EFFECTS OF BRANCH ZONE AND FRUITING POSITION ON THE LENGTH BY WEIGHT DISTRIBUTION

Jonn Foulk
USDA ARS CQRS
Clemson, SC
Philip Bauer
USDA ARS CPSWPRC
Florence, SC
Herman Senter
Clemson University
Clemson, SC

Abstract

Cotton (*Gossypium hirsutum L.)* is grown by producers as a raw material input for textile mills. Cotton fiber qualities continue to improve through crop management, genetic, and ginning improvements. Competition from synthetic fibers, mill modernization, and global market competition have increased the demand for improved fiber quality, while changes in the textile industry and fiber measurement technology have resulted in a steady improvement in cotton fiber quality. The Advanced Fiber Information System (AFIS) analyzes cotton fiber length distributions because variations in fiber length distribution impacts spinning performance. The goal was to evaluate the entire AFIS fiber length distribution so distributions were evaluated rather than mean values. Chi-square and Kolmogorov-Smirnov tests were used to evaluate AFIS fiber length distributions among two cultivars [DPL555 (mid-full maturity) and PM1218 (early maturity)). Fiber properties were determined on first and second branch position bolls on reproductive branches in a 1-m section of row in each plot. The objective was to evaluate differences in the shape of histograms between cotton plant zones, cotton boll position, and cotton variety.

Introduction

The USDA Agricultural Marketing Service provides cotton (Gossypium hirsutum L.) fiber quality measurements on every bale grown in the US using High Volume Instrumentation (HVI™). Little attention has been paid to understanding fiber quality variation, though it has long been recognized that cotton fibers are naturally variable (Balls, 1928). Reducing the variability for individual fiber properties within bales appears important for further quality improvements of cotton crops. A bale of cotton’s average fiber properties are from bolls that developed under different environments both spatially and temporally. Research demonstrates that fiber properties differ among bolls that develop at different times during the season (Bennett et al., 1967; Meredith and Bridge, 1973). Planting date (Bauer et al., 2000; Davidonis et al., 2004) and plant population (Bednarz et al., 2006) influence fiber properties at specific canopy positions. Each year new varieties are marketed to producers distinguished from each other due to plant type, maturity, fiber properties, added value traits (e.g., insect and/or herbicide resistance transgenes), yield, and environmental adaptation. Textile industries desire longer more uniform cotton fibers.

Along with other results, AFIS provides cotton fiber length and length distributions. Typically mean values are evaluated for processing however; length histograms provide additional information and could be an effective graphical method to demonstrate fiber length skewness or kurtosis. For cotton fiber length unimodal distributions, a positive skewness indicates the distribution is right skewed (equal mean lengths and higher skewness leads to longer fibers). Skewness is a judgment of the lack of symmetry and is a measure of the asymmetry of the distribution (normal distribution has a skewness of zero and the mean = the median = the mode) (Snedecor and Cochran, 1980). Kurtosis is a measure of whether the data are peaked or flat relative to a normal distribution. Kurtosis is a measure of peakedness of a unimodal distribution (zero for normal distribution) (Snedecor and Cochran, 1980). Distributions with high kurtosis tend to have a distinct sharp peak near the mean and decline rather rapidly (higher concentration of fibers within uniform length with slight length variability).

Other techniques to evaluate fiber length distributions include the Chi-square test to test for differences between pairs of AFIS length distributions and the two-sample Kolmogorov-Smirnov test for differences in the cumulative distributions. Chi-square is used to assess the goodness of fit and establishes whether an observed frequency distribution of fiber lengths in a sample differs from another fiber length distribution (Snedecor and Cochran, 1980). The two-sample Kolmogorov–Smirnov test is a practical nonparametric technique for comparing two samples, as it is sensitive to differences in both location and shape of the empirical cumulative distribution functions of the two samples (Conover, 1999). Both are able to evaluate distributions; however the Chi-square tests provide additional information about where differences occur.

If fibers were more uniform in length there should be a lower percentage of short fibers in cotton bales, sliver, and yarn thus producing stronger more uniform yarns that can subsequently be processed at a higher speed. More uniform fiber length and stronger yarns should lead to a reduction in spinning costs, knitting costs, weaving costs, and energy costs. Length can be affected by cultivar, maturity, environment, boll position, field weathering, production practices, harvest method and speed, ginning type and speed, and moisture content. The International Cotton Advisory Committee (2001) states ginning influences fiber length distributions while Bradow et al. (1999) state that short fiber content by weight ranges from 6.2% for hand ginned samples, 10.2% for saw ginned, and 11.8% for roller ginned. The objective was to evaluate differences in the entire shape of hand-ginned (best inherent representation of fiber length) histograms between cotton plant zones, cotton boll position, and cotton variety via skewness, kurtosis, Chi-square, and Kolmogorov-Smirnov tests.

Materials and Methods

A mid-full season maturity cultivar (DPL555 BG/RR) was compared to an early maturing cultivar (PM1218 BG/RR) in this study. The study was conducted in 2004 and 2005 at Clemson University's Pee Dee Research and Education Center near Florence, SC. Soil was Goldsboro loamy sand (fine-loamy, siliceous, thermic Aquic Paleudult). Cultivars were planted into plots that were twelve 1 m wide X 15 m long rows. Experimental design was randomized complete block with four replicates.

In both years all plants in a 1-m section of row in each plot were selected for determining within-canopy fiber properties. These row sections were inspected daily from early July through mid-August and dated tags were placed on blooms on the day of anthesis. At the end of the season, all bolls in the 1-m section of row were hand-harvested. Mainstem node position, fruiting position (FP) (1 or 2), and flowering date (when dated tag was present) were recorded for each boll. To simplify analysis three zones were created from mainstem node positions with mainstem nodes 5-8 representing ZONE1, mainstem nodes 9-12 representing ZONE2, and mainstem nodes 13-16 representing ZONE3. Bolls were weighed and then fiber was hand-separated from the seeds. Bolls evaluated in this study were harvested at several times during harvest season to minimize the effect of in-field weathering of the cotton fibers.

Prior to testing, all samples were conditioned for 48 hours at 65 % RH and 21 ^{o}C (ASTM International, 1997d). Fiber length distributions were determined on 180 of these individual hand-ginned bolls (Tables 1, 2, 3, and 4). Bolls evaluated were first and second node position bolls on sympodial branches using the Advanced Fiber Information System (AFIS™) (Uster Technologies; Knoxville, TN). AFIS™ is a destructive method that aeromechanically opens fibers and separates fiber, trash, and dust for electro-optical measurement thus producing various distributions. These distributions are presented with percentage of fiber length by weight on the Y-axis (%) and fiber length on the X-axis (index of 4 equal to 0.25 inches).

Table 1. Chi-square test summary of 24 pair-wise comparisons of length distributions*

Variety	DPL555		PM1218	
Year	2004	2005	2004	2005
ZONE1	Branch1 = Branch2	Branch1 << Branch2	Branch1 < Branch2	Branch1 > Branch2
ZONE2	Branch1 = Branch2	Branch1 >> Branch2	Branch1 >> Branch2	Branch1 << Branch2
ZONE3	Branch1 < Branch2	Branch1 > Branch2	Branch1 >> Branch2	Branch1 = Branch2
Plant length	ZONE1>ZONE2	ZONE1<<ZONE2	ZONE1=ZONE2	ZONE1<<ZONE2
Plant length	ZONE2>ZONE3	ZONE2>>ZONE3	ZONE2=ZONE3	ZONE2=ZONE3
Plant length	ZONE1>>ZONE3	ZONE1>ZONE3	ZONE1=ZONE3	ZONE1<<ZONE3

* Branch1 > Branch2 indicates the length distribution of Branch1 is significantly shifted (Chi-square test p-value < 0.10) to the right of Branch2, while Branch1 < Branch2 would mean Branch1 is shifted left of Branch2, and Branch1 = Branch2 signifies no significant difference. The symbols >> and << indicate highly significant differences (Chi-square test p-value < 0.000).

Table 2. 2004 AFIS fiber length measurements

	Branchnode	ZONE	L(w) (mm)	L(w) CV (%)	UQL(w) (mm)	SFC(w) (%)	Skewness	Kurtosis
DPL555	1	1	28.4	27.6	32.3	3.38	1.42	0.60
DPL555	2	1	27.9	27.4	31.8	3.48	1.61	1.32
		ZONE 1 Mean	**28.2**	**27.5**	**32.0**	**3.42**	**1.51**	**0.95**
DPL555	1	2	26.9	29.9	31.2	4.84	1.43	0.68
DPL555	2	2	27.2	28.7	31.0	4.00	1.44	0.68
		ZONE 2 Mean	**26.9**	**29.3**	**31.2**	**4.44**	**1.43**	**0.68**
DPL555	1	3	25.9	30.7	30.0	5.40	1.34	0.35
DPL555	2	3	26.4	31.8	31.0	5.77	1.35	0.57
		ZONE 3 Mean	**26.2**	**31.0**	**30.2**	**5.48**	**1.33**	**0.41**
	Branchnode 1 mean		**26.9**	**29.7**	**31.0**	**4.72**	**1.37**	**0.48**
	Branchnode 2 mean		**27.2**	**29.0**	**31.2**	**4.18**	**1.47**	**0.84**
DPL555 Mean			**26.9**	**29.4**	**31.0**	**4.52**	**1.42**	**0.66**
	Branchnode	ZONE	L(w) (mm)	L(w) CV (%)	UQL(w) (mm)	SFC(w) (%)	Skewness	Kurtosis
PM1218	1	1	26.2	26.0	29.0	2.93	1.71	1.65
PM1218	2	1	26.2	27.3	29.7	4.07	1.73	1.78
		ZONE 1 Mean	**26.2**	**26.6**	**29.2**	**3.45**	**1.71**	**1.65**
PM1218	1	2	26.2	26.4	29.7	3.73	1.76	1.86
PM1218	2	2	24.6	27.4	27.9	4.40	1.71	1.59
		ZONE 2 Mean	**25.9**	**26.5**	**29.5**	**3.83**	**1.70**	**1.57**
PM1218	1	3	27.2	25.9	30.5	2.43	1.68	1.54
PM1218	2	3	24.9	27.8	27.7	3.10	1.89	2.43
		ZONE 3 Mean	**26.7**	**26.4**	**30.0**	**2.60**	**1.70**	**1.62**
	Branchnode 1 mean		**26.2**	**26.2**	**29.5**	**3.31**	**1.71**	**1.63**
	Branchnode 2 mean		**25.7**	**27.4**	**29.2**	**4.07**	**1.72**	**1.69**
PM1218 Mean			**26.2**	**26.6**	**29.5**	**3.54**	**1.70**	**1.58**

Table 3. 2005 AFIS fiber length measurements

	Branchnode	ZONE	L(w) (mm)	L(w) CV (%)	UQL(w) (mm)	SFC(w) (%)	Skewness	Kurtosis
DPL555	1	1	26.9	27.1	30.5	3.55	1.64	1.45
DPL555	2	1	27.2	26.7	30.5	3.18	1.60	1.32
		ZONE 1 Mean	**26.9**	**27.0**	**30.5**	**3.43**	**1.61**	**1.31**
DPL555	1	2	29.5	25.5	33.0	2.10	1.58	1.20
DPL555	2	2	27.9	30.4	32.3	4.70	1.52	1.14
		ZONE 2 Mean	**29.2**	**26.4**	**32.8**	**2.57**	**1.56**	**1.19**
DPL555	1	3	27.2	27.9	31.0	3.64	1.41	0.64
DPL555	2	3	26.4	30.9	30.5	5.37	1.34	0.48
		ZONE 3 Mean	**26.9**	**28.9**	**30.7**	**4.18**	**1.33**	**0.41**
	Branchnode 1 mean		**27.7**	**27.0**	**31.2**	**3.19**	**1.49**	**0.87**
	Branchnode 2 mean		**26.9**	**29.2**	**30.7**	**4.42**	**1.48**	**0.96**
DPL555 Mean			**27.4**	**27.6**	**31.2**	**3.54**	**1.48**	**0.90**
	Branchnode	ZONE	L(w) (mm)	L(w) CV (%)	UQL(w) (mm)	SFC(w) (%)	Skewness	Kurtosis
PM1218	1	1	24.9	25.0	27.9	3.47	1.84	2.14
PM1218	2	1	25.1	25.2	27.7	2.41	1.78	1.88
		ZONE 1 Mean	**24.9**	**25.1**	**27.9**	**2.94**	**1.80**	**1.95**
PM1218	1	2	26.2	24.4	29.0	2.30	1.62	1.26
PM1218	2	2	28.7	23.2	31.8	2.01	1.74	1.84
		ZONE 2 Mean	**27.2**	**23.9**	**48.3**	**2.17**	**1.50**	**0.82**
PM1218	1	3	27.7	23.9	30.7	2.15	1.67	1.48
PM1218	2	3	27.4	25.9	31.0	2.80	1.52	0.95
		ZONE 3 Mean	**27.4**	**24.5**	**30.7**	**2.37**	**1.59**	**1.21**
	Branchnode 1 mean		**26.2**	**24.4**	**29.2**	**2.58**	**1.65**	**1.38**
	Branchnode 2 mean		**26.9**	**24.5**	**30.2**	**2.33**	**1.47**	**0.75**
PM1218 Mean			**26.7**	**24.5**	**29.7**	**2.47**	**1.56**	**1.04**

Table 4. HVI /AFIS length and length uniformity relationship to yarn processing and strength*

	Spinning System											
	Rotor				Ring				Vortex			
Fiber Measurement Prediction Variable	R^2 Dependent Variable	Regression Model Stepwise Placement[!]	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement
Yarn Property	Ends Down		Statimat Strength		Ends Down		Statimat Strength		Ends Down		Statimat Strength	
HVI	0.49	3-Length	0.85	3-Uniform	N/A	N/A	0.88	4-Uniform	0.24	1-Uniform	0.79	3-Uniform
HVI Stdev	0.55	5-Length	0.85	3-Uniform	0.08	4-Length	0.85	4-Uniform	0.24	1-Uniform	0.79	3-Uniform
AFIS	0.27	2-Length	N/A	N/A	N/A	N/A	N/A	N/A	0.17	2-Length	N/A	N/A
AFIS Stdev	0.27	2-Length	N/A	N/A	N/A	N/A	0.62	6-Uniform	0.17	2-Length	N/A	N/A
AFIS/HVI	0.49	3-Length	0.89	6-Uniform	N/A	N/A	0.88	4-Uniform	0.24	1-Uniform	0.79	3-Uniform
AFIS/HVIStdev	0.59	6-Length	0.90	7-Uniform	0.19	9-Uniform	0.90	5-Uniform	0.24	1-Uniform	0.79	3-Uniform

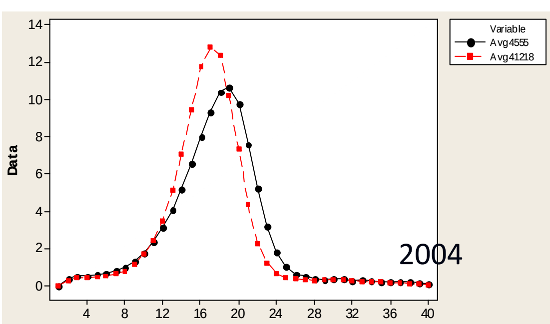
* R^2 is derived from the relationship of HVI/AFIS fiber properties to the spinning performance variables according to Foulk et al. (2007a). For each spinning method and spinning performance outcome, multiple linear regression models were fit using as predictors: (1.) the (mean) HVI fiber properties alone; (2.) the means and standard deviations of the HVI properties; (3.) the (mean) AFIS fiber properties alone; (4.) the means and standard deviations of the AFIS properties; (5.) the (mean) HVI and AFIS properties together; and, (6) the means and standard deviations of the HVI and AFIS properties together.

** The regression model stepwise placement number indicates the number of variables in the model that contains either a length (HVI mean length or AFIS upper quartile length) or a length uniformity (HVI length uniformity standard deviation and AFIS upper quartile length standard deviation) measurements contribution according to Foulk et al. (2007a).

Results and Discussion

The length of cotton fibers on individual seeds varies and it is commonly understood that cotton fiber length decreases along the seed from the chalazal (bottom) to the micropyle "top" (Lyengar, 1939; Krishnan and Lygengar. 1960). However, there appears to be little understanding of cotton fiber length distribution on and within plants. To examine the effects of plant ZONE and FP on the fiber length distribution, samples of cotton from each of three ZONES and two FP per zone were taken from plants of each of the two varieties for two seasons. Several AFIS length by weight summary histograms were generated for each combination of ZONE, FP, variety, and year (3 x 2 x 2 x 2 = 24 combinations) and were averaged to yield 24 length by weight distributions. Within each year and variety, length distributions were compared by FP (FP 1 and 2), within ZONE (ZONES 1, 2, and 3), and by ZONES (averaged across both FP). A Chi-square test based on a sample size of 3,000 fibers was used to test for differences between pairs of distributions. To test for differences, the 40 length categories of the AFIS histogram were collapsed into 18 length groups. The one-sixteen inch intervals were grouped by 4 for lengths 0 to 0.5 inch, by 2 for lengths 0.5 to 0.75 inch, by 1 for lengths 0.75 to 1.25 inch, by 2 for lengths 1.25 to 1.50 inch, and by 4 for lengths 1.50 to 2.50 inch. In addition, two-sample Kolmogorov-Smirnov tests for differences in the cumulative distributions were examined. Concurrently, skewness and kurtosis were determined for each combination to measure the asymmetry of the distribution and to evaluate measure of peakedness of a unimodal distribution.

These results demonstrate how variety and environment influence biological mean fiber length, not necessarily fiber lengths and fiber length distributions that will be encountered in commercial production channels. Nevertheless, both years had good rainfall distribution and nearly the same total rainfall by the end of August. Results of 24 pair-wise comparisons of length distributions are summarized in Table 1. Branch1 > Branch2 indicates the length distribution of Branch1 is significantly shifted (Chi-square test p-value < 0.10) to the right of Branch2, while Branch1 < Branch2 would mean Branch1 is shifted left of Branch2, and Branch1 = Branch2 signifies no significant difference. This corresponds with the evaluation of plant ZONES as well. Ramey (1999) demonstrated that drought during fiber development can shorten fiber length and reduce fiber uniformity. Lack of rain in July of 2005 caused water deficit stress during early reproductive growth. An early season drought can produce fibers with a greater maturity and higher micronaire in the lower plant zones (Bradow and Davidonis, 2000) as variations in fiber length are transformed by factors in the micro- and macroenvironment (Bradow et al., 1997a,b). Fiber length and coefficient of length variation are in Tables 2 and 3. Figure 1 visibly demonstrates length histogram shape differences between the two cotton varieties. Chi-square and Kolmogorov-Smirnov tests concur with visible inspection of the curves that the two cotton variety length distributions are statistically different (p=0.05). According to Chi-square tests these differences in 2004 occur around 1 inch and 1.3125 to 1.75 inches while in 2005 these differences occur from 0.9375 to 1 inch and from 1.5625 to 1.75 inches.



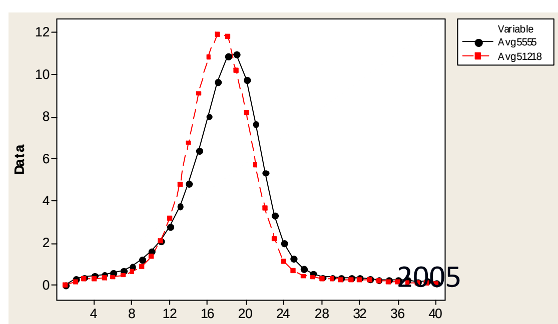
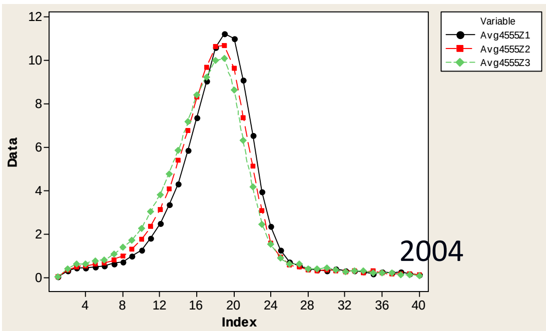


Figure 1. AFIS length histogram assessment for DPL555 and PM1218 cotton within both years (2004 and 2005).

For Variety DPL555, ZONE appears to have an important effect on the length distribution but the effect is not entirely consistent for both years (Table 1). For 2004, the length distribution of cotton from ZONE1 (both FP) is shifted to the right of that for ZONE2, while the reverse is true for year 2005 in which the plant was stressed due to water deficit in early reproductive growth. Figure 2 visibly demonstrates these length histogram shape differences between the three ZONES in DPL555. In both cases, the main differences are in the proportions of fibers of length 1.3125 to 1.5 inches with more in ZONE1 than ZONE2 in 2004 and fewer in ZONE1 than ZONE2 in 2005. For both years, the length distribution for cotton from ZONE2 is shifted right of that for ZONE3. For 2005, ZONE2 fiber has proportionally fewer short fibers in the range of 0.6875 to 0.875 inches than ZONE3 and more fibers in the range of 1.3125 to 1.75inches. Relative to ZONES 1 and 2, fiber from ZONE3 has proportionally more short fibers in the range from 0.5625 to 0.75 inches and fewer fibers in the range of 1.3125 to 1.75 inches. For variety DPL555, the effect of FP within each ZONE on the fiber length distribution depends on the year. The 2004 crop showed less difference between FPs within ZONES than did the 2005 cotton that was stressed due to water deficit in early reproductive growth. In almost every case, the Kolmogorov-Smirnov tests concurred with the Chi-square tests. However the Chi-square tests provide additional information about where length differences occur. Figure 6 demonstrates where Chi-Square found differences between ZONES in each year.



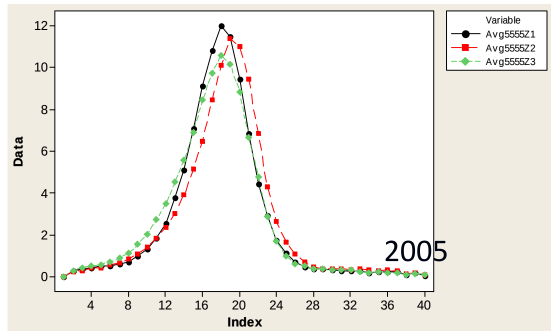
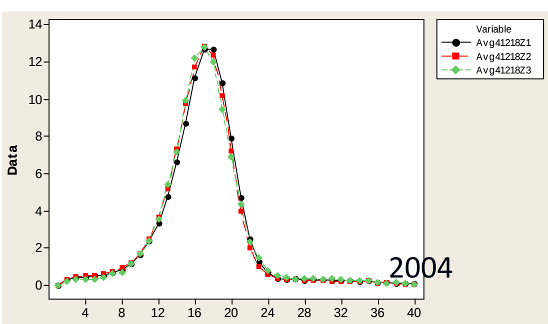


Figure 2. AFIS length histogram assessment for DPL555 between ZONES 1, 2, and 3 in 2004 and 2005.

For cotton variety PM1218, ZONE has much less effect on the fiber length distribution than for Variety DPL555. For year 2004, ZONE had no significant effect on the distribution of fiber lengths for PM1218. For the 2005 crop, the fiber length distribution for ZONE1 cotton was shifted left of that for ZONES 2 and 3 which did not differ. Figure 3 visibly demonstrates the minor length histogram shape differences between the three ZONES in PM1218. The proportion of fibers of length 1.25 to 1.5 inches was substantially less in ZONE1 relative to ZONES 2 and 3. Within ZONE1, the FP 1 length distribution is shifted left relative to that for FP 2 for the 2004 crop, but right for the 2005 crop. In ZONE2, the FP 1 distribution was shifted right of that for FP 2 in 2004 but left in 2005 with water deficit stress during early reproductive growth. Within ZONE3, the FP 1 distribution showed more long fibers than the FP distribution for the 2004 crop, but no difference in year 2005. Stapper et al. (2001) demonstrated that significantly longer fibers are produced on mainstem nodes 1-10 than mainstem nodes 11-16. There appears to be more inherent fiber length variability in variety DPL555 as demonstrated by wider base and gentle slope. The wider base is skewed towards shorter fibers so that variety DPL555 appears to contain more fibers that are shorter in length. Mean AFIS length values appear to be concealing this varietal difference. Figure 6 demonstrates where Chi-Square found differences between ZONES in each year.



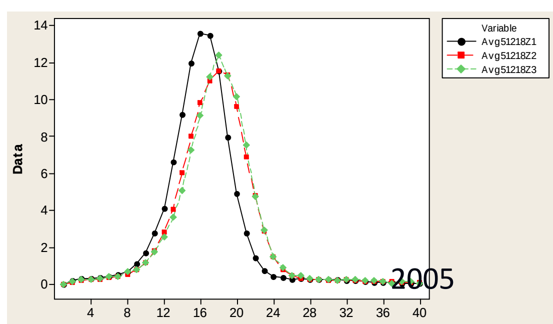


Figure 3. AFIS length histogram assessment for PM1218 between ZONES 1, 2, and 3 in 2004 and 2005.

Cotton bolls typically develop from the bottom to the top of the plant and from those bolls closest to the stalk and out. Within every ZONE at each plant branch node location the cotton boll develops and matures in a different micro-environment. Regarding plant ZONES on the plant, DPL555 appears to have more spread in fiber variability than PM1218. Bottom bolls in Zone1 appear to have less variability compared to Zone3 in DPL555. This agrees with work by Bradow et al. (1997) who demonstrated that changes in fiber quality along cotton plant branches and Davidonis et al. (2004) who demonstrated that fiber length was dependent upon boll position. PM1218 fiber length distributions vary very little among plant ZONES implying a more uniform fiber length throughout the plant. (Figure 4) Evaluating differences between the two varieties of cotton are more substantial than differences among

ZONES within each variety for the 2004 crop. While the DPL555 variety has more long fiber, it is also more variable. Differences between varieties are not as sharp for the 2005 cotton because of greater variation among ZONES in that year. However, when averaged across the three ZONES, there is a consistent difference between the two varieties for both 2004 and 2005.

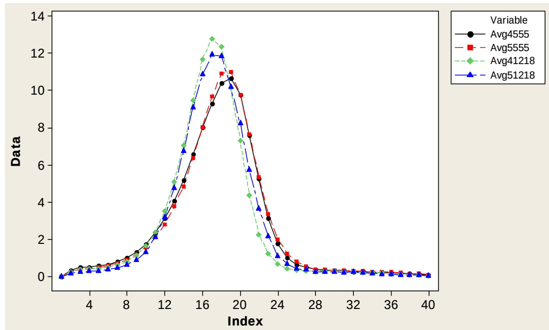


Figure 4. Overall AFIS length histograms for PM1218 and DPL555 across ZONES and FPs.

Fiber length is a top fiber quality measurement due to it relationship with yarn quality. Over FP each year, DPL555 had longer length by weight (27.3 and 27.1 mm) than PM1218 (26.2 and 26.3 mm) FP1 and FP2 respectively. For both years, variety DPL555 demonstrated a longer length and upper quartile length by weight basis as well as a higher short fiber content by weight than variety PM1218. Fiber length by weight was quite similar at all mainstem nodes in 2004 (Tables 2 and 3). In 2005 under water deficit stress, fiber length was lower for FP1 bolls in ZONE1 than for FP1 bolls in ZONES 2 and 3. Figure 7 demonstrates where Chi-Square found differences between each branch node in ZONES in each year. Lower fiber lengths are likely due to the environment during fiber development. Improved water management appears to be one possible method for reducing within canopy variability for fiber length, similar to what was proposed for reducing within canopy variability for micronaire (Bauer and Frederick, 2005).

Cotton variety DPL555 simultaneously demonstrated a lower skewness than variety PM1218 (Tables 2 and 3). For cotton fiber length unimodal distribution, a positive skewness indicates the distribution is right skewed (equal mean lengths and higher skewness leads to longer fibers). Kurtosis values for variety DPL555 were lower than variety PM1218 and distributions with high kurtosis tend to have a distinct sharp peak near the mean and decline rather rapidly (higher concentration of fibers within uniform length with slight length variability). In 2004 cotton variety DPL555 skewness and kurtosis values decreased from ZONE1 through ZONE3 while variety PM1218 demonstrated very little differences between zones. In evaluating FP in 2004 the kurtosis and skewness values for FP 1 are consistently lower than FP 2 for both cotton variety DPL555 and PM1218. Water stress caused by a deficiency of water reduces many plant functions with skewness and kurtosis values again demonstrating that skewness decreases from ZONE1 through ZONE3 for cotton variety DPL555. Water stress tends to produce different skewness and kurtosis trends within cotton variety PM1218 so that the highest values are found in ZONE1 followed by either ZONE2 or ZONE3**.** It is possible to determine statistical differences between means and variances but becomes more difficult with skewness and kurtosis values because one does not know their statistical distribution. To determine equality in kurtosis and/or skewness the distributions are standardized and the Kolmogorov-Smirnov two-sample test is used as a non-parametric test to locate differences in skewness and kurtosis between two sample distributions (Tang, 1996). Figure 5 demonstrates how the fiber length skewness and kurtosis values decrease from the bottom of the plant to the top.

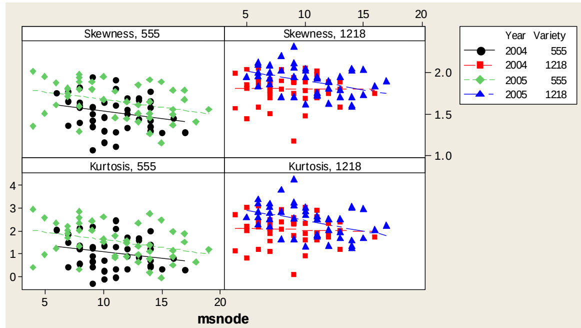


Figure 5. Kurtosis and skewness vs. mainstem node

Different spinning systems must be addressed to determine whether cotton fiber length or uniformity measurements contribute more to spinning performance. Foulk et al. (2007) demonstrates that length, as measured by HVI and AFIS, contributes more to rotor spinning ends down while length uniformity contributes more to rotor yarn strength (Table 4). This table further indicates that ring spinning performance as measured by ends down is not affected significantly by length; however, length uniformity does appear to contribute to yarn strength. Table 4 further indicates that length and length uniformity play a minor roll in vortex spinning ends down while length uniformity plays a major role in vortex yarn strength. When classic measurements of length and length uniformity are evaluated length progresses in importance for rotor spinning ends down and is included with fewer variables in the model (Table 5). Both length and uniformity contribute to rotor yarn Statimat strength, while ring spinning ends down remains marginally affected by length and length uniformity. Length significantly affects ring yarn strength, while, vortex yarn ends down is marginally affected by length and length uniformity. Vortex yarn strength is mostly affected by length and length uniformity. It has been stated that key properties for the three spinning systems are as follows: length, strength, fineness, and friction (ring-spinning); strength, fineness, length, cleanliness, friction (rotor-spinning); and length, fineness, strength, friction, cleanliness (vortex-spinning) (Deussen, 1993). There does appear to be a difference in length distribution between cotton varieties and years (Figures 1-4) with these length distributions likely related to spinning and yarn properties. Previous research has demonstrated the importance of fiber length and uniformity on ends down during processing and Statimat yarn strength (Tables 5 and 6). Foulk et al. (2007a) examined the relationship of HVI™ and AFIS fiber properties to yarn properties using SAS regression models limited to no more than 10 different variables. For each spinning method and spinning performance outcome, multiple linear regression models were fit using as predictors the means and standard deviations of the HVI™ and AFIS properties. Related to AFIS length histogram data Foulk et al. (2007a) demonstrated that rotor yarn strength is dependent upon HVI™ length, length uniformity, and the standard deviation of these values along with AFIS SFC and SFC standard deviation. Foulk et al. (2007a) demonstrated that ring yarn strength is dependent upon HVI™ length uniformity, length uniformity standard deviation along with SFC, SFC standard deviation, and UQL standard deviation. Foulk et al. (2007a) demonstrated that vortex yarn strength is dependent upon HVI™ length, length uniformity, length uniformity standard deviation, SFC, SFC standard deviation, and UQL. HVI™ and AFIS length values and their standard deviations are likely related to length distribution differences measured by skewness, kurtosis, Chi-Square, and Kolmogorov-Smirnov tests performed in this study.

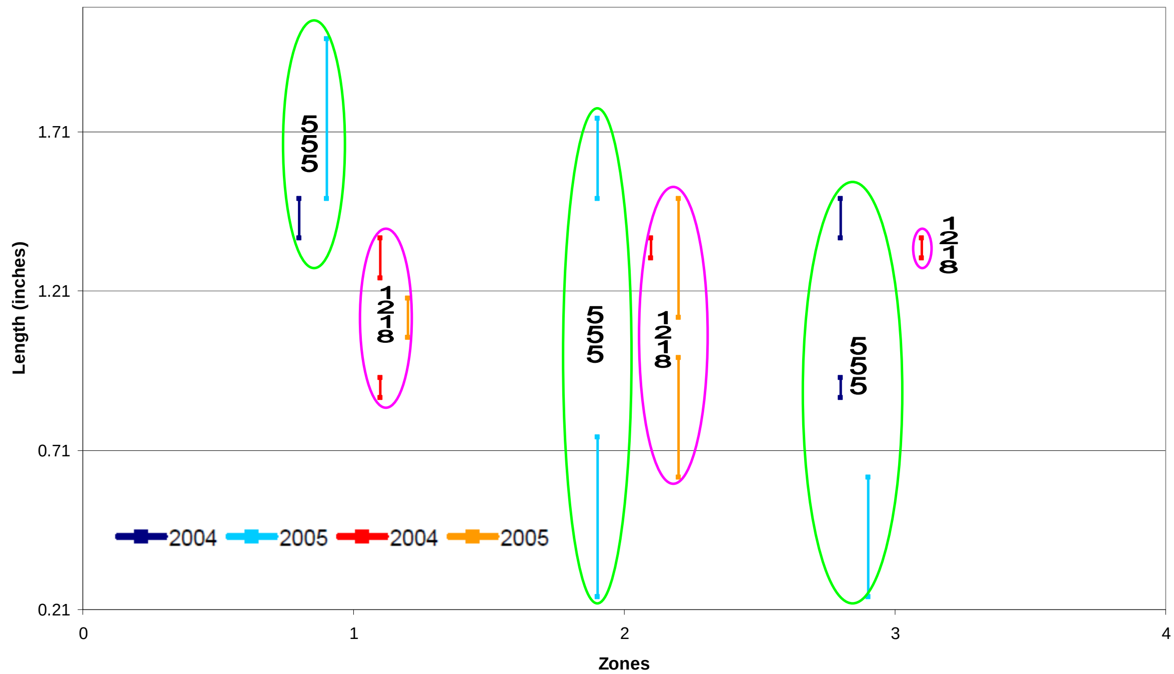


Figure 6. Areas in the range of fiber length histograms where Chi-Square differences occur between Branch node 1 & Branch node 2 in ZONES 1, 2, and 3.

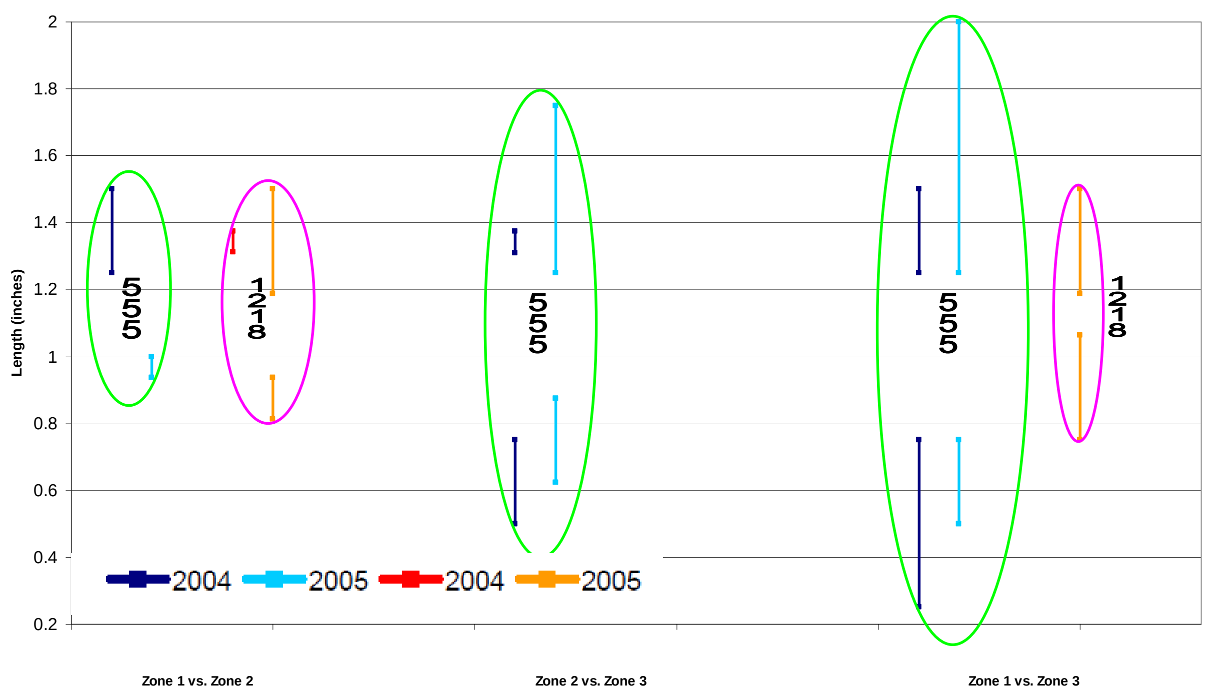


Figure 7. Areas in the range of fiber length histograms where Chi-Square differences occur between Zones across both branch nodes.

Table 5. Classic/supplementary measurement relationships linking length and length uniformity to yarn processing and strength.

	Spinning System Rotor				Ring				Vortex			
Fiber Measurement Prediction Variable*	R^2 Dependent Variable	Regression Model Stepwise Placement!	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement	R^2 Dependent Variable	Model Stepwise Placement	R^2 Dependent Variable	Regression Model Stepwise Placement
Yarn Property	Ends Down		Statimat Strength		Ends Down		Statimat Strength		Ends Down		Statimat Strength	
Classic	0.70	2-Length	0.85	4-Length	0.38	3-Length	0.84	2-Length	0.49	4-Length	0.81	4-Length
Classic Stdev	0.76	3-Length	0.84	6-Length	0.26	2-Length	0.86	2-Length	N/A	N/A	0.78	4-Uniform
Classic HVI	0.70	2-Length	0.92	7-Length	0.38	3-Length	0.84	2-Length	0.49	4-Length	0.83	4-Uniform
Classic HVI Stdev	0.76	3-Length	N/A	N/A	0.26	2-Length	0.86	2-Length	0.32	3-Length	0.74	2-Uniform
Classic AFIS	0.70	2-Length	0.86	3-Uniform	0.38	3-Length	0.84	2-Length	0.49	4-Length	0.81	4-Length
Classic AFIS Stdev	0.76	3-Length	0.90	6-Uniform	0.26	2-Uniform	0.86	2-Length	0.39	7-Uniform	0.83	5-Uniform
Classic/AFIS HVI	0.70	2-Length	0.86	3-Uniform	0.38	3-Length	0.84	2-Length	0.49	4-Length	0.83	4-Uniform
Classic/AFIS HVI Stdev	0.76	3-Length	N/A	N/A	0.26	2-Uniform	0.86	2-Length	0.32	3-Length	0.74	2-Uniform

* R^2 is derived from the relationship of Classic/supplementary fiber properties to the spinning performance variables according to Foulk et al. (2007b). For each spinning method and spinning performance outcome, multiple linear regression models are fit using as predictors: (1.) the (mean) HVI fiber properties alone; (2.) the means and standard deviations of the HVI properties; (3.) the (mean) AFIS fiber properties alone; (4.) the means and standard deviations of the AFIS properties; (5.) the (mean) HVI and AFIS properties together; and, (6) the means and standard deviations of the HVI and AFIS properties together.

** The regression model stepwise placement number indicates the number of variables in the model that contains either a length (Peyer mean length, Suter Webb array mean length, Suter Webb array upper quartile length) or a length uniformity (HVI length standard deviation, Suter Webb array coefficient of variation, Peyer coefficient of variation, Suter Webb array mean length standard deviation, HVI uniformity) measurements contribution according to Foulk et al. (2007b)

Conclusions

Textile mills prefer to have cotton with fibers more uniform in length demonstrated by histograms that have a steeper slope and narrower base. For two commercial varieties of cotton each grown in two years, the effect of location of the boll on the distribution of fiber length was examined in terms of ZONE and FP. In this study it appears that in terms of cotton fiber length distributions variability is most likely due to variety followed by the plant ZONE and finally FP position. For one variety, DPL555, ZONE has an important effect on fiber length distribution. For this variety, ZONE 3 cotton showed more short fiber than that from ZONES 1 or 2 in both years. The effect of FP was less clear. For the 2004 crop, the FP 1 distribution showed more long fibers than that of FP 2 within ZONE 3, but no difference between FP within ZONES 1 and 2 and fewer long fibers within ZONE3. Results for year 2005 were also inconsistent with the FP 1 distribution shifted left of that for FP 2 within ZONE 1 but right within ZONES 2 and 3. For variety PM1218 cotton, ZONE appeared to have little effect on the fiber length distribution of the 2004 crop. In 2005, the fiber length distribution of cotton from ZONE 1 had fewer fibers in the range 1.25 to 1.5 inches relative to ZONES 2 and 3. Differences between FP within ZONES are significant but not consistent across the two years. Variety DPL555 cotton is variable in fiber length. Cotton variety DPL555 has previously demonstrated spinning problems, with these results indicating that this could be attributed to this difference in the distribution of fibers, lower skewness, lower kurtosis, the higher length by weight CV (more variability), and the slightly higher SFC. Variation in fiber length distributions among ZONES, more strongly evident in DPL555 than in PM1218, may explain some of the additional variation. Variety DPL555 has a lower kurtosis and lower positive skewness than variety PM1218 at both FP. There does not appear to be a difference between the two FP within a cultivar. Further research will continue to statistically evaluate histogram distribution shapes in the cotton plant, Zones, cotton boll position, and cotton varieties.

Acknowledgements

Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the USDA and does not imply approval of a product to the exclusion of others that may be suitable.

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