AN EXAMINATION OF THE ACCURACY OF HVI COLOR/TRASH METERS FOR USE IN GINS

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Abstract

Color and trash meters, similar to those used in the high volume instrument (HVI) system, were installed in the microgin at the United States Department of Agriculture (USDA), U. S. Cotton Ginning Laboratory, Stoneville, MS. Cotton color (Rd and +b) and trash measurements from these meters were compared to data obtained at a USDA, Agricultural Marketing Service (AMS), Cotton Division, Cotton Classing Office (CO). Data were compared for ceramic tiles, stationary cotton (such as is done at the CO), and cotton samples obtained automatically while ginning. Temperature changes and vibration of the measurement heads were added to further simulate conditions in the gin. Results indicated that 1) an ambient temperature range of ±11°C (±20°F) from the reference temperature gave acceptable data, 2) the drift with time of Rd and +b was low and no drift of trash readings was measured, 3) vibration had no adverse affect on the measurements, 4) no differences in measurements of color or trash occurred between the gin based equipment and the classing office when the samples were presented manually, 5) Rd and percent area were consistently lower for automated sampling, and 6) +b was not different for automated sampling than for samples measured at the CO.

Introduction

Measurements of the color and trash levels of cotton in the gin are an integral part of the gin process control system (Anthony and Byler, 1995; Byler and Anthony, 1997). These measurements must adequately predict the color and trash grades given the cotton by the Classing Office, CO. Prior to 1996 color and trash measurement equipment manufactured by Motion Control Inc. were used in the Stoneville Gin Process Control Project, but in 1996 equipment manufactured by Zellweger Uster, Inc was installed. The first meters were installed in the microgin at the USDA Cotton Ginning Laboratory at Stoneville, MS, and tested before similar ones were installed in a commercial gin as part of the process control system.

Reprinted from the *Proceedings of the Beltwide Cotton Conference*
Volume 2:1567-1572 (1998)
National Cotton Council, Memphis TN

Discussion and Results

Five tests were performed to evaluate how the Zellweger Uster model 750 color head, fitted with a camera for video analysis, performed under gin conditions. The equipment was the same as that used in the gin process control system in 1996. Test A was designed to detect an ambient temperature effect on the color and trash readings. Test B was designed to detect drift of the meters, which had been a problem with color/trash meters used previously. Test C determined if vibration caused obvious problems in the color/trash readings. The test was designed to show shifts in color reading because experience has shown that vibration caused shifts in readings from the units used previously. Test D was designed to compare the color and trash readings of cotton samples presented by hand with previous readings by AMS on the same samples. Test E was designed to compare the color and trash readings of samples collected automatically while ginning with readings on the same lots of cotton made by the AMS CO at Dumas, AR.

Test A. Color/trash shift due to temperature changes.

Solid state electronics that detect light are also temperature sensitive. Initial data indicated a strong influence of temperature on Rd and +b. As a result a small, electronically controlled heater was added to each color sensor by Zellweger Uster to maintain the temperature of the sensor at about 50°C (Williams, 1996). Data were collected on May 10, 1996 to determine if the four color/trash meters with heaters were sensitive to temperature changes. The meters were adequately warmed up by allowing them to operate for 24 hours. Then the room temperature was raised to 24.2°C and held there for 90 minutes. Two sets of color and trash readings were made at four stations with five color tiles and one trash tile. The temperature was then lowered to 15.9°C and held there for 90 minutes. The color/trash readings were then repeated. Next, the temperature was raised to 29.0°C and held for 90 minutes, and the color/trash readings were repeated. Finally, the temperature was lowered to 17.2°C and held for 90 minutes, and the color/trash readings were repeated.

These data were analyzed with the GLM procedure (SAS Institute, Inc., 1996) with all combinations of tile, temperature, and station modeling the Rd, +b, and percent area readings. Tile and station combinations contributed significantly to explaining the variation in the Rd readings but the temperature was not a significant factor. The significance of the station factor indicated that the stations were not calibrated the same, and the stations had not been calibrated for several days. Except for the differences in calibration with respect to Rd, test A showed no effects on Rd. Therefore, it was concluded that Rd did not change with temperature.

When the +b readings were analyzed with the same procedure as was used for Rd, the only factors remaining after factors not contributing to the prediction of +b were removed were tile, station, and temperature. The slope of temperature was 0.022 units/°C. It appeared that while the temperature effect was relatively small, but was not altogether eliminated. If the error in +b were to be kept to no more than ±0.25 units, then the temperature change would have to be no more than ±11°C from the temperature at which calibration was done. For example, if the temperature were 25°C (77°F) when calibration was performed, then the temperature effect would contribute no more than 0.25 units error to +b from 14°C (57°F) to 36°C (97°F). The temperature that controls this drift is actually the temperature of one or more of the electronic components, and the relationship between the ambient temperature changes and the electronics temperature changes is unknown.

Percent area was analyzed the same way as Rd, but the analysis considered only the data from the central tile and the trash tile, because all of the color tiles have zero trash. The only factors to remain after removing those which did not contribute to explaining the variation for the stations was tile, which should remain. There was no significant effect of temperature on the trash measurement.

The purpose of this portion of the study was to determine if the meter readings were affected by the ambient temperature. It was concluded that Rd and area did not change with temperature, but that +b did.

Test B. Drift of color and trash without recalibration.

Data were collected to determine if the four color/trash meters newly installed in the microgin drifted with time. The five color calibration tiles and the trash tile were measured periodically at each station over a four-day period from May 20 to May 24, 1996. The meters were not calibrated during this period and had not been calibrated for several days before this data collection began. The Rd and +b readings for the five color tiles were examined with the GLM procedure. To obtain an accurate model a different intercept was needed at each station. This meant that the stations were not calibrated consistently before the test began and, in fact, the meters were not calibrated at the beginning of the test. The Rd and +b slopes by meter are presented in Table 1.

The standard error of the estimate of the slope for Rd was 0.010 units/day and for +b was 0.012 units/day. Therefore, the regression indicated that the slopes were significantly different than zero and were different between the meters except Rd for meters 3 and 4 and +b for meters 1 and 2. For Rd drift to change by the industry standard of 1.0 units, would take about 3.2 days. The +b for unit 3 would require about 2.7 days to change by the industry standard of 0.5.

These slopes are not obvious if the data were plotted but a real trend was measured. The drift was easily seen when the mean Rd and +b readings were calculated by day and by tile for all four meters and all 10 readings per day (Tables 2 and 3). It appeared that there was a measurable drift with time for these meters and that daily calibration would be prudent. The percent area readings of the central and trash tile were examined with the GLM procedure. The initial model allowed for variation due to tile, meter, time, and their combinations. Factors that did not significantly contribute to explaining the variation were removed leaving only station and tile. The purpose of this test was to determine if there was any measurable drift with time, and this study over four days found that there was no drift in the percent area measurement with time.

The trash count readings were analyzed with meter, tile, time, and all combinations of these. When the factors that did not contribute to the prediction of count were removed, only station and tile were left. The conclusion based on the data was that count did not change significantly with time, but that the meters were not all in calibration during the test.

The purpose of this portion of the study was to determine if there was a detectable drift with time of the color and trash measurements. Conclusions based on these data were that Rd and +b both drift with time such that daily calibration is recommended. The area and count measurements did not experience any significant drift over the four-day test period.

Test C. Vibration effect on color and trash measurement stability.

During the initial testing of the Zellweger Uster color/trash meters in the microgin, it was observed that if the meters were struck, even gently with a hand, the Rd and +b tended to shift. Considerable vibration in the gin might continuously shift the color readings. After the Uster personnel soldered the power supply leads directly to the light bulbs, vibration did not seem to affect the readings. To test the system response to vibration further, a motor was clamped to one of the color/trash meter housings with an off balance weight attached to the shaft. The vibration caused by this device was easily noticeable and appeared to be greater than normally experienced in a commercial gin. The vibration was also at a frequency similar to that experienced in a gin. The meter was calibrated and vibration begun at 3:00 p.m. May 29, 1996. Seven readings of each of the five color tiles and the trash tile were made that afternoon. Vibration was continued and two days later seven more sets of readings were taken over the day, ending the test at 3:45 p.m. The Rd and +b readings were examined to determine if any shift in readings could be attributed to the vibration.

The Rd and +b values were first plotted vs. time and no shift was apparent. The procedure GLM was used to determine if there was any shift with time. A model was used allowing for a different intercept for each tile but a common slope for all tiles. This allowed the data from the different tiles to be compared directly. A linear regression was done and the analysis of Rd showed no correlation with time. The errors in the +b readings were correlated with time with a slope of -0.09 units/day. This slope would result in a shift of 0.5 units in about 5.7 days. The correlation of +b was statistically significant but the root mean square residual was only reduced from 0.14 to 0.11.

It was also not clear that the change in +b was due to the vibration or to another factor. It is interesting that the shift expected from the drift study was -0.4 Rd units and 0.2 +b units. No shift in Rd was seen in this study and the shift in +b was slightly negative instead of positive as expected. Although these shifts were statistically significant, they may not have been based on consistent changes. Perhaps the vibration works in the opposite direction from the drift measured in test B and offset the shift in Rd and more than offset the shift in +b.

When the trash readings were examined, there was obviously no effect on the percent area with time. There were 28 trash readings of each of the two tiles used in this study and all readings were exactly the same. The count reading mean was 202, the standard deviation was 1.4, and readings varied from 200 to 205. There was some variation of the count but the variation was not related to time. There had been no drift with time without the vibration and no change with time was detected with the vibration. Therefore, the conclusion was made that the vibration did not affect the trash readings.

The purpose of this portion of the study was to simulate the vibration often experienced in a gin, and determine if it affected the color and trash readings. It was observed that Rd and +b changes were insignificant. There was no measurable effect of the vibration on the trash measurements.

Test D. Color and trash accuracy compared to the CO with samples presented by hand.

The data for this study were collected from Feb. 23 to March 8, 1996 with one meter in the microgin. The meter was calibrated each day before measuring any cotton samples. The tiles were measured after calibration at the beginning of each day, at two hour intervals during the day, and at the end of data collection on each day. The cotton samples for which Rd, +b, and percent area were measured had been classed previously at the Dumas CO.

The first step was to analyze the data from the tiles to determine if the instruments were in calibration. An analysis by the GLM procedure was done considering the tile and the time order of calibration checks and the combination of the two as the model. All factors were statistically significant but after the interaction and the term for which order in the series of calibration checks were removed, the root error mean square was still quite low. Table 4 shows the mean and standard deviation of the measurements by tile and the standard values for each tile. The standard deviations of the readings are lower than that experienced when measuring cotton, especially for Rd. Based on the data presented in Table 4, it was concluded that the instrument was well calibrated for color throughout the test. The Rd and +b observations had been rounded to 0.1, and the standard deviations were all below this level.

The percent area data were examined, and over the 83 measurements of the central tile, the percent area was always 0.0. Over the 80 measurements of the trash tile, the percent area was always 2.3. Therefore, the meter was in calibration for percent area over the testing period.

The data from the Dumas CO were compared with the data from the meter being tested. The root mean square residual was used to judge whether there was a significant difference between four different models: 1) there was no difference between the data from the meter being tested and the CO, 2) there was a simple offset in the data between the two measurement locations, 3) there was a slope difference in the data, and 4) there was both a slope and offset in the data between the two measurement locations.

Based on the results shown in Table 5, it was concluded that there was no significant difference in the Rd values from the two sources. There was an indication that there may be an offset difference between the sets of readings. AMS allows for an offset between their classing offices, so including an offset here would be reasonable. There was no indication that any of the other models should be used. These root mean square residuals of 1.7 or 1.3 are higher than the AMS repeatability target of 1.0 for Rd (but these two numbers are not directly comparable). There were no repeated measurements from AMS so an analysis of the variability of the AMS data was not possible.

Table 6 shows the root mean square residual data for a similar analysis of the +b data. The linear fit produced a residual slightly lower than the others but the model may have over-fit the data. The slope is very low and the intercept was very high for the type of correction that would be expected from one well calibrated and stable instrument to another. In addition, the root mean square residual of 0.69 was reasonable for these data. The conclusion was that there was no difference in the +b readings between the meter in the microgin and at the Dumas CO for these samples.

The area analysis was done the same way as the Rd and +b analysis, and the root mean square residuals for all four models were 0.39. Hence, there was no evidence that the area measurements were different between the Dumas CO and the microgin.

The purpose of this portion of the study was to determine if a well calibrated instrument in the microgin would measure the same color and trash as the meters at the CO. Based on the measurements of the tiles, it was concluded that the instrument was well calibrated throughout the testing. Based on analysis of Rd, +b, and percent area from the microgin and the Dumas CO on the same samples, it was concluded that the HVI color and trash readings are the same for samples presented manually.

Test E. Color and trash accuracy compared to the CO with samples presented by the automated sampler and by hand.

The purpose of this portion of the study was to determine the relationship between Rd, +b, and percent area readings in the microgin and the Dumas CO for different cotton sample presentation techniques.

The first set of color and trash readings were taken in the microgin while ginning. The samples were obtained with an automated paddle sampler (Anthony, 1995) and pressed against the color/trash meter glass, then released. In this test, there were seven combinations of cleaning machinery. Most combinations included fewer than the standard number of cleaning machines. Six varieties of cotton were ginned with each of the seven machine combinations for a total of 42 lots. While each lot was being ginned, three samples were taken manually for classing by the Dumas CO and referred to, in this report, as the second set of data. Three of these 126 samples were held by the CO for their accuracy check procedures, but no more than one sample was kept per lot. The remaining 123 samples were returned to the microgin. Color/trash measurements were repeated at station 4 with manual placement of the samples on the glass and manual closing of the paddle on the sample. This created a data set referred to, in this report, as the third set of data. The fourth set was obtained on May 2 the same way as the third set was obtained. The fifth set was obtained the same way as the third and fourth except that a switch was wired to the air solenoid so that the air cylinder held the paddle closed during the color/trash measurement.

Data from station 4 in the microgin, the last station in the gin, obtained while ginning was analyzed first. Experience has shown that poor samples can be identified by low Rd readings. The Rd mean by lot was calculated for the data and any observation with Rd more than 2.0 lower than the mean for that lot was discarded. This left an average of over 17 observations per lot that were averaged to obtain a reading representative of that lot. Table 7 shows some basic descriptive statistics for these data. Note that these readings were not on the same samples as sets 2, 3, 4, and 5; but were readings made on samples from the same lot. Because the samples were obtained with fewer than normal cleaning machines for many lots, the trash levels were higher than what is normally seen in classing of cotton, but better covered the range needed for gin process control.

Next, the repeat readings from the Dumas CO were averaged to get the representative reading for each lot. Table 8 shows some descriptive statistics for the CO data.

The data from the samples which were manually presented and held in the microgin were examined next. Except for three cases, each of the 42 lots had three samples returned from the CO. The remaining three had two samples each. Each sample was presented twice, once on each side, for a color and trash measurement. Descriptive statistics for these data are presented in Table 9.

Data set four, the second set of manually presented and held samples in the microgin, was examined next. Except for three cases, each of the 42 lots had three samples returned from the CO and the remaining three had two samples each. Each sample was presented twice, once on each side, for a color and trash measurement. Descriptive statistics for these data are in Table 10.

Data set five, the set of manually presented and mechanically held samples in the microgin, were examined next. Each sample was presented twice, once on each side, for a color and trash measurement. Descriptive statistics for these data are in Table 11.

Next, the Rd values of the first three sets of data were compared. The AMS acceptable range for Rd is ±1 unit (Boyd, 1996). The SAS Institute, Inc. (1996) procedure MIXED was used in the analysis of the data presented in tables 7 through 12. A data set including the data from sets 1 through 5 was analyzed allowing for differences due to the lot of cotton (variety and cleaning equipment) and the set (measurement technique). The analysis showed that there were significant differences between the lots, which was expected. Table 12 summarizes the analysis with the means by data set listed and categorized showing those which were significantly different from each other. The Rd analysis showed that the Rd data from the first set was different from all other sets, and none of the other sets were significantly different from each other.

There were two major differences between the first set of data and the other sets: 1) the cotton samples were identical for the second through the fifth set of data but were different from those of the first set, and 2) the sample collection with the first set was with a paddle sampler and the collection with the other four sets was manual. It was believed that the cotton in the individual lots was uniform, and that the three samples taken during the processing of each lot represented the cotton in that lot. Therefore, it is unlikely that the causes of this Rd difference would be actual differences in the cotton. It is unlikely that calibration was the cause of this problem because the differences were so great in the Rd readings. Data sets one and three through five were collected with the same meter using the same calibration procedures. The meter was recalibrated between sets three, four, and five. In addition, the equipment was recalibrated three times during the collection of set one so variations remaining after calibration should have reduced the differences between that set and the others if the problem was related to calibration.

Next, the +b readings were compared using the same approach used for the Rd readings. The AMS acceptable range for +b is ±0.5 unit (Boyd, 1996). From the analysis of +b it was concluded that there were no significant differences in the +b readings between any of the data sets. Of course, there were differences between the lots. Again, if the means for the +b values for the three data sets are compared, they vary only slightly so it was not surprising that no differences between the data sets were found.

The fact that the +b readings (yellowness) did not vary with the data set but the Rd readings (reflectance) did vary, supports the theory that the samples presented by the automated sampler were not pressed against the glass to a high enough or even enough density. Additional analysis using GLM showed that the Rd difference between the automated and manual samples was consistent across samples and a simple offset can be used to predict the data in set 2 from the data in set 1.

Finally, the percent area readings from the three sets of data were compared, by lot, using the same approach as was used for Rd and +b. The AMS acceptable range for area is ±0.1 unit and the sample standard deviation within modules and trailers was reported to be 0.10 and 0.12 respectively (Boyd, 1996). The analysis showed that there were significant differences in the percent area measured by lot, Table 12. Based on the analysis it was concluded that the area measured in the first data set was significantly lower than that measured in the other data sets and that there were no other differences significant at the 95% confidence level. In addition data sets 2 and 3, but none of the other pairs, would have been significantly different at the 90% confidence level. Additional analysis by GLM show that these data could be "corrected" with a simple slope between the percent area measured in set 1 compared to set 2. The slope correction was better than an offset but the linear fit was no improvement.

Summary

Test A. The meters were tested with different ambient temperatures. This test showed no significant changes in the Rd readings but the +b readings changed significantly with temperature. No significant changes in the trash readings were observed due to the temperature changes. Based on this test, attention needs to be paid to the temperature of the system during calibration compared to the temperature during operation. A periodic calibration should be done during the season to reduce this difference. An ambient temperature range of ±11°C (±20°F) was estimated to be acceptable.

Test B. Both Rd and +b for all four meters were found to drift with time. The drift was such that daily calibration would be prudent, but not necessary. Based on these data, calibration every two days is necessary. There was no measurable drift of trash count or percent area with time.

Test C. The vibration test did not reveal any problems. In fact, the variation during vibration testing was less than what would have been expected due to drift from test B.

Test D. Based on the data collected for this test, it was concluded that there was no difference in the Rd, +b, or percent area readings of cotton samples when AMS readings were compared with readings made with this equipment with manually presented samples.

Test E. There was a significant difference in the Rd readings for the samples when the samples were presented automatically vs. those presented manually but none of the other differences were significant. It was concluded, based on these data, that the meters adequately measure Rd with manually presented samples but that there was a significant offset in Rd when the automated sampler was used. There were no significant differences in +b in this test. A conclusion was made that most of the small differences between the sets of readings were not statistically significant. The only significant difference was that percent area measured from samples collected automatically while ginning was lower than that obtained with the manually positioned check samples. The difference appeared to be related to slope, not to offset.

Overall the meters performed well and produced data similar to what were obtained from AMS for cotton. The exception was the automated sampler which had a consistent offset for Rd readings and the percent area readings which varied in slope from the reference data.

Disclaimer

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Table 1. The change of color factors with time over a five-day period, test B.

Meter	Slope of Rd with time units/day	Slope of +b with time units/day
1	-0.20	0.11
2	-0.32	0.11
3	-0.17	0.19
4	-0.16	

Table 2. The means of all readings by tile and day for the Rd data, test B.

	Tile				
Day	1	2	3	4	5
May 20	82.9	55.3	69.8	54.3	73.9
May 21	82.5	55.2	69.7	54.2	73.7
May 22	82.4	55.1	69.5	54.1	73.5
May 23	82.1	54.9	69.4	53.9	73.3
May 24	81.6	54.5	69.0	53.7	73.0

Table 3. The means of all readings by tile and day for the +b data, test B.

	Tile				
Day	1	2	3	4	5
May 20	6.3	12.4	15.1	5.9	9.6
May 21	6.4	12.5	15.1	6.0	9.7
May 22	6.6	12.6	15.2	6.1	9.9
May 23	6.7	12.7	15.3	6.3	10.0
May 24	6.9	12.7	15.6	6.4	10.1

Table 4. Analysis of the color data by tile for the calibration check data, test D.

	Reflectance (Rd)			Yellowness (+b)		
Tile	Mean	Standard deviation	Standard value	Mean	Standard deviation	Standard value
1	83.3	0.06	83.3	5.8	0.06	5.7
2	56.0	0.06	55.9	12.0	0.05	11.9
3	70.3	0.09	70.5	14.5	0.08	14.5
4	54.6	0.04	54.6	5.5	0.05	5.5
5	74.3	0.09	74.1	9.0	0.05	8.9

Table 5. Results of predicting Rd values at the CO with measurements from the microgin, test D.

Model	Root mean square residual
RdD = RdM	1.73
RdD = RdM + 1.12	1.32
RdD = 1.016*RdM	1.33
RdD = 0.9382*RdM + 5.4	1.31

Note: the D suffix refers to data from Dumas CO, and the M refers to data from the microgin.

Table 6. Results of predicting +b values at the CO with measurements from the microgin, test E.

Model	Root mean square residual
+bD = +bM	0.69
+bD = +bM + 0.26	0.64
+bD = 1.027*(+bM)	0.65
+bD = 0.1381*(+bM) + 7.769	0.47

Note: the D suffix refers to data from Dumas CO, and the M refers to data from the microgin.

Table 7. Descriptive statistics for the color and trash readings in the gin taken while ginning, test E.

	Mean	Std. error of mean	Low	High
Rd	70.2	0.45	64.6	75.0
+b	8.28	0.093	7.0	9.4
area	0.37	0.038	0.03	0.84

Table 8. Descriptive statistics for color and trash readings from the Dumas CO for the mean of the three samples per lot, test E.

	Mean	Std. error of mean	Low	High
Rd	73.45	0.40	67.7	77.7
+b	8.27	0.098	6.93	9.40
area	0.52	0.095	0.07	1.10

Table 9. Descriptive statistics for color and trash readings from the manually placed and held samples at station 4 in the microgin, data set 3, test E.

	Mean	Std. error of mean	Low	High
Rd	73.4	0.44	67.1	78.0
+b	8.24	0.091	7.0	9.3
area	0.65	0.063	0.1	1.65

Table 10. Descriptive statistics for color and trash readings from the manually placed and held samples at station 4 in the microgin, data set 4, test E.

	Mean	Low	High
Rd	72.8	67.3	78.2
+b	8.4	6.8	9.4
area	0.60	0.08	1.62

Table 11. Descriptive statistics for color and trash readings from the manually placed but mechanically held samples at station 4 in the microgin, data set 5, test E.

	Mean	Low	High
Rd	73.0	68.2	78.2
+b	8.4	7.1	9.4
area	0.61	0.13	1.40

Table 12. Means by data set of the three measured variables and significance grouping at the 95% confidence interval, test E.

	Measured variable		
Data set	Rd	+b	percent area
1	70.2 a	8.3 a	0.37 a
2	73.5 b	8.3 a	0.51 b
3	73.4 b	8.2 a	0.65 b
4	72.8 b	8.4 a	0.60 b
5	73.0 b	8.4 a	0.61 b