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CHANGES IN YIELD AND FIBER QUALITY DUE TO VARIETY GROWN

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Abstract

The introduction of transgenic technology to US cotton production in 1996 brought rapid changes in varieties grown. Environment and management are known to affect yield and fiber quality. This paper attempts to document the impact of variety selection on yield and fiber quality of cotton produced in the Mid-South and Southeastern states from 1995 to 2001. A total of 58 varieties made up approximately 90 percent of the varieties planted in the picker market excluding Acala and Pima cottons. Variety performance data was compared for public data only against Delta and Pine Land Company field trials. The two data sets are in close agreement regarding response of the 58 varieties across the US (R^2 of 0.71, 0.94, 0.96, 0.88, and 0.81 for lint yield, fiber length, fiber strength, micronaire, and fiber length uniformity, respectively with N = 7,300 for public data and N = 11,131 for D&PL data). When year and environmental effects were removed, variety choice by growers resulted in an average increase of 5.9 lbs lint/A/yr, a reduction of 0.05 staple units (32^{nds} of an inch) per year, no change in fiber strength or fiber length uniformity, but an increase of 0.013 micronaire units per year between 1995 and 2001.

Introduction

Concern has been expressed in recent years by many segments of the industry regarding yield and quality trends for some regions of the US cotton belt, especially the Mid-South and Southeastern states. There has been a rapid change in varieties grown, many containing transgenic traits. Yield of varieties containing Bollgard or Roundup Ready + Bollgard (stacked) showed yield improvement compared to conventional parent variety, while Roundup Ready only varieties were similar to the yield of the conventional parent in trials between 1998 through 2000 (Lege et al. (2001). Kerby et al. (2000) provided detailed head to head data for seven Delta and Pine Land Company varieties where the conventional parents were compared against the *Bollgard®, Roundup Ready®*, or *Bollgard* and *Roundup Ready* (stacked) versions of the conventional varieties. Their results demonstrated similar fiber quality characteristics for all transgenic gene combinations. Ethridge and Hequet (2000) reported similar spinning results among conventional parents and their transgenic derivatives.

Kerby et al. (2000) demonstrated that environment was a major factor in yield, fiber length, fiber strength, and micronaire accounting for 90, 85, 66, and 78 percent of the variation, respectively, between 12 varieties grown over 16 states over a three year period in a total of 785 test locations. While environment plays a large role in outcomes, we wished to estimate any contribution of varieties being grown to see if they appeared to contribute to yield and quality trends. Once trends were established for varieties, expected values could be calculated and compared against actual state or regional averages to see genetic trends and environmental variation together.

Materials and Methods

USDA-AMS data were used each year to determine the percentage of acreage planted to varieties by state from 1995 through 2001. Yield estimates for the 2001 season were from the December crop report. Fiber quality measures were from the December 20th Smith-Doxey data by state. Stripper, Pima, and Acala varieties of New Mexico and California were not included since these varieties would generally not be present in the majority of trials across the rest of the cotton growing area of the US. Varieties grown in VA, NC, SC, GA, FL, AL, TN, MS, LA, AR, and MO were included until 90 percent of the market was accounted for in each state for the years 1995 through 2001. SAS GLM (JMP from the SAS Institute) was used to calculate average yield and quality of the 58 varieties eliminating (adjusting for) year and location (environment) affects. To minimize error, a location was excluded from the analysis unless it had five or more of the varieties present.

There were 7,300 data points from public Official Variety Trials (OVT) from 572 test locations (locations and years). For Delta and Pine Land Company tests there were 11,131 data points from 1146 test locations over the years. The combined data set had 18,431 data points from 1718 test locations. Once yield and fiber quality data were calculated for the 58 varieties over years and environments, these mean values for varieties were weighted with the percentage of acreage planted by state to the variety to calculate an expected yield for the state due to varieties planted with year and environment affects removed. Regional summaries were calculated weighting yield and quality for varieties planted by the number of acres for the state within a year.

Actual yields and quality were plotted against the USDA-AMS classing data for the state. Weighted summaries for the Mid-South and Southeastern states were calculated according to the acreage of a state. State yield averages (and frequently quality factors) were lower than the average of tests within a state. This suggests tests on average are on better land and / or receive a higher level of management. Performance in tests were factored according to a ratio that achieved the same average actual state average over the seven year period for summary graphical comparisons.

Results and Discussion

Comparison of Public OVT Data to that from Delta and Pine Land Company Field Trials

Yield and fiber qualities were estimated across years and locations for the 58 varieties that occupied significant market share in one or more state between 1995 and 2001 for OVT as well as Delta and Pine Land Company Agronomic Service Trials (AST's). The 58 varieties included in this analysis are given in alphabetical order in Table 1. Several of the varieties in Table 1 had such a low number of varieties either in OVT or AST trials, that an estimate of performance was not possible.

Table 2 summarizes regression data for consistency of the two data sets with regard to yield and fiber quality ranking. There is good agreement between the average yield and fiber quality predictions of the varieties as indicated by the highly significant R^2 values noted in Table 2. This simply establishes that the two data sets each provide a consistent estimate of the yield and fiber quality of the 58 varieties averaged over hundreds of locations (environments). The consistency between these two data sets provides the justification to combine them and make yield and fiber quality estimates of the 58 varieties across 7 years utilizing 1718 locations of data with N = 18,431 instead of only 572 locations of data with N = 7,300 if only public OVT data were used.

Trends in Yield for Varieties Planted

Expected yield for the Mid-South and Southeastern states based on varieties planted (performance of the variety over years to remove environmental effects, then weighted for percentage of the acreage planted to the variety in the region) is given in Figure 1. The number of varieties included within a year and the percentage of the US market planted to these varieties is given at the bottom of the Figures. These same varieties account for approximately 90 of the market in the Mid-South and Southeastern states of LA, AR, MO, TN, MS, AL, FL, GA, SC, NC, AND VA. Florida was not used in the 2001 data as USDA-AMS has not made a yield estimate for the state.

Yield based on the varieties planted (with environmental effects removed) has shown a consistent improvement averaging 5.9 lbs/A lint increase between 1995 and 2001 (R^2 = 0.929). Actual yields versus expected yields based on the varieties planted indicate substantial environmental effects. Yield in 1996, 1997, and 2001 are above what would be expected based on varieties planted, but yields in 1995, 1998, 1999, and 2000 were below expected values. Expect yield for the varieties was adjusted so that average yields over the 7 year period have identical values to the actual values for consistency in graphical comparisons. While genetic improvement has been consistent and significant (increase of 5.4 % over the period), realized yields have been erratic. Many factors can influence yield including environment, acreage, economics, farm programs, and other possible factors. Simply looking at the actual yields of the region and placing cause on varieties is an over simplification of all the factors that influence yield. Doing so results in an inaccurate assessment of variety contribution to yield trends.

Trends in Staple Length for Varieties Planted

Varieties growers have chosen to plant have resulted in an average decline of 0.05 staple units (32^{nds} of an inch) per year between 1995 and 2001 (Figure 2). This decline is significant (R^2 = 0.967). In 1997, average staple length was much longer than expected for varieties planted. This has been consistent across states, and begs the question as to what the environmental factors were in 1997 that resulted in average fiber length being nearly 0.6 staple units longer than expected. Summer drought in many areas of the region during the summers of 1998, 1999, and 2000 was thought to play a significant part in shorter staple during those years. However, the environment for staple development in the region has been considered generally favorable during 2001, but actual staple is not quite up to predicted values based on varieties planted. This suggests factors other that environment and varieties planted may be important in understanding recent year trends. Number of acres in cotton (average quality of cotton land), the depressed farm economy (level of crop inputs and management), as well as the possible influence of farm programs may be important factors. With yields higher than average for the varieties (Figure 1), staple length shorter than normal is not consistent. Perhaps yield should have been even higher than they were and were held down by cotton on poor land, reduced inputs, and the influence of government programs. A possible way to compare this would be to compare yield and fiber quality results of similar varieties over years at locations where similar crop management was used. This should be possible from many of the OVT test locations.

Trends in Fiber Strength for Varieties Planted

Predicted and actual regional average fiber strength is given in Figure 3. There are no apparent trends due to either variety or environment.

Trends in Micronaire for Varieties Planted

Micronaire has increased an average of 0.013 units per year between 1995 and 2001 due to varieties planted (Figure 4). This is highly significant ($R^2 = 0.957$). Micronaire was lower than expected in 1996, 1997, and 2000 but higher than expected in 1995, 1998, and 2001. In 1997 yields were higher than expected and micronaire lower than expected. This is not the case in 2001. As we began to see trends in 2001, we evaluated boll size, yield accumulation, and fiber quality by weeks of flowering for selected fields in Mississippi and Tennessee. Much of this data was collected in collaboration with the National Cotton Council and the summary by week of flowering averaged over all 11field locations is presented in Table 3.

Fiber quality by zone of the plant showed the longest fiber to be from early set bolls with the highest micronaire coming from middle bolls with late set bolls having micronaire more than 10 percent less than the middle of the plant (Kerby and Ruppenicker, 1989). Box map data was collected in 1999 for 29 fields from North Carolina to California and fiber quality was summarized for bottom, middle, and top first position bolls (Table 3). This data clearly showed the trend for lower micronaire in top of the plant bolls. Average micronaire of 11 box map fields from Mississippi and Tennessee in 2001 averaged 4.69. The upper and outer bolls (week 4+) had an average micronaire of 4.80 (Table 4). This is unexpected and probably accounts for trends noted in 2001 for higher micronaire than predicted for varieties planted. Possible reasons include crops that were generally cut out early in August, frequent and adequate rainfall during August and September, and warm nights until well into September.

Trends in Fiber Length Uniformity (Mean/UHM) for Varieties Planted

Predicted and actual regional average fiber length uniformity is given in Figure 5. There are no apparent trends due to either variety or environment.

Summary

This manuscript represents a significant effort at identifying the varieties that occupied the major market share in the Mid-South and Southeastern cotton growing states between 1995 and 2001. Statistical analysis was used to remove location and year (environmental) effects. The resultant average yield and quality represent the best unbiased estimate of genetic contribution to yield and quality. These values were applied by state according to percent of the acreage planted, then applied by state to region according to percent of the total region acreage by year. Data presented used the combined data set from OVT trials as well as Delta and Pine Land Company AST trials since they were demonstrated to be in close agreement with performance of the 58 varieties included in this analysis.

Results from 18,431 data points from 1146 test locations over years and environments indicate that varieties planted has increased yield an average of 5.9 lbs lint/A/year between 1995 to 2001. Staple length declined by 0.05 32^{nds} of an inch per year due to varieties planted. Micronaire increased an average of 0.013 units per year due to varieties planted. There were no variety trends for fiber strength or length uniformity. Actual observed yields and quality are not consistent with what is expected for the varieties when environmental effects are removed. This indicates the role of environment on yield and quality. It is possible that more than variety or environment is affecting actual yield and quality of the crop in the Mid-South and Southeastern states. Possible methods to evaluate this influence were discussed, but are beyond the scope of this manuscript.

Grower variety choices have been influenced by yield potential. Varieties grown today have higher genetic potential than previous varieties. However, analysis of the data indicates the average fiber length has declined while micronaire has increased (with environmental effects removed). Growers have planted varieties based on what has been most beneficial to their net revenue. This has not resulted in the quality that is in demand by textile mills. While this represents a current problem for producers and consumers, varieties in the latter stages of development indicate increased yield potential with improved fiber qualities.

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Table 1. Alphabetical listing of varieties with the number of locations they are present in over year and location analysis in OVT or AST test locations.

Variety	N OVT	N AST	Variety	N OVT	N AST	Variety	N OVT	N AST
BG4740	83	56	DP5415R	174	305	PM1220BR	194	176
BXN47	291	39	DP5690	73	285	PM1220R	143	108
DES119	18	72	DP5690R	62	224	SG1001	43	13
DP20	56	242	DP655BR	108	233	SG125	293	436
DP20B	181	289	DP688BR	2	18	SG125BR	155	291
DP32B	100	279	DP90	112	190	SG125R	92	115
DP388	163	156	DP90B	53	147	SG404	37	61
DP420R	64	103	DP90R	21	96	SG501	201	263
DP422BR	122	195	FM832	193	49	SG501BR	154	228
DP425R	166	246	FM958	89	11	SG521R	51	76
DP428B	169	225	FM989	246	69	SG747	314	252
DP436R	177	297	HS46	118	37	ST132	37	62
DP451BR	166	402	HZ1220	56	40	ST373	96	45
DP458BR	182	460	LA887	122	149	ST453	12	27
DP50	81	303	NUCOTN33B	367	659	ST4691B	117	64
DP50B	57	133	NUCOTN35B	87	314	ST474	398	591
DP51	128	481	PM1215BR	13	25	ST4793R	114	20
DP5111	124	249	PM1215R	22	5	ST4892BR	91	93
DP5409	145	429	PM1218BR	223	207			
DP5415	116	476	PM1220B	28	15			

Table 2. Comparison of Public OVT (x-variable) and Delta and Pine Land Company AST (y-variable) data for yield and fiber quality estimates for the 58 varieties used in analysis over locations and years (1994 through 2000). Variety average rankings for public OVT data developed from 572 locations with N of 7,300 and 1146 locations with N of 11,131 for Delta and Pine Land Company AST data.

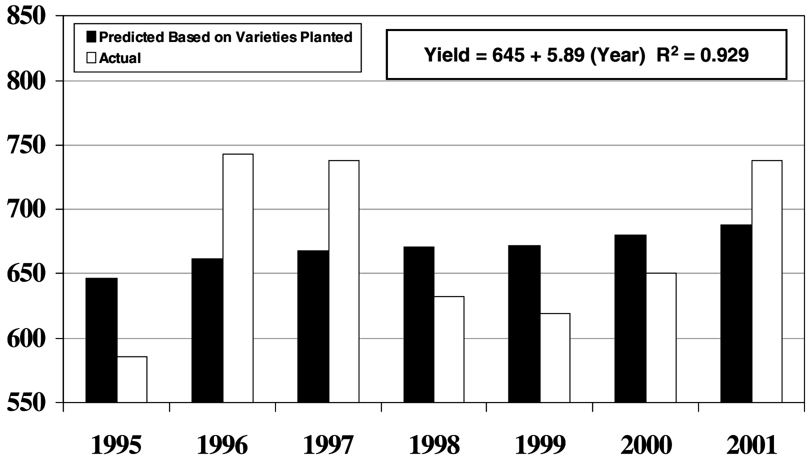
Variable	Intercept	Slope	R^2
Lint Yield (lbs/A)	38.6	0.910	0.710
Fiber Length (inches)	0.081	0.916	0.942
Fiber Strength (g/tex)	5.30	0.810	0.955
Micronaire	-0.316	1.036	0.875
Length Uniformity (Mean/UHM)	6.641	0.917	0.808

Table 3. Comparative fiber quality for first position bolls by node number for 29 fields box mapped during 1999 from North Carolina to California.

Node Number	Staple Length (In)	Fiber Strength (g/tex)	Micronaire	Uniformity (Mean/UHM)
< 11	34.2	29.2	4.46	81.8
11 to 15	34.6	29.9	4.76	82.6
> 15	35.0	29.7	4.27	82.0

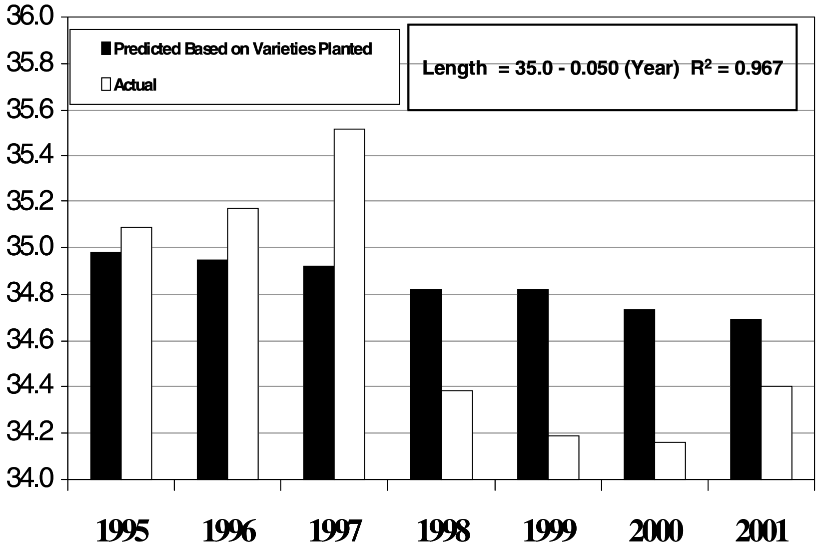
Table 4. Yield distribution, boll size, fiber length, and micronaire of 11 fields (Mississippi and Tennessee) box mapped in 2001 and summarized according to approximate week of flowering.

Variable	Week 1	Week 2	Week 3	Week 4+	Veg. Bolls
% Total Yield	12.4	30.2	28.3	20.8	8.2
Boll Size (g)	4.10	4.54	4.48	4.21	4.06
Staple Length (Inches)	34.4	34.7	35.1	34.8	35.0
Micronaire	4.55	4.67	4.69	4.80	4.57



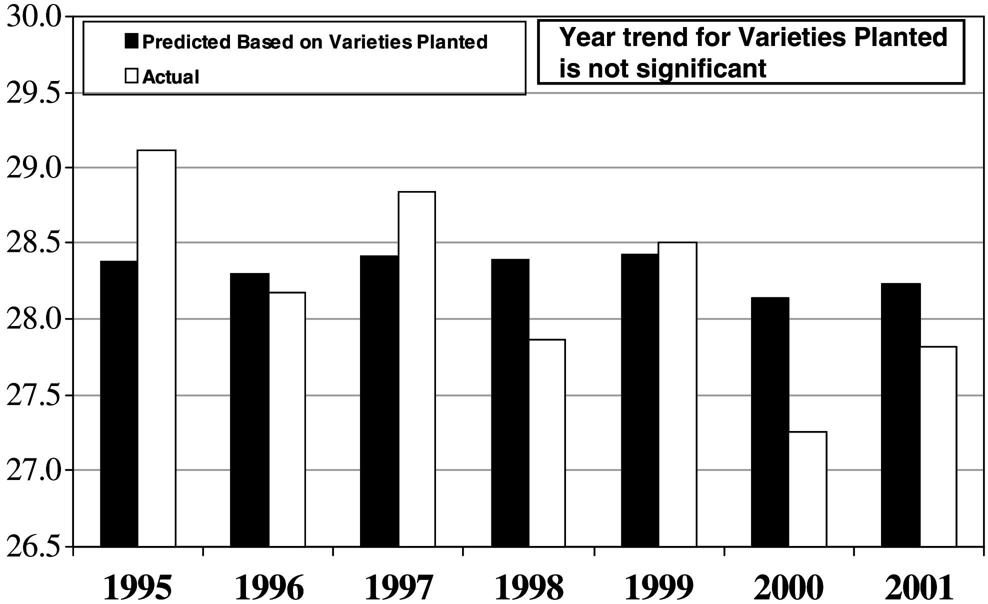
No. Varieties	17	17	20	32	33	34	30
%US Market	58.1	59.1	58.0	60.2	62.6	61.6	60.2

Figure 1. Expected yield (lbs/A lint) for varieties planted in the Mid-South and Southeastern states compared to observed values. Actual values are weighted USDA-AMS values with 2001 represented by the December estimate. 2001 Estimate Dec USDA-AMS LA; AR; MO; TN; MS; AL; GA; SC; NC; and VA



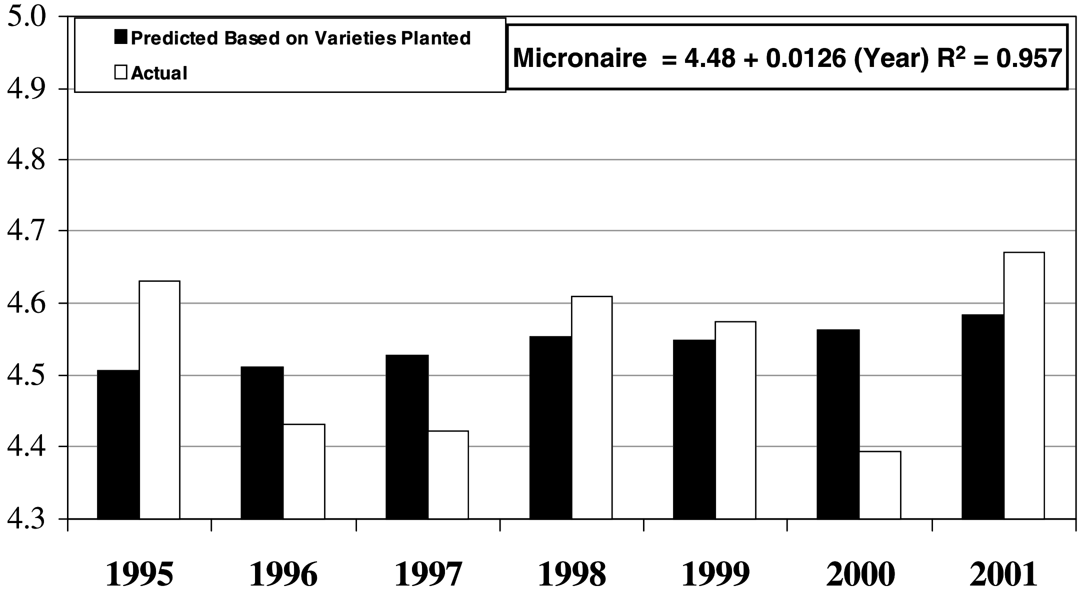
No. Varieties	17	17	20	32	33	34	30
% US Market	58.1	59.1	58.0	60.2	62.6	61.6	60.2

Figure 2. Expected staple length (32nds of an inch) for varieties planted in the Mid-South and Southeastern states compared to observed values. Actual values are weighted USDA-AMS values with 2001 represented by the December 20th estimate. 2001 Estimate Dec 20 USDA-AMS LA; AR; MO; TN; MS; AL; GA; SC; NC; and VA



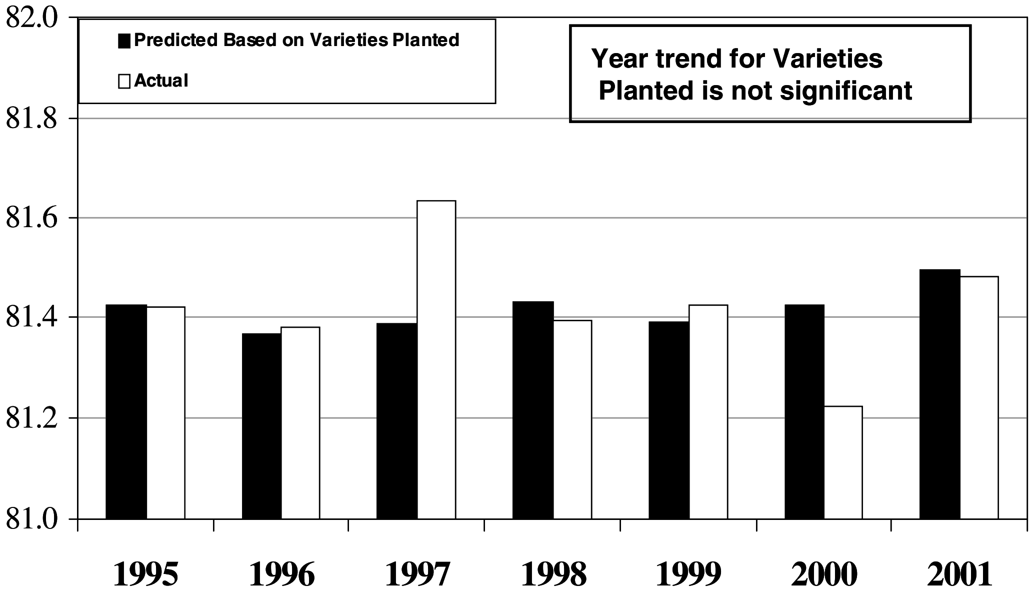
No. Varieties	17	17	20	32	33	34	30
% US Market	58.1	59.1	58.0	60.2	62.6	61.6	60.2

Figure 3. Expected fiber strength (g/tex) for varieties planted in the Mid-South and Southeastern states compared to observed values. Actual values are weighted USDA-AMS values with 2001 represented by the December 20th estimate. 2001 Estimate Dec 20 USDA-AMS LA; AR; MO; TN; MS; AL; GA; SC; NC; and VA



No. Varieties	17	17	20	32	33	34	30
%US Market	58.1	59.1	58.0	60.2	62.6	61.6	60.2

Figure 4. Expected micronaire for varieties planted in the Mid-South and Southeastern states compared to observed values. Actual values are weighted USDA-AMS values with 2001 represented by the December 20th estimate. **2001** Estimate Dec 20 USDA-AMS LA; AR; MO; TN; MS; AL; GA; SC; NC; and VA



No. Varieties	17	17	20	32	33	34	30
%US Market	58.1	59.1	58.0	60.2	62.6	61.6	60.2

Figure 5. Expected fiber length uniformity (mean/UHM) for varieties planted in the Mid-South and Southeastern states compared to observed values. Actual values are weighted USDA-AMS values with 2001 represented by the December 20th estimate. 2001 Estimate Dec 20 USDA-AMS LA; AR; MO; TN; MS; AL; GA; SC; NC; and VA