HAND-GINNED COTTON LENGTH DISTRIBUTIONS

Jonn Foulk,
USDA-ARS Cotton Quality Research Station
Clemson, SC
P. Bauer
USDA-ARS Coastal Plains Soil, Water, and Plant Research Center,
Florence, SC
H. Senter,
Mathematical Science Clemson University
Clemson, SC

Abstract

Instrumentation such as the Advanced Fiber Information System (AFIS™) analyzes cotton (*Gossypium hirsutum* L.) fiber length distributions because variations in fiber length distribution impacts spinning performance. AFIS provides mean length, upper quartile length, fineness, and maturity for fibers tested. However, the goal was to evaluate the entire fiber length distribution so distributions were evaluated visually. Slope angle and histograms base distance comparisons were used to evaluate AFIS fiber length distributions among two cultivars. Two commercial cultivars [DPL 555 (mid-full maturity) and PM 1218 (early maturity)] were grown in plots on a Goldsboro loamy sand in 2004 and 2005. Fiber properties were determined on first and second branch position bolls on reproductive branches in a 1-m section of row in each plot. Due to different weather patterns the results were separated into 2004 and 2005. The objective was to evaluate differences in the shape of histograms between cotton plant zones, cotton boll position, and cotton variety.

Introduction

Cotton (Gossypium hirsutum L.) is a plant fiber crop that has a long history of being utilized in clothing by the textile apparel industry due to their comfort level. Competition from synthetic fibers has 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. Nevertheless, mill modernization and foreign customer requirements necessitate the need for improved fiber properties. International cotton fiber purchase contracts typically average ~28 g/tex, with a length ~1.1 inch, and micronaire between 3.8 and 4.6 (M. Watson, personal communication). Each year many different upland cotton varieties are marketed to producers. These varieties are 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. Stronger, longer, finer, and more uniform cotton fibers are desired for modern textile industries.

The USDA Agricultural Marketing Service provides average cotton fiber quality measurements on every bale grown in the US using High Volume Instrumentation (HVI™). Most agronomic research on assessing and improving fiber quality has focused on improving these average fiber quality measures. Less attention has been paid to understanding cotton 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. Earlier research showed 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.

In order to meet the needs of spinning, knitting, and weaving, cotton fiber properties must continually improve to remain competitive with synthetic fibers and in foreign markets. 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 shape of hand-ginned (best inherent representation of fiber length) histograms between cotton plant zones, cotton boll position, and cotton variety.

Materials and Methods

Cotton

A mid-full season maturity cultivar (DPL 555 BG/RR) was compared to an early maturing cultivar (PM 1218 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. Precipitation was measured with a weather station at the Center that was approximately 500 m from the experiment.

Cotton was planted on 11 May 2004 and on 10 May 2005. Plots were over-seeded and hand-thinned to approximately eight plants per m of row. Before planting, soil samples were collected each year and P, K, secondary nutrients, and lime applied as recommended by Clemson University Extension. A 45 kg N ha^{-1} sidedress application of NH_4NO_3 was made at planting and at about 4 weeks after planting each year (total of 90 kg N ha^{-1}). Weeds were controlled with a combination of herbicides and hand-weeding. Insect pests were scouted regularly and insecticides applied as needed.

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, branch node position, and flowering date (when dated tag was present) were recorded for each boll. Bolls were weighed and then fiber was hand-separated from the seeds. Bolls evaluated in this study were harvested at several times during each 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. Delta Pineland 555 Cross Tabulation of Zone by Branch Node for 2004

Zone	Branch Node 1	Branch Node 2	Total Bolls
1	6	4	10
2	11	10	21
3	10	3	13
Total Bolls	27	17	44

Table 2. Paymaster Cross Tabulation of Zone by Branch Node for 2004

Zone	Branch Node 1	Branch Node 2	Total Bolls
1	12	10	22
2	17	3	20
3	3	1	4
Total Bolls	32	14	46

Table 3. Delta Pineland 555 Cross Tabulation of Zone by Branch Node for 2005

Zone	Branch Node 1	Branch Node 2	Total Bolls
1	11	4	15
2	9	2	11
3	13	6	19
Total Bolls	33	12	45

Table 4. Paymaster 1218 Cross Tabulation of Zone by Branch Node for 2005

Zone	Branch Node 1	Branch Node 2	Total Bolls
1	7	8	15
2	10	8	18
3	8	4	12
Total Bolls	25	20	45

Results and Discussion

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. Both years had good rainfall distribution and nearly the same total rainfall by the end of August (Figure 1). However, lack of rain in July of 2005 caused water deficit stress during early reproductive growth. Similar rainfall between years resulted in HVI properties that were not significantly different. Over branch nodes each year, DPL 555 had longer length by weight (27.5 and 27.4 mm) than PM 1218 (26.4 and 26.0 mm) FP1 and FP2 respectively. The difference between the cultivars for fiber length by weight tended to be the same across all mainstem branch nodes (Figure 2). Fiber length by weight was quite similar at all mainstem nodes in 2004. In 2005 under water deficit stress, fiber length was lower for FP1 bolls in zone 1 than for FP1 bolls in zones 2 and 3. 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).

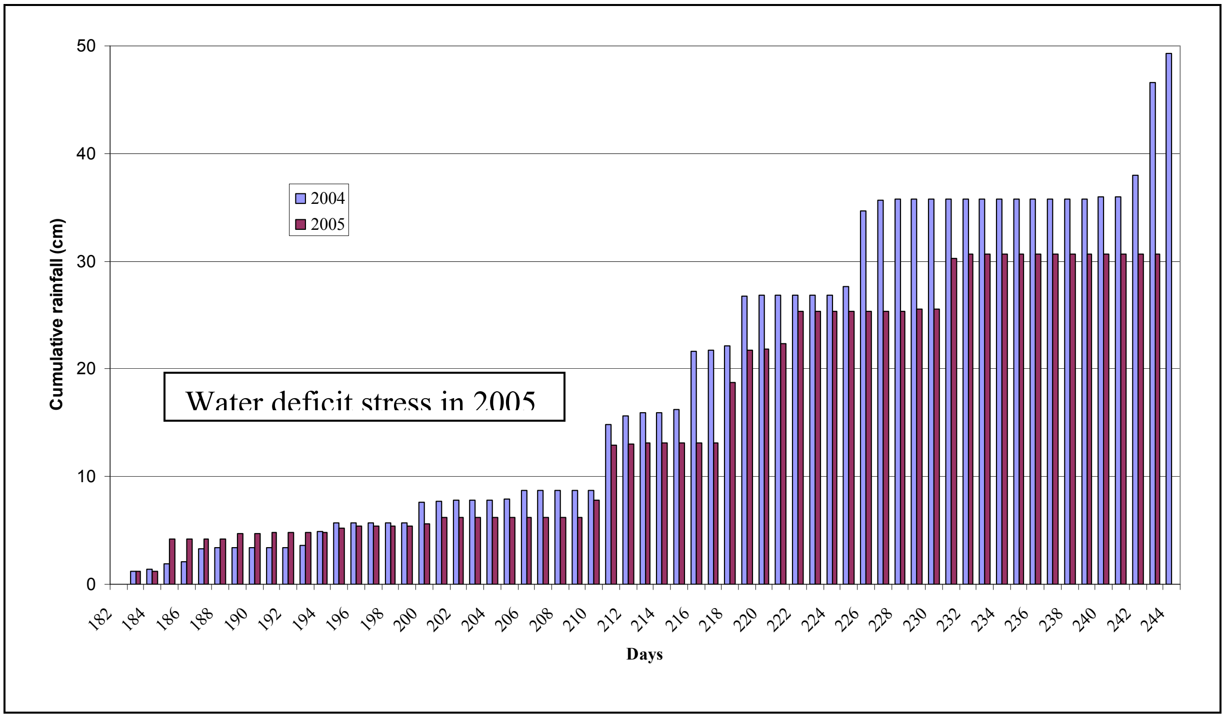

Figure 1. Cumulative rainfall from flowering (early-July) through August 2004 and 2005.

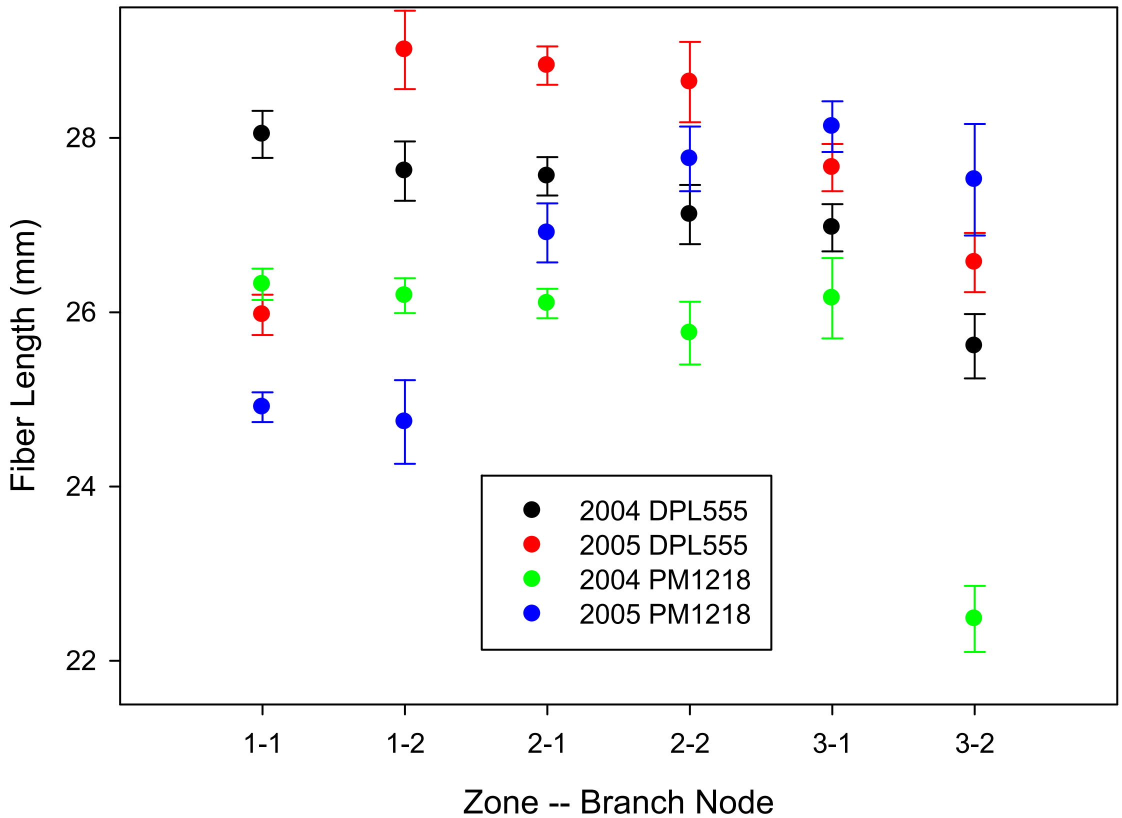

Figure 2. Within canopy distribution of cotton fiber length of first and second branch nodes in 2004 and 2005 over both cultivars.

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). HVI length measurements did not appear to differ between years or variety but there does appear to be a difference in length distribution between cotton varieties and years (Figures 3-8). There appears to be little understanding in how this fiber length distribution affects spinning (Gardunia et al., 2008).

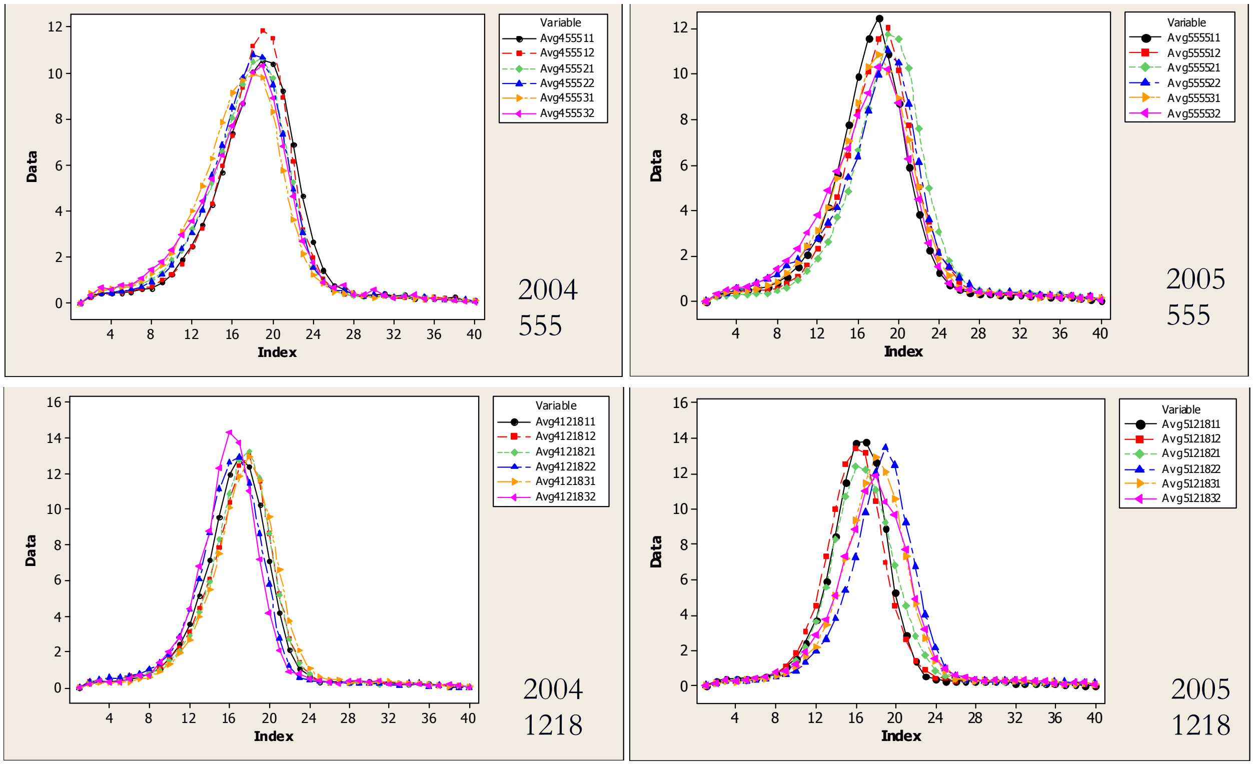

Figure 3. Histogram means across zones & branch nodes.

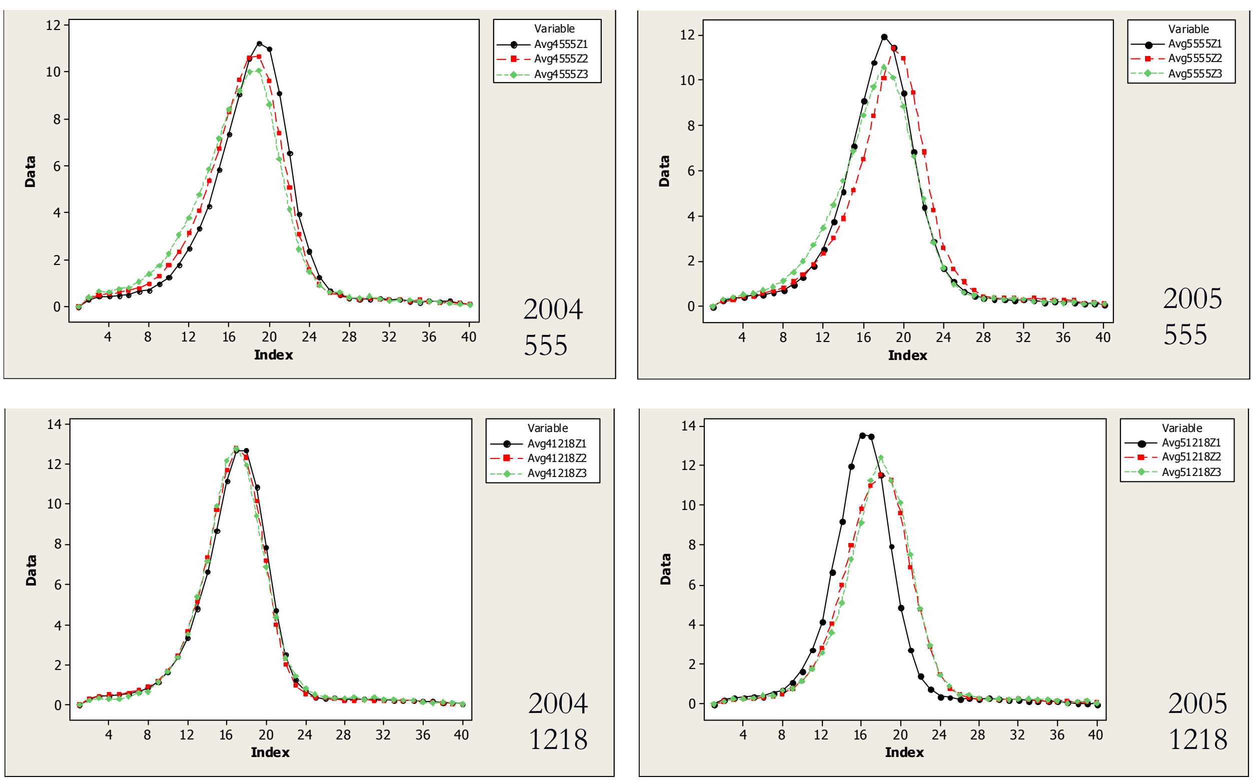

Figure 4. Histogram means across branch nodes 1 and 2

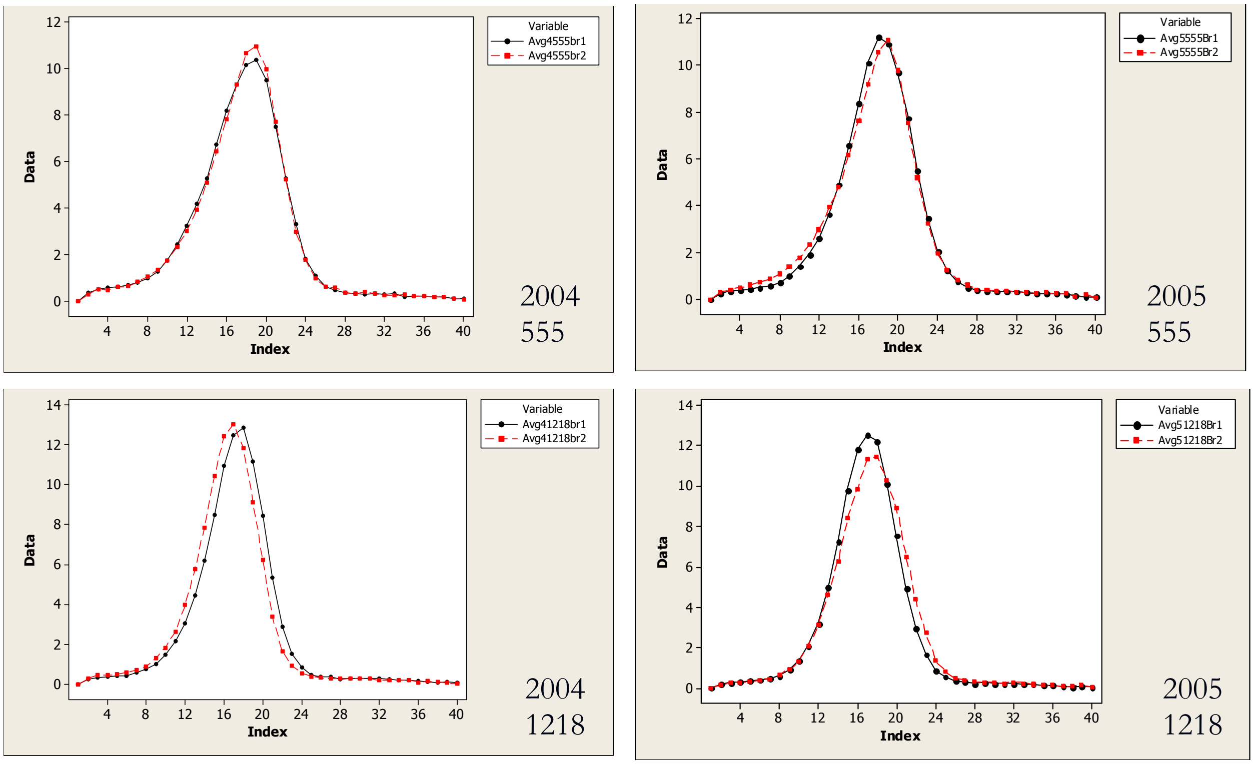

Figure 5. Histogram means across zones 1, 2, and 3.

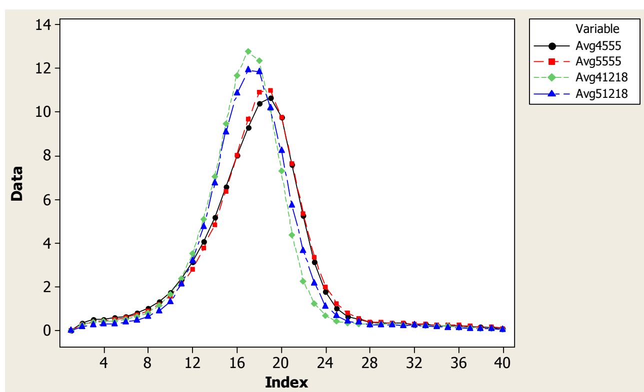

Figure 6. Overall histogram means across zones and branch nodes.

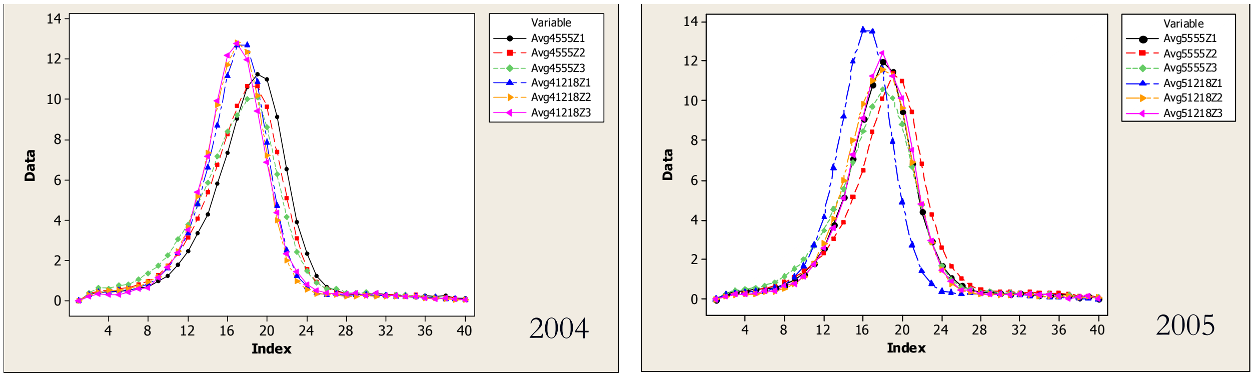

Figure 7. Histogram means of variety 555 vs. 1218 zones 1, 2, and 3 across branch nodes 1 and 2.

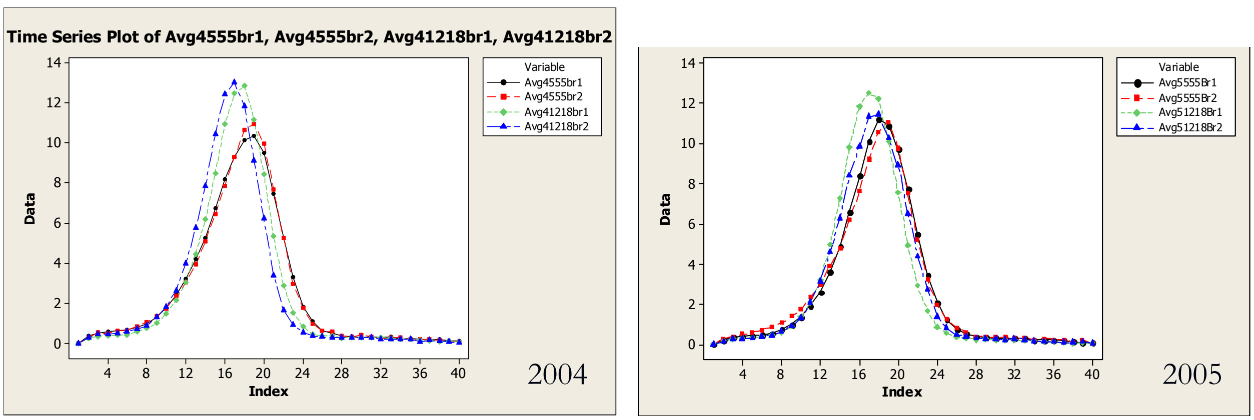

Figure 8. Histogram means across variety 555 vs. 1218 Branch nodes 1 and 2 across zones 1, 2, and 3.

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 branch node position. The cotton variety appears to greatly affect fiber length distributions demonstrated by Figures 3-8 that demonstrate steeper slopes (~5% greater) for cotton variety PM1218. This same PM1218 cotton variety also demonstrates a narrow base approximately 14% smaller (Figure 5). 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. Textile mills prefer to have cotton with fibers more uniform in length demonstrated by histograms that have a steeper slope and narrower base. In order to generate a uniform cotton crop it does not appear to be related to the branch node position as demonstrated by very similar branch node position fiber length distributions (Figures 3 and 5). Drought does not appear to affect fiber length distributions visually demonstrated by minimal distribution differences between years (Figures 3-8). Regarding plant zones on the plant, DPL555 appears to have more spread in fiber variability than PM1218 (Figure 4). Bottom bolls in zone 1 appear to have less variability compared to zone 3 in DPL555. PM1218 fiber length distributions vary very little among plant zones implying a more uniform fiber length throughout the plant. Further research will continue to statistically evaluate histogram distribution shapes in the cotton plant, zones, cotton boll position, and cotton varieties.

References

Balls, W.L. 1928. Studies of quality in cotton. MacMillan & Co., London.

Bauer, P.J. and J.R. Frederick. 2005. Tillage effects on canopy position specific cotton fiber properties on two soils. Crop Sci. 45:698–703.

Bauer, P.J., J.R. Frederick, J.M. Bradow, E.J. Sadler, and D.E. Evans. 2000. Canopy photosynthesis and fiber properties of normal- and late-planted cotton. Agron. J. 92(3):518-523.

Bednarz, C.W., R.L. Nichols, and S.M. Brown. 2006. Plant density modifies within-canopy cotton fiber quality. Crop Sci. 46:950-956.

Bennett, O.L. 1967. Boll, fiber, and spinning properties of cotton as affected by management practices. USDA Agricultural Research Service Technical Bulletin No. 1372. Washington, D.C.

Bradow, J.M., R.M. Johnson, P.J. Bauer, G.F. Sassenrath-Cole, and R.M. Johnson. 1999. Pre-harvest spatial and temporal variability in short-fiber content in relation to processing success. p. 716-718. In P. Dugger and D. Richter (ed.) Proc. Beltwide Cotton Conf. Orlando, FL. 3-7 Jan. 1999. Natl. Cotton Council, Memphis, TN.

Davidonis, G.H., A.S. Johnson, J.A. Landivar, and C.J. Fernandez. 2004. Cotton fiber quality is related to boll location and planting date. Agron. J. 96:42-47.

Deussen, H. 1993. Rotor Spinning Technology. Schlafhorst Inc. Charlotte, NC. 128 pp.

Gardunia, B., Braden, C., Hequet, E., and Smith, W. 2008. Applying quantile regression to analysis of AFIS cotton fiber distribution. Crop Sci. 48(4), 1328-1336.

International Cotton Advisory Committee. 2001. Impact of ginning on fiber quality: The best ginning practices [Online]. Available at http://alida-algodon.org/tis/misc/expert_panel_ginning_methods_sept01.pdf (accessed December 2008; verified 17 Dec. 2008). ICAC, Washington, DC.

Meredith, W.R. Jr. and R.R. Bridge. 1973. Yield, yield component and fiber property variation of cotton (*Gossypium hirustum* L.) within and among environments. Crop Sci.13:307-312.