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EFFECTS OF LOCATION ON DISTRIBUTIONS OF FIBER QUALITY

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Abstract

A group of modern commercial cottons were selected to be grown, harvested, and processed to test their suitability for high performance spinning. A total of twenty-one lots were studied comprising cottons grown in one of three locations in either Georgia, Mississippi, or Texas. Results reported here emphasized the maturity of these cottons and compared several different methods of measuring maturity. Two of the cultivars, Fibermax-832 and -966, were grown in all three locations during the 2000 season. While studying the utility of different fiber property measurements in determining suitability for spinning, we emphasized how the average values of fiber maturity, as well as their distributions, varied with growing location. Instrumentation utilized here to measure average micronaire, fineness, and maturity included the HVI, AFIS, and Micromat F/MT. Image analysis of microscopic fiber cross-sections was utilized to determine the average values and distributions of fiber wall area, perimeter, and degree of thickening (θ).

Introduction

This work comprises a study of the suitability of a group of modern cottons for high performance spinning. In recent years we have seen great advances in textile processing operations. One of these is in spinning where increases in rotary speeds of open end systems and the introduction of vortex spinning systems have yielded significant increases in spinning productivity for cotton processing. These new technologies put additional stresses on cotton and different requirements that have not as yet been quantified in terms of the optimum fiber properties for the cotton to be suitable for these systems (Felker, 2001). To better understand the relationships between spinning performance and fiber properties it is essential that we monitor all significant fiber properties using the best methods available. The present study centers on the maturity or degree of cell wall development of the fibers we are investigating. In particular, our objectives were to: a) determine the absolute maturity of the cottons using the image analysis of thin cross-sections; b) study the effects of growing location on the fineness and maturity of two Fibermax varieties (FM 832 and FM 966); c) compare results of fineness and maturity measurements by image analysis with FMT and AFIS; and d) study the effects of growing location on the distribution of fineness and maturity as measured by image analysis.

Materials and Methods

Candidate cottons were selected based upon results of annual national cotton variety tests. Three growing locations were chosen –Texas, Georgia, and Mississippi. There were twenty-one lots of cotton each grown in quantities of approximately one module per lot. There were eight cottons grown in Texas including: Paymaster (PM) -2200, -2326, and -2800 and Fibermax (FM) –819, -832, -958, -966, and –989. Six cottons were grown in Georgia including: Deltapine (DPL) – 491 and – DP(Delta Pearl); Fibermax (FM)-832 and –966; Phytogen (PHY) –355; and Suregrow (SG)-747. Seven cottons were grown in Mississippi: Deltapine (DPL) – 491 and – DP(Delta Pearl); Fibermax (FM)-832 and –966; Phytogen (PHY) –355; Suregrow (SG)-747; and Paymaster (PM)-1218. Please note that we have included all pertinent abbreviations that will be used in the remainder of this paper as capitalized and enclosed in parentheses.

The principal experimental procedures carried out in this study comprised the image analysis of cross-sections of cotton fiber, the Micromat Fineness/Maturity Tester (F/MT), and three different versions of the Advanced Fiber Instrumentation System (AFIS). For the image analysis method, bundles of parallel cotton fibers are formed and embedded in a pre-polymer. After the bundle is polymerized, it is cut into cross-sections so that thin (~1 μm thick) sections may be mounted on microscope slides and image analyzed. Details of this procedure are found in Thibodeaux, et al. (2001). Results for the parameters directly measured by image analysis can be understood by considering Figure 1. Here is a typical fiber cross-section showing the perimeter (P), area of the cellulose wall (A_C), and area of the inner lumen (A_L). Given that the fundamental fiber cross-sectional properties are available, some very useful parameters can be calculated (Thibodeaux, et al. 1999) including:

the fiber degree of thickening or circularity referred to as theta (θ) defined by

$$\theta = 4 \pi A_C / P^2 \tag{1}$$

and the maturity ratio (M) given by

$$M = \theta / 0.577 \tag{2}$$

An upgraded and recalibrated Micromat Fineness/Maturity Tester (F/MT) was used to determine fiber maturity ratio, fineness, and Micronaire (Von Hoven, et al., 2001 and Von Hoven, et al., 2002). Maturity data is also reported from three different models of AFIS – the AFIS V.2 and AFIS V.4 located at SRRC (New Orleans) and the AFIS V.5 at CQRS (Clemson).

Results and Discussion

The first part of the study centers on average values of maturity for all twenty-one cottons. Results for fiber fineness and maturity of the eight cottons grown in Texas are shown in Table I. Here we include values from image analysis of the fiber cross-sections including for average fiber perimeter P(IA), wall area A(IA), and maturity ratio M(IA) calculated from Equation 2. Table I also gives values from the Micromat average values of micronaire Mic(F/MT), and maturity ratio M(F/MT). Notice the rather low average micronaire (3.21) with a minimum of about 2.8 for FM-832. In general, the average fiber maturity by image analysis is rather low [M(IA) = 0.8] and by Micromat is very low [M(F/MT) = 0.68]. The average fiber perimeter is rather low [P(IA) = 52.19 μm] with a low standard deviation [STD = 1.66 μm]. Fineness and maturity data for the six cottons grown in Georgia are given in Table II. Notice that the average micronaire (4.34) is higher than for the cottons grown in Texas. It follows that the average maturity by image analysis is also higher [M(IA) = 0.92] and that once again M(F/MT) = 0.8 is higher than for Texas but tracks lower than for image analysis. The average for the perimeters of the cottons grown in Georgia is about 1.5 μm higher than for the Texas cottons. Likewise, the average fiber wall area indicated by A(IA) is significantly higher than for the cottons from Texas. Data from the seven Mississippi cottons are shown in Table III. The average micronaire (4.55) is somewhat higher and the range of micronaires (3.89 - 5.57) is also larger. The average maturity values as measured by image analysis [M(IA) = 0.99] and the Micromat [M(F/MT) = 0.84] are somewhat larger than the corresponding averages for the Georgia grown cottons and are significantly larger than for those from Texas. There is no difference in average fiber perimeters between Mississippi and Georgia, but A(IA) of the Mississippi cottons are significantly larger than for the Georgia cottons which is consistent with the rise in M(IA).

In Table IV we have summarized the values of M(IA) and M(F/MT), and of the three versions of AFIS [M(V.2), M(V.4), and M(V.5)] for the eight cottons grown in Texas. The average values for M(IA), M(V.4), and M(V.5) appear to be at the same level while, M(F/MT) and M(V.2) are at somewhat lower average values. It is interesting that the standard deviation of the M(IA) values is a higher than the corresponding values for the other four other values. This may be a result of the fact that the image analysis sample consists of a few hundred fibers whereas the F/MT is based on 4 g and AFIS measures 25,000 fibers (~0.1 g). Tables V and VI reflect similar results for the six Georgia cottons and seven Mississippi cottons, respectively. As was the case for Table IV, the average values for M(IA), M(V.4), and M(V.5) appear to be at the same levels while, M(F/MT) and M(V.2) are at somewhat lower average values. Unlike the results from Table IV, all the standard deviations reported in Tables V and VI are similar.

Results for the correlation analyses of the maturity ratios from image analysis [M(IA)] and Micromat [M(F/MT)] with AFIS maturity ratios [M(V.2), M(V.4), and M(V.5)] from all twenty-one cotton lots, i.e. we pooled the results from the cottons grown in Texas, Georgia, and Mississippi, are given in Table VII. These include coefficients of determination (R^2) and the slopes and intercepts for the linear correlation curves for all seven relationships indicated. Considering the relations to M(IA), the highest R^2- value occurs with respect to the Micromat, M(F/MT) with R^2 = 0.741. When relating M(IA) to the corresponding maturity values measured with the three versions of AFIS, the values of R^2 decrease, the slopes decrease, and the values of the intercepts increase. In the case of M(F/MT), its relationship to M(V.2) appears to be better than to M(V.4) or M(V.5) since the R^2 between M(F/MT) and M(V.2) is relatively good (0.714) but its slope is a good deal higher and intercept is quite a bit lower than for those from M(V.4) or M(V.5).

The second part of the study deals with the two Fibermax cottons grown in all three states and how the distribution of their maturity values changes with growing location. Distributions of the degree of thickening (theta) values for cotton cross-sections from FM-832 grown in Texas, Mississippi, and Georgia are shown in Figure 2. The mean values for theta from each location are included in the legend in parentheses. Although theta for Georgia FM-832 is significantly higher than for Texas FM-832, the content of very immature cotton (theta < 0.2) for the two is about the same. The larger average value for Georgia FM-832 is due to its significantly larger content of very mature fibers (theta > 0.6). The maturity of Mississippi FM-832 is quite high with only trace amounts of very immature cotton, almost half being very mature.

Results for the distributions of theta for the FM-966 grown in Texas, Mississippi, and Georgia are shown in Figure 3. We see here that the overall shapes of the theta distributions are similar for the FM-832 cottons and that, as was the case for FM-832, theta from Mississippi is higher than from Georgia, which is higher than FM-832 grown in Texas. Unlike FM-832, however, the theta distributions for the Mississippi and Georgia cottons are much closer together than the distribution for the FM-832 grown in Texas.

Distributions of the values of perimeter for cotton cross-sections from FM-832 grown in Texas, Mississippi, and Georgia are shown in Figure 4. The mean values for the perimeter from each location are included in the legend in parentheses. Although the mean value for the perimeter of the FM-832 Texas cotton (52.5 µm) is slightly higher than the perimeters for the corresponding Georgia and Mississippi cottons (50.5 and 50.6 µm, respectively), all three distributions are rather narrow and practically overlap. This substantiates the long-held opinion that fiber perimeter is essentially a genetic property that is little affected by growing location.

These findings are even more firmly demonstrated by the distributions for perimeter for FM-966 grown in the three states as shown in Figure 5. The mean values here are closer together and a little higher than for FM-832. Notice that the distributions are in even closer agreement for the three growing locations of the FM-966.

Distributions of the values of wall area for individual cotton cross-sections of FM-832 grown in Texas, Mississippi, and Georgia are given in Figure 6. The mean values for the fiber wall area (with the units of μm^2) from each location are included in the legend in parentheses. The overall shape of the distribution curves from Mississippi and Georgia are quite similar but, in line with the differences in average area for Mississippi (119.1 μm^2) as opposed to Georgia (107.4 μm^2), the Mississippi distribution is shifted the right. Although the mean value for the wall area of the FM-832 Texas cotton (96.6 μm^2) is somewhat lower than for the areas of the corresponding Georgia and Mississippi cottons, its fine fraction (< 50 μm^2) is quite similar to the Georgia-grown cotton.

Similar distributions for the wall areas for FM-966 cotton grown in Texas, Mississippi, and Georgia are shown in Figure 7. Again, the average area for Mississippi-grown (136.0 μm^2) is larger than for Georgia-grown (122.3 μm^2) which is likewise larger than for Texas (107.8 μm^2). These averages for wall area are correspondingly larger than for the FM-832 cottons grown at the same locations. One final point of note is that the average theta values for the two cottons are essentially the same grown at each of the three locations. This is a result of the fact that, even though the wall areas of the FM-966 are larger, their perimeters are also larger and compensate to yield similar theta values.

Conclusions

In general, both the Micronaire and maturity of the cotton grown in Georgia and Mississippi were larger than for the cottons grown in Texas. This is true in general looking at all of the cottons in this experiment and especially for the two varieties (FM-966 and FM-832) grown in all three locations.

Comparisons of maturity measurements as made by image analysis with results obtained with the Micromat F/MT indicate that the FMT closely tracks image analysis but is at a somewhat lower level.

Comparing maturity measurements as made by the AFIS with image analysis of fiber cross-sections indicates that the correlation diminishes with later versions of AFIS.

Location significantly affected the distributions of both degree of thickening (theta) and fiber wall area as measured by image analysis.

The cotton varieties chosen for the study exhibited a rather wide range of fiber perimeters.

In the case of the two varieties grown in all three locations (FM-832 and FM-966), distributions of perimeter as measured by image analysis did not change with location.

References

Felker, G. S. 2001. Cotton Variety Improvement. Proc. of the Beltwide Cotton Confs., National Cotton Council of America. Vol I:8.

Thibodeaux, D. P. and Rajasekaran, K. 2002. Update on proposed reference method for cotton maturity. Part I: Sample preparation and image analysis. In P. Dugger and D.A. Richter (ed.) Proc. of the Beltwide Cotton Confs., Natl. Cotton Council Am., Memphis, Tennessee.

Thibodeaux, D. P. and Rajasekaran, K. 1999. Development of new reference standards for cotton fiber maturity. *Journal of Cotton Science*, 3:188-193.

Von Hoven, T. M., Montalvo, J. G., Jr. Reed, S., Francois, D., Buco, S. and Faught, S. 2001. Calibration of upgraded FMTs. Proc. of the Beltwide Cotton Confs., National Cotton Council of America. Vol II:1307 1309.

Von Hoven, T.M., J.G. Montalvo, Jr., D.L. Francois, S.S. Reed, and S.E. Faught. 2002. Calibration of upgraded FMTs. Part II. Expansion of results. In P. Dugger and D.A. Richter (ed.) Proc. of the Beltwide Cotton Confs., Natl. Cotton Council Am., Memphis, Tennessee.

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Table 1. Values from image analysis of fiber cross-sections including: perimeter [P(IA)], wall area [A(IA)], and maturity ratio [M(IA) = 0.577 θ]; and also values from the Micromat (F/MT) including: micronaire [Mic(F/MT)], and maturity ratio [M(F/MT)] for the eight cottons grown in Texas.

	P(IA)(μm)	A(IA)(μm)^2	M (IA)	Mic(F/MT)	M(F/MT)
FM-832	52.49	96.58	0.76	2.79	0.65
FM-966	54.17	107.84	0.80	3.18	0.70
PM-2200	53.38	94.26	0.72	3.34	0.67
PM-2800	49.66	93.60	0.83	3.42	0.71
FM-989	51.68	98.58	0.80	2.94	0.65
FM-819	51.90	104.07	0.87	3.06	0.70
FM-958	50.22	97.22	0.84	3.17	0.69
PM-2326	54.01	99.51	0.74	3.80	0.71
MEAN	52.19	98.96	0.80	3.21	0.68
STD	1.66	4.85	0.05	0.31	0.02

Table 2. Values from image analysis of fiber cross-sections including: perimeter [P(IA)], wall area [A(IA)], and maturity ration [M(IA) = 0.577 θ]; and also values from the Micromat (F/MT) including: micronaire [Mic(F/MT)], and maturity ratio [M(F/MT)] for the six cottons grown in Georgia.

	P(IA)(μm)	A(IA)(μm)^2	M(IA)	Mic (F/MT)	M (F/MT)
FM-832	50.52	107.43	0.92	3.97	0.79
FM-966	53.25	122.30	0.94	4.28	0.82
DPL-DP	53.44	116.65	0.91	4.36	0.80
PHY-355	57.72	126.80	0.86	4.75	0.81
DPL-491	53.53	108.17	0.84	3.96	0.77
SG-747	57.15	132.43	0.91	4.76	0.79
MEAN	53.64	118.96	0.92	4.34	0.80
STD	3.33	10.09	0.02	0.40	0.02

Table 3. Values from image analysis of fiber cross-sections including: perimeter [P(IA)], wall area [A(IA)], and maturity ration [M(IA) = 0.577 θ]; and also values from the Micromat (F/MT) including: micronaire [Mic(F/MT)], fineness [F(F/MT)], and maturity ratio [M(F/MT)] for the seven cottons grown in Mississippi.

	P(IA)(μm)	A(IA)(μm)^2	M (IA)	Mic(F/MT)	M (F/MT)
FM-832	50.58	119.10	1.01	3.89	0.81
FM-966	53.85	136.04	1.02	4.49	0.85
DPL-DP	53.19	129.81	1.03	4.53	0.88
PHY-355	58.02	129.4	0.87	4.81	0.81
DPL-491	51.72	102.79	0.87	4.02	0.80
SG-747	57.38	138.38	0.95	5.07	0.91
PM-1218	56.32	148.25	1.04	5.57	0.89
MEAN	53.94	135.44	0.99	4.55	0.84
STD	2.5	6.48	0.05	0.57	0.04

Table 4. Values of the maturity ratio from image analysis [M(IA)], the Micromat F/MT [M(F/MT)], and three versions of AFIS [M(V.2), M(V.4), and M(V.5)] for the eight cottons grown in Texas.

	M(IA)	M(F/MT)	M(V.2)	M(V.4)	M(V.5)
FM-832	0.76	0.65	0.72	0.85	0.85
FM-966	0.80	0.70	0.75	0.86	0.88
PM-2200	0.72	0.67	0.72	0.86	0.83
PM-2800	0.83	0.71	0.73	0.86	0.85
FM-989	0.80	0.65	0.73	0.86	0.86
FM-819	0.87	0.70	0.74	0.85	0.85
FM-958	0.84	0.69	0.72	0.86	0.85
PM-2326	0.74	0.71	0.73	0.87	0.87
MEAN	0.80	0.69	0.73	0.86	0.86
STD	0.05	0.02	0.01	0.01	0.02

Table 5. Values of the maturity ratio from image analysis [M(IA)], the Micromat F/MT [M(F/MT)], and three versions of AFIS [M(V.2), M(V.4), and M(V.5)] for the six cottons grown in Georgia.

	M(IA)	M(F/MT)	M(V.2)	M(V.4)	M(V.5)
FM-832	0.92	0.79	0.82	0.89	0.91
FM-966	0.94	0.82	0.82	0.90	0.92
DPL-DP	0.91	0.80	0.80	0.88	0.90
PHY-355	0.86	0.81	0.76	0.88	0.86
DPL-491	0.87	0.77	0.76	0.89	0.89
SG-747	0.91	0.79	0.74	0.87	0.84
MEAN	0.90	0.80	0.78	0.89	0.89
STD	0.03	0.02	0.03	0.01	0.03

Table 6. Values of the maturity ratio from image analysis [M(IA)], the Micromat F/MT [M(F/MT)], and three versions of AFIS [M(V.2), M(V.4), and M(V.5)] for the seven cottons grown in Mississippi.

	M(IA)	M(F/MT)	M(V.2)	M(V.4)	M(V.5)
FM-832	1.01	0.81	0.80	0.89	0.90
FM-966	1.02	0.85	0.85	0.90	0.90
DPL-DP	1.03	0.88	0.81	0.90	0.91
PSC-355	0.87	0.81	0.77	0.89	0.89
DPL-491	0.87	0.80	0.75	0.89	0.88
SG-747	0.95	0.91	0.79	0.89	0.86
PM-1218	1.04	0.89	0.88	0.95	0.93
MEAN	0.97	0.85	0.81	0.90	0.89
STD	0.08	0.04	0.05	0.02	0.02

Table 7. Results for correlations of maturity ratios from image analysis [M(IA)] and Micromat [M(F/MT)] with AFIS maturity ratios [M(V.2), M(V.4), and M(V.5)] for all twenty-one cotton lots.

Variables	R-Squared	Slope	Intercept
M(IA):M(F/MT)	.741	.729	.128
M(IA):M(V.2)	.749	.428	.393
M(IA):M(V.4)	.603	.193	.710
M(IA):M(V.5)	.501	.216	.686
M(F/MT):M(V.2)	.657	.473	.406
M(F/MT):M(V.4)	.702	.246	.691
M(F/MT):M(V.5)	.414	.232	.699

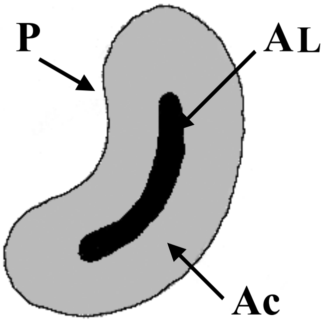

Figure 1. A typical fiber cross-section showing the perimeter (P), area of the cellulose wall (A_C), and area of the inner lumen (A_L).

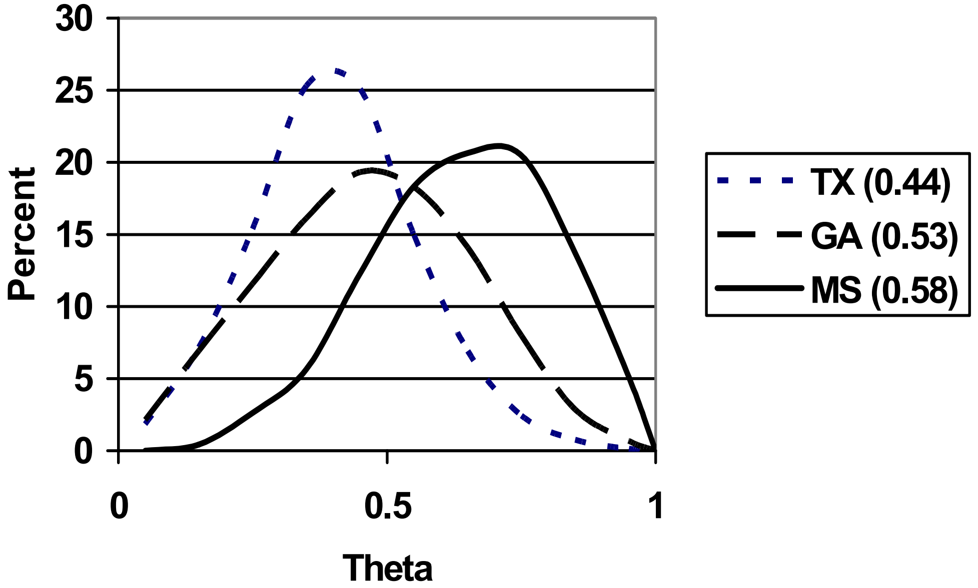

Figure 2. Distribution of the theta values for cotton cross-sections from FM-832 grown in Texas, Mississippi, and Georgia.

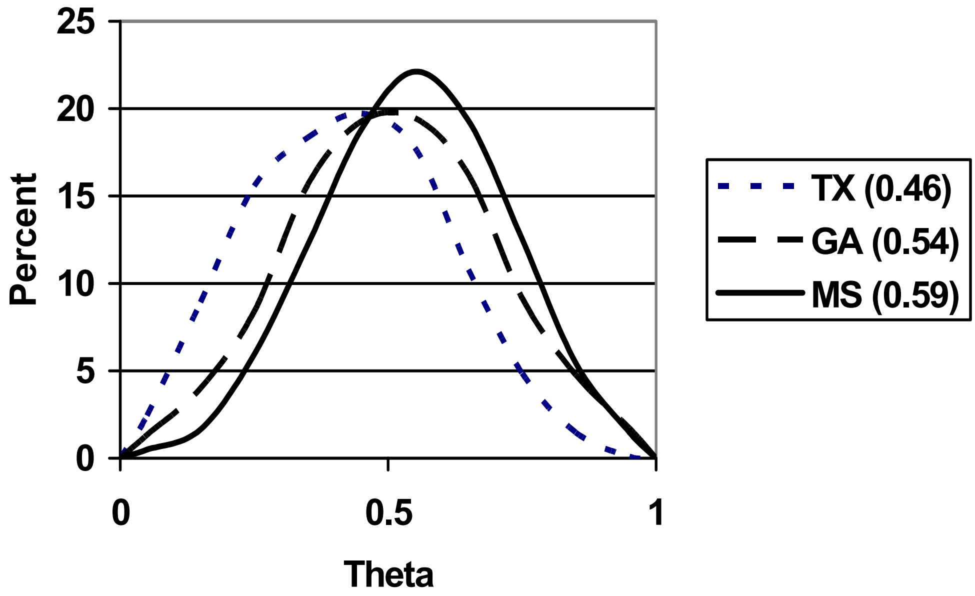

Figure 3. Distribution of the theta values for cotton cross-sections from FM-966 grown in Texas, Mississippi, and Georgia.

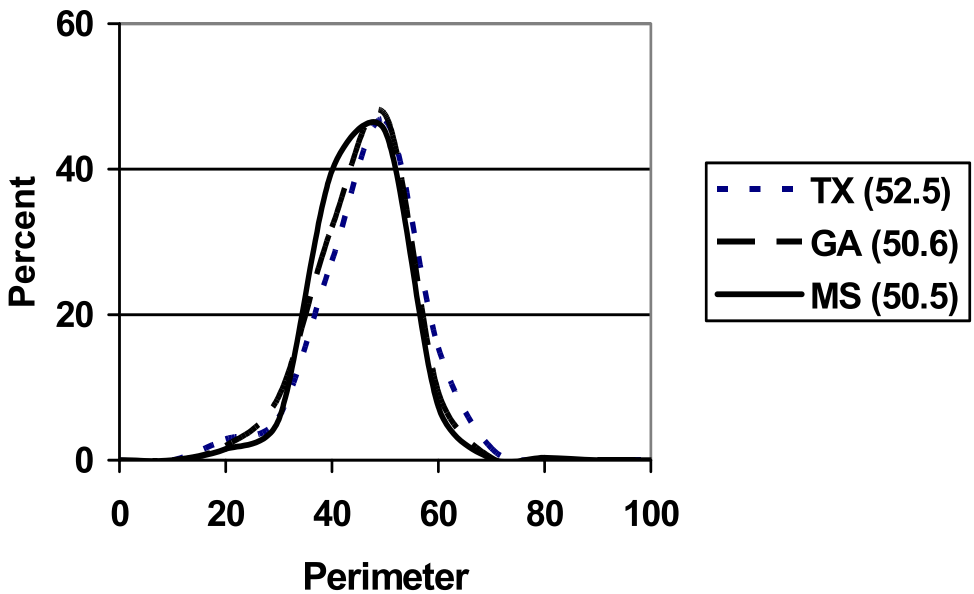

Figure 4. Distribution of the perimeter [P(µm)] values for cotton cross-sections from FM-832 grown in Texas, Mississippi, and Georgia.

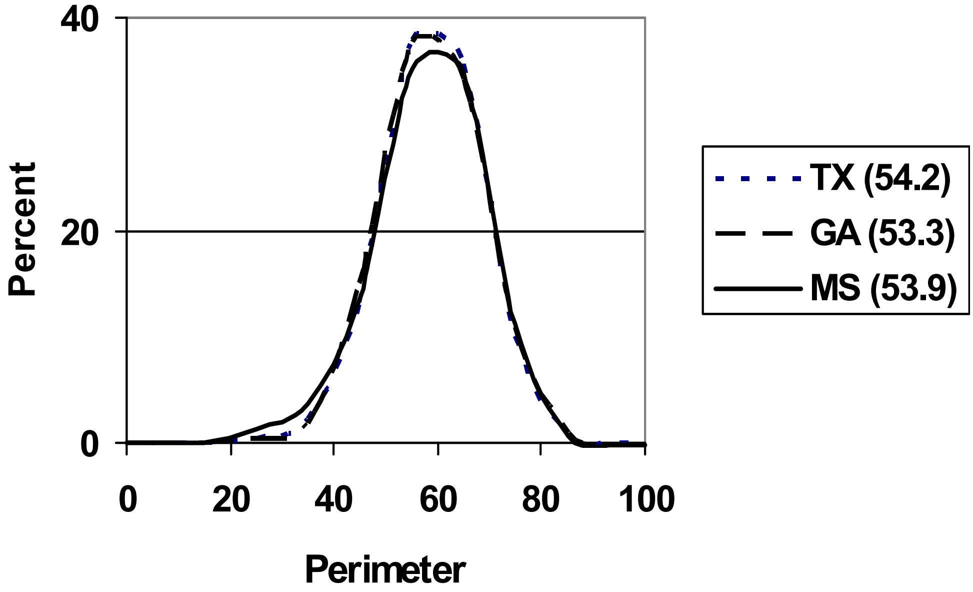

Figure 5. Distribution of the perimeter [P(µm)] values for cotton cross-sections from FM-966 grown in Texas, Mississippi, and Georgia.

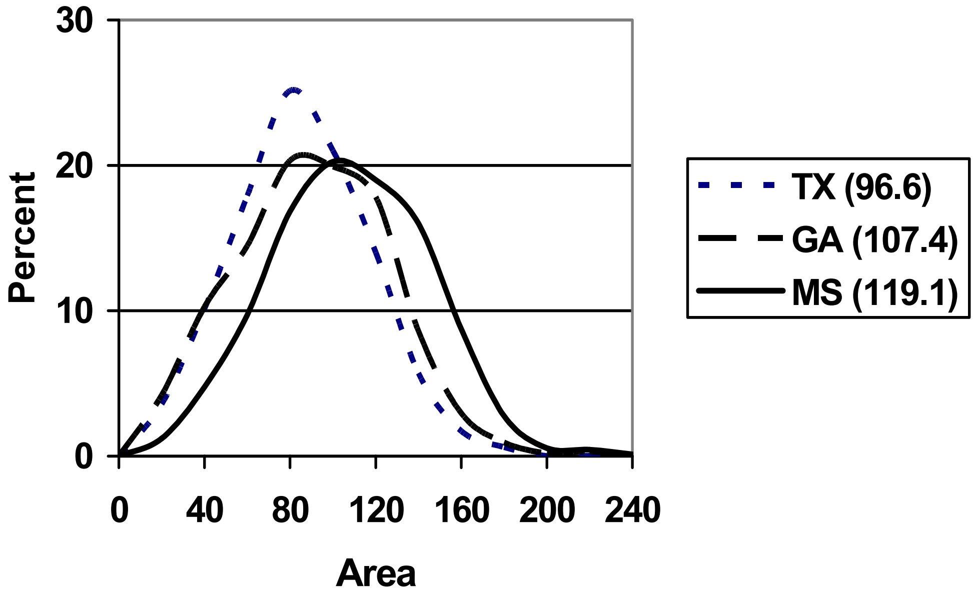

Figure 6. Distribution of wall areas [A(µm)^2] for cotton cross-sections from FM-832 grown in Texas, Mississippi, and Georgia.

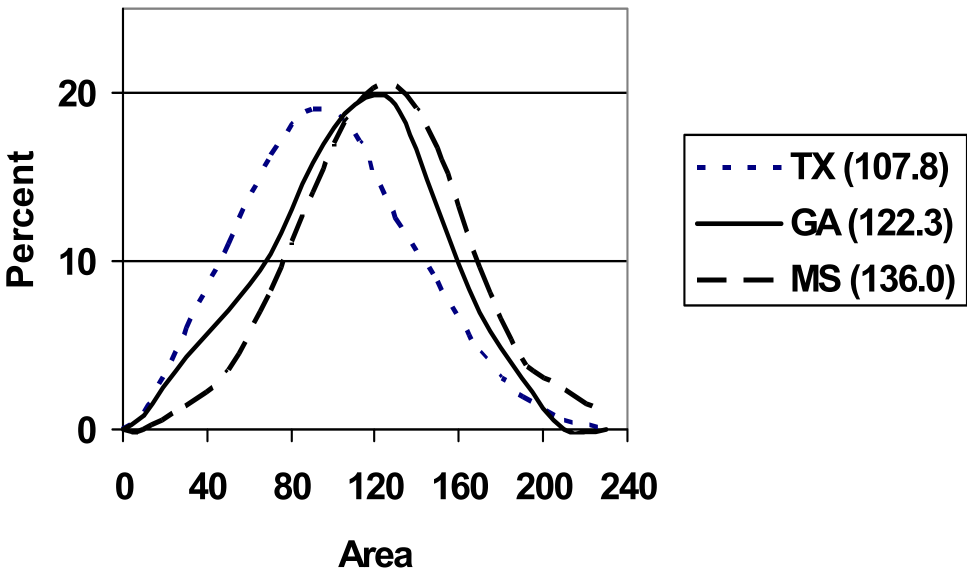

Figure 7. Distribution of wall areas [A(μm)^2] for cotton cross-sections from FM-966 grown in Texas, Mississippi, and Georgia.