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PRELIMINARY DATA ON FIBER PROPERTIES OF NEWLY HARVESTED VERSUS WEATHERED COTTON

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Abstract

This study was conducted to establish the impact of humidity cycling in the field and laboratory on the moisture content (mc) and physical properties of cotton fiber. Fiber mc has been shown to differ due to environmental conditions such as relative humidity and temperature. White blossoms on cotton plants were tagged in the field and the tagged mature bolls were later hand harvested when the bolls were in one of three conditions--cracked, open, or weathered. All of the bolls were stored in a controlled environment after harvest until the cracked bolls opened. The locules were removed from the carpels and the fiber was then removed from the cottonseed with a small roller gin. The ginned fiber was then exposed to controlled conditions of 70° F and 55% relative humidity (RH) at least another 7 days before the mc was determined by the oven method and Advanced Fiber Information System (AFIS) properties measured. The mc of the fiber did not vary between the cracked and open bolls (5.6%) but the mc from the weathered bolls was significantly lower (5.4%). So, the freshly harvested fiber had a higher mc than the weathered fiber that had been cycled climatically in the field. After exposing the fiber to higher and lower humidity (76° F and 80% RH, and 70° F and 55% RH) repeatedly, the difference in mc between freshly harvested cotton and weathered cotton was reduced (5.7% versus 5.6%) but not eliminated. The relative date of blossom (anthesis) did not affect the mc data but did affect the AFIS fiber length properties. In addition to the blossom tagging order within the row, the humidity cycling significantly affected the AFIS fiber length measurements while the fiber mc had a much lower importance. Additional study is needed to better understand the importance and impact of the relationship between fiber length distribution and humidity cycling.

Introduction

Griffin (1974) reported that newly harvested cotton fiber conditioned at either high or low humidity and then stored at a fixed temperature and relative humidity equilibrated at different moistures. He reported that the equilibrium moisture content (EMC) of cotton fiber differed by about 2 percentage points in the range 4% to 10% depending on whether the fiber had previously been at a higher or lower mc. Griffin did not consider the impact of repeated changes from high to low humidity on the EMC of cotton. Somasundar (1965) reviewed data from others and presented his own data for cotton yarn. Somasundar reported a smaller difference of around 1 percentage point for cotton which had been processed to varying degrees before making the mc measurements. The desorption and adsorption EMC values are known to differ in many agricultural products and the difference decreases with repeated wetting/drying cycles. Chung and Pfost (1967) proposed that the hysteresis was due to shrinkage of the structure on a molecular level thereby reducing the number of bonding sites for water vapor.

The AFIS is a laboratory-type instrument for the study of cotton fiber samples. The samples are manually formed into loose bundles. These bundles are taken into the AFIS and individual particles are transported aerodynamically through a electro-optical sensor where the length and shape of the particles are measured. These data are analyzed digitally to determine if the particles were trash or fiber and statistics accumulated regarding different categories of the particles. Finally, the results of the analysis are stored on computer disk. These data characterize the sample with regard to average fiber length, short fiber content, fiber maturity, nep content, trash content, etc. Different cotton fiber samples may have different length distributions which are not well represented by a simple average fiber length measurement. The different measures of fiber length available in the AFIS data set help describe the fiber length distribution without including the complete distribution.

The purpose of this study was to collect lint which had been and had not been subjected to natural humidity cycles in the field and determine if there were significant differences in the EMC of the lint samples. An additional purpose was to examine any variation in AFIS measurements which may also be related to the lint humidity history.

Materials and Methods

A field located in Stoneville, MS, was planted to Delta Pine 555 RR/BG cotton on May 8, 2003. The cotton received two mechanical cultivations in May. The field was sprayed for insects seven times, with the last date of application Aug. 6. Pix (plant growth regulator) was applied on July 16. The field was sprayed with Finish plant growth regulator on Sept. 8 and with Ginstar defoliant on Sept. 18.

The cotton was monitored for blossoms and a reasonable number of flowers were noted on July 18. Individual blossoms were tagged with colored paper tags, Figure 1, on July 18, 21, 23, 28, 30 and Aug. 1. Twenty-five bolls were tagged in each row, starting approximately 20 feet into the row from the east end of the field. Fourteen rows were used in the study with the same rows tagged two times about 10 days apart resulting in 700 tagged bolls. Rows adjacent to the wheel tracks of the field equipment were not used in the test. All of the blossoms from the first tagging of each row were from the first position, or the blossom nearest the main stem. All of the blossoms from the second tagging of each row were from the second position, or the second blossom on a branch. All of the plants had been planted on the same day and were the same age and maturity. Most of the blossoms for all of the plants blooming on one day had blossoms at the same location on the plant so it was not possible to identify date of tagging independently from boll location on the plant.

The field was monitored for opening bolls, Figure 2. About 1/3 of the bolls were picked as "cracked," and another 1/3 picked as "opened," Figure 3. This picking procedure was repeated for all tagging dates. In some cases, insufficient cracked or open bolls were available the first time the row was picked and a second picking was done within 5 days to get approximately 1/3 of the bolls in each category. The cracked and open bolls used in the test were all harvested before defoliation. The remaining 1/3 of the bolls in the field were subjected to daily humidity cycles and normal dew. For the two week period before the remainder of the bolls were harvested the average daily maximum RH was 93% and the average daily minimum was 41%. For the same two week period the average daily maximum temperature was 86° F and the average daily minimum was 63° F. Two rainfall events occurred while the bolls were open, a total of 1.0 inches were recorded on Sept. 13 and 14 and on Sept. 22 2.3 inches were recorded. This rainfall event was after all of the "cracked" and "open" bolls were harvested for this test and after defoliant was applied. On Sept. 26 the lint had dried and all of the remaining tagged bolls were harvested by hand, Figure 4. Undersized bolls were harvested but bolls which substantially failed to develop were not included in the study.

Overall, 81% of the tagged bolls were harvested. Of the first bolls tagged on a row 87% were harvested and 75% of those tagged second were harvested. Of the harvested bolls, 35% were in the category cracked, 36% were open, and 29% were weathered. The lint from a single boll weighed roughly 2 g.

The locules of seed cotton were removed from the carpels by hand. A laboratory roller gin, Figure 5, was used to separate the samples into cottonseed and lint, Figure 6. The lint samples from different rows and with different pre-harvest boll conditions were kept separate in open paper bags for at least 7 days in a controlled environment at temperature 70° F and 55% RH. The ISO standard conditions for a laboratory are 20±2°C (68±4°F) and 65±2% RH. After the samples had equilibrated, the wet basis mc was determined by the oven method (Shepherd, 1972) and samples were taken for fiber analysis by the AFIS. The fibers subjected to the mc and AFIS testing were discarded. These data were analyzed to determine if there were differences in fiber properties which correlated with boll history, i.e. cracked, open, and weathered.

All of the remaining cotton was then exposed to higher moisture conditions at 76° F and 80% RH for a minimum of 3 days and then exposed to the lower moisture conditions at 70° F and 55% RH for a minimum of 3 days. This cycle was repeated four times. It was theorized that the cycling of moisture for the lint from the cracked and open bolls would result in less difference between the weathered lint fiber properties and the un-weathered lint, cracked and open. Samples were taken for determination of mc by the oven method and fiber properties by the AFIS.

The data set then included AFIS and mc data for the samples as harvested in the field and also data for the same samples (but different actual fibers) after it had been intentionally exposed to some humidity cycling in the laboratory. All of the oven mc data were coded for row, field location, boll condition, whether the sample had been intentionally subjected to humidity cycling in addition to the natural cycling, and the tagging order within the row then combined into one data set. This data set was analyzed using SAS procedure MIXED (SAS Institute, 2001). There were two tagging dates for each group of rows; and the tagging order was included as an effect in the analysis. One effect which the study was designed to examine was the boll condition at harvest (cracked, open, and weathered). An additional effect was whether the cotton had been purposely put through humidity cycling in addition to whatever cycling had occurred naturally. These factors and all interactions were included in the model as the fixed effects. There were 491 mc observations in the data set. All of the AFIS data were combined into one data set. The SAS procedure MIXED was used to analyze the data with the boll condition at harvest (related to natural humidity cycling), whether the cotton had been purposely put through humidity cycling in the laboratory before the sample was tested or not, the tagging order per row, and all interactions were the fixed effects in the model. The covariance parameters included as random effects in the MIXED analysis were the section of the field in which the rows were located and the interaction of the field section with the tagging order, the boll condition at harvest, and whether the lint had been intentionally subjected to humidity cycling.

Results

The fiber mc data were analyzed statistically. When predicting the measured fiber mc, the only effects which were statistically significant were the boll condition at harvest and the effect of cycling the mc of the fiber. If the cycling of the humidity affected the EMC as expected, then the interaction between the boll condition and the humidity cycling should have been significant because the weathered fiber had been exposed to many humidity cycles in the field. The fact that only the humidity cycling was significant could have been caused by the ambient conditions to which the fiber was exposed before the cycling being different from those after the cycling or by the differences being too small to be statistically significant. The significance of the boll condition on the EMC showed that moisture history did cause a difference in EMC between newly harvested and normally weathered cotton despite any possible longer term variation in environment. The mc mean due to “cracked” was not different from “opened,” but “cracked” was different from “weathered” (P=0.03) and “open” was different from “weathered” (P=0.006), Table 1.

Because cracked and open were not significantly different in Table 1, these data were combined and a new effect of weathered was created with entries of “yes” or “no.” The least squares means were estimated for the mc with the fiber moisture cycled or not. These means of 5.40 and 5.66 were different (P<0.0001), Table 2. These mc measurements were carefully done and the means were based on 474 degrees of freedom so the error in the mean estimate was lower than normally expected.

The covariance values from the statistical analysis of the mc are shown in Table 3 and the importance of the various factors in the model are shown in Table 4. The least squares means for the interaction between the boll weathering at harvest and the humidity cycling are shown in Table 5. This interaction was not statistically significant but the mc difference due to weathering in the field was smaller after moisture cycling than before. In this analysis the interaction between these two effects was not statistically significant but the means due to weathering within the data with no humidity cycling were significantly different with a probability of 0.006 while the means due to weathering within the data with humidity cycling were not significantly different with a probability of 0.07. The humidity cycling had not included conditions much drier than those at which the mc was measured and the humidity cycling was not as great as must have occurred in the field, so more rigorous humidity cycling may produce statistically significant interactions between weathering in the field and cycling in the lab. Also, only 4 cycles were used and the weathered cotton was exposed for 2 to 3 weeks of daily moisture variation. Therefore, repeated high/low moisture conditions did slightly affect the EMC difference, but the difference was not completely removed by the artificial variation achieved during the study.

The results from AFIS analysis of samples taken before humidity cycling and after cycling were combined and the data analyzed using the SAS procedure MIXED. The effects of tag order, whether the lint had come from bolls tagged first or second in the particular row; boll condition; whether the boll was picked cracked, open, or weathered; humidity cycling; and all interactions of these effects were included in the model. The effect of the first versus the second tagging of blossoms within a row was significant for some AFIS measurements. This is logical because the earlier tagged blossoms would have had more time to mature, different plant nutrition, and also would have been exposed to different growing conditions than the later tagged blossoms. The two effects of boll condition when harvested (cracked, open, and weathered) and moisture cycling were of primary interest in this study.

The AFIS nep-related data generally showed no statistically significant variation due to the fixed effects. Likewise, the trash-related AFIS data did not have statistically significant variations due to the fixed effects, however, the AFIS fiber length and maturity data did have significant variations. The covariance values from the statistical analysis of the AFIS mean fiber length calculated by weight are shown in Table 6 and the importance of the various factors in the model are shown in Table 7. For the fiber length averaged by weight the tagging order and the humidity cycling were both significant. The earlier tagged cotton averaged 0.06 in. longer than the later tagged cotton and the fiber without moisture cycling averaged 0.03 in. longer than after the humidity was cycled, Table 8.

The covariance values from the statistical analysis of the AFIS upper quartile length calculated by weight are shown in Table 9 and the importance of the various factors in the model are shown in Table 10. Tag order was most significant but the humidity cycling also had a significant effect. Table 11 shows means of the upper quartile length calculated by weight by tagging order and humidity cycling. The fiber from the bolls tagged first was significantly longer and the cotton without humidity cycling was longer as with the fiber length mean data.

The covariance values from the statistical analysis of the AFIS short fiber content calculated by weight are shown in Table 12 and the importance of the various factors in the model are shown in Table 13. The AFIS short fiber content calculated on a weight basis was greater for the later tagged bolls and for the cotton after humidity cycling, Table 14. Presumably, the humidity cycling caused the fibers to become less straight which resulted in slightly shorter AFIS fiber measurements.

The covariance values from the statistical analysis of the AFIS length measurement of the longest 5% of the fibers calculated by number are shown in Table 15 and the importance of the various factors in the model are shown in Table 16. The results of the length measurement of the longest 5% of the fibers are shown in Table 17. The most significant factor was the tag order with the earlier tagged bolls having longer fiber. The next most important factor was the humidity cycling, with shorter fiber after humidity cycling. There was a significant interaction between the tag order and the humidity cycling, Table 17, there was not a significant difference in the mean length of the fiber from the first tagging due to the humidity cycling but the difference was significant for the fiber from the second tagging. The effect of the boll condition (cracked, open, or weathered) was barely significant and the interactions with it were not significant. The fiber from the cracked and open bolls was more similar to each other than either one was to the weathered fiber. The effect of tagging order on length could logically be due to different growing conditions and boll location on the plant but the humidity cycling still significantly affected the fiber length measurement.

In all of the length measurements, the earlier tagged bolls had longer fiber than the fiber from bolls tagged later. The fiber length was lower after humidity cycling, but if the cycling were the important factor then the boll condition by humidity cycling interaction should have been significant because the weathered bolls had already had more dramatic humidity cycling than the cracked and opened bolls experienced. The analysis was rerun with the oven-based mc measurement under standard conditions used in addition to whether the boll humidity had been cycled. This analysis showed that the humidity cycling was much more significant that the mc of the fiber based on the F-values from type III analysis of model components. The tag order and the humidity cycling by tag order interaction were also statistically significant. So while the mc history affected the EMC, the fiber moisture differences did not correlate strongly with AFIS fiber length properties but did correlate with the effects which produced different mc levels.

The AFIS fineness measurement was affected significantly by the boll tag order, with first tagged bolls having more weight per unit length than the bolls tagged second in the rows. Similarly, AFIS immature fiber content from the bolls tagged first was lower than that from the bolls tagged second. None of the other factors included in the study were statistically significant in predicting immature fiber. The covariance values from the statistical analysis of the AFIS maturity ratio are shown in Table 18 and the importance of the various factors in the model are shown in Table 19. The AFIS maturity ratio of the fibers from the bolls tagged first were very significantly higher than that from the bolls tagged second, Table 20. In addition, the humidity cycling resulted in a slight, but statistically significant, reduction of maturity ratio readings.

The environmental treatment of the seed cotton lint after the boll matured affected the lint mc. Some of the AFIS measurements, including mean fiber length and short fiber content, were found to vary with moisture history of the boll in a pattern which was expected based on the mc variation. But the actual mc measurements did not explain the variations seen in the AFIS fiber length. Additional work is required to better understand if and how much these fiber mc variations may affect the measured fiber properties.

Conclusion

Since the mc of the cotton fiber did not differ significantly due to anthesis date (or boll position) and the difference in mc after repeated cycling in the field or laboratory was only 0.14%, weathered cotton fiber from humid growth areas will equilibrate at the same mc within ±0.1% regardless of climatic history.

Disclaimer

Mention of trade names or commercial products in this report 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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Table 1. Means and standard error of mc separated by boll condition.

Boll condition	Mean estimate†	Standard error estimate
Cracked	5.56 a	0.047
Open	5.61 a	0.044
Weathered	5.42 b	0.046

† Means with the same letter are not statistically different at the 0.05 level.

Table 2. Means and standard error for mc due to cycling of humidity.

Humidity cycle	Mean estimate†	Standard error estimate
No	5.40	0.037
Yes	5.66	0.036

† These means were statistically different ($P<0.0001$).

Table 3. Covariance values from analysis of moisture content

Parameter	Estimate
Field position	0
Field position * tag order interaction	0.001553
Field position * boll conditioning interaction	0.000534
Field position * humidity cycled interaction	0.004345
Residual	0.1206

Table 4. F-values and significance from type III sums of squares of components in model of moisture content.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	3.25	0.1523
Boll conditioning	1	16.61	0.0421
Tag order * boll conditioning interaction	1	6.08	0.0140
Humidity cycled	1	18.57	0.0125
Tag order * humidity cycled interaction	1	2.35	0.1260
Boll conditioning * humidity cycled interaction	1	0.95	0.3305
Tag order * boll conditioning * humidity cycled interaction	1	4.40	0.0364

Table 5. Means of mc by boll weathering at harvest and mc history after harvest.†

		Humidity cycled	
		No	Yes
Weathered in field	No	5.47 b	5.72 a
	Yes	5.27 c	5.58 b

† Means with the same letter did not differ at the 0.05 level.

Table 6. Covariance values from analysis AFIS mean fiber length calculated by weight

Parameter	Estimate
Field position	0.000570
Field position * tag order interaction	0.0000003
Field position * boll conditioning interaction	0
Field position * humidity cycled interaction	0
Residual	0.000753

Table 7. F-values and significance from type III sums of squares of components in model of AFIS mean fiber length calculated by weight.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	30.83	<0.0001
Boll conditioning	2	2.86	0.0709
Tag order * boll conditioning interaction	2	1.86	0.1706
Humidity cycled	1	9.98	0.0033
Tag order * humidity cycled interaction	1	1.95	0.1711
Boll conditioning * humidity cycled interaction	2	0.13	0.8800
Tag order * boll conditioning * humidity cycled interaction	2	0.07	0.9298

Table 8. Means of the AFIS mean fiber length calculated by weight, in inches.†

		Humidity cycled	
		No	Yes
Tag order	First	1.035 a	1.019 a
	Second	0.990 b	0.948 c

† Means with the same letter did not differ at the 0.05 level.

Table 9. Covariance values from analysis AFIS upper quartile length calculated by weight.

Parameter	Estimate
Field position	0.000751
Field position * tag order interaction	0.0000005
Field position * boll conditioning interaction	0
Field position * humidity cycled interaction	0
Residual	0.000864

Table 10. F -values and significance from type III sums of squares of components in model of AFIS upper quartile length calculated by weight.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	33.77	<0.0001
Boll conditioning	2	2.19	0.1269
Tag order * boll conditioning interaction	2	1.18	0.3184
Humidity cycled	1	6.23	0.0175
Tag order * humidity cycled interaction	1	1.56	0.2205
Boll conditioning * humidity cycled interaction	2	0.50	0.6122
Tag order * boll conditioning * humidity cycled interaction	2	0.16	0.8569

Table 11. Means of the AFIS upper quartile length calculated by weight, in inches.†

		Humidity cycled	
		No	Yes
Tag order	First	1.247 a	1.234 a
	Second	1.194 b	1.157 c

† Means with the same letter did not differ at the 0.05 level.

Table 12. Covariance values from analysis AFIS short fiber content calculated by weight.

Parameter	Estimate
Field position	0.3573
Field position * tag order interaction	0.002055
Field position * boll conditioning interaction	0
Field position * humidity cycled interaction	0
Residual	1.3715

Table 13. F-values and significance from type III sums of squares of components in model of AFIS short fiber content calculated by weight.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	7.71	0.0087
Boll conditioning	2	2.84	0.0720
Tag order * boll conditioning interaction	2	1.74	0.1895
Humidity cycled	1	10.58	0.0025
Tag order * humidity cycled interaction	1	0.95	0.3363
Boll conditioning * humidity cycled interaction	2	0.05	0.9540
Tag order * boll conditioning * humidity cycled interaction	2	0.45	0.6396

Table 14. Means of the AFIS short fiber content calculated by weight, in whole percent.†

		Humidity cycled	
		No	Yes
Tag order	First	7.83 b	8.73 b
	Second	8.75 b	10.40 a

† Means with the same letter did not differ at the 0.05 level.

Table 15. Covariance values from analysis AFIS fifth percentile length calculated by number.

Parameter	Estimate
Field position	0.000849
Field position * tag order interaction	0.0000001
Field position * boll conditioning interaction	0
Field position * humidity cycled interaction	0
Residual	0.000765

Table 16. F-values and significance from type III sums of squares of components in model of AFIS fifth percentile length calculated by number.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	35.52	<0.0001
Boll conditioning	2	3.48	0.0417
Tag order * boll conditioning interaction	2	0.90	0.4152
Humidity cycled	1	13.74	0.0007
Tag order * humidity cycled interaction	1	5.11	0.0302
Boll conditioning * humidity cycled interaction	2	0.67	0.5168
Tag order * boll conditioning * humidity cycled interaction	2	0.12	0.8898

Table 17. Means of the AFIS fifth percentile length calculated by number, in inches.†

		Humidity cycled	
		No	Yes
Tag order	First	1.40 a	1.39 ab
	Second	1.36 b	1.30 c

† Means with the same letter did not differ at the 0.05 level.

Table 18. Covariance values from analysis AFIS maturity ratio.

Parameter	Estimate
Field position	0
Field position * tag order interaction	0
Field position * boll conditioning interaction	0.000004
Field position * humidity cycled interaction	0
Residual	0.000177

Table 19. F-values and significance from type III sums of squares of components in model of AFIS maturity ratio.

Factor	Numerator degrees of freedom	F-value	Probability of greater F
Tag order	1	14.03	0.0008
Boll conditioning	2	1.46	0.3936
Tag order * boll conditioning interaction	2	0.11	0.8965
Humidity cycled	1	4.55	0.0405
Tag order * humidity cycled interaction	1	0.06	0.8035
Boll conditioning * humidity cycled interaction	2	0.68	0.5152
Tag order * boll conditioning * humidity cycled interaction	2	1.15	0.3294

Table 20. Means of the AFIS maturity ratio.†

		Humidity cycled	
		No	Yes
Tag order	First	0.917 a	0.907 b
	Second	0.897 bc	0.889 c

† Means with the same letter did not differ at the 0.05 level.

Figure 1. Photograph of a new blossom immediately after it was tagged.

Figure 2. Photograph of a tagged boll after development.

Figure 3. Photograph of cracked bolls, left, and open bolls, right, from row 48, tagged on July 21 and picked on Sept. 5, 2003.

Figure 4. Photograph of one of the weathered bolls included in the study before harvest.

Figure 5. Laboratory roller gin in operation.

Figure 6. Three components of cotton bolls—carpels (left), fiber (right) and cottonseed (top).