rusca, R.A., H.W. Little, and W.H. Gray. 1964. An evaluation of the SRRL Non-Lint Tester for determining the trash content of lint cotton. Text. Res. J. 34: 61–68.

USDA, AMS. 2012. Revision of cotton classification procedures for determining cotton leaf grade. Fed Regist. 77: 20503-20505.

Wakelyn, P.J., N.R, Bertoniere, A.D. French, D.P. Thibodeaux, B.A. Triplett, A.A. Rousselle, W.R. Goynes Jr, J.V. Edwards, L. Hunter, D.D Mcalister, and G.R. Gamble GR. 2007 Cotton fiber chemistry and technology. CRC Press, Boca Raton, FL. p.118-119.

Whitelock, D., V. Martin, and E. Barnes. 2016. Evaluation of relationship between HVI estimated leaf grade and MDTA 3 measured percent trash. *In* Proc. Beltwide Cotton Conf., New Orleans, LA. 5-7 Jan. 2016. Natl. Cotton Counc. Am., Memphis, TN. p. 470-475.