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BREEDING AND GENETICS

Interpretation of AFIS and HVI Fiber Property Measurements in Breeding for Cotton Fiber Quality Improvement

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ABSTRACT

For the last two decades, cotton breeders have used High Volume Instrument (HVI) as their primary and often sole source of fiber quality data when making plant selections. Fiber data generated by Advanced Fiber Information System (AFIS) technology is also now available to plant breeders, and provides additional information on length characteristics and fiber maturity. Two methods of evaluating fiber quality of upland cotton (*Gossypium hirsutum* L.) in a breeding program were compared. One method used only HVI data for plant selections, whereas the other method used only AFIS data. One critical difference between the selection methods was use of fiber length distributions as the only selection criteria in the AFIS method. Line development began with 15 intraspecific F_2 populations in 2005. Selections were made in the F_2 and F_3 generations based upon data generated from either HVI or AFIS. In the F_5 generation, 10 lines from each selection method and four commercial cultivars were planted at three locations. Improvement of fiber quality in selected lines was apparent in the F_3 generation. Both selection methods resulted in F_5 lines with better fiber quality than commercial cultivars. Fiber maturity had a significant impact on length characteristics. Data indicated it is possible to improve fiber length distribution using either selection method. Principle component analysis revealed differences between length distribution of HVI selection lines and AFIS selection lines, even though average fiber properties from each selection method were similar.

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For the past two decades, cotton breeders have used High Volume Instrument (HVI) fiber measurements as their primary and often sole source of data making plant selections for fiber quality improvement. Now that additional methods of fiber property evaluation are available, this method of screening needs further evaluation. Demands on breeders regarding fiber quality are intensifying. Merchants demand fiber quality that is competitive in a global market, and textile mills need fibers that produce quality products and minimize waste. Breeding programs must continue to evolve with new technology to stay efficient and up to date if they are going to continue to contribute as an integral part of a competitive cotton industry. Cotton industry dynamics suggest breeders must begin to think globally to understand markets challenges and strive to be proactive rather than reactive. Data exist to support the theory that Advanced Fiber Information System (AFIS) might be an effective tool in predicting spinning performance and yarn quality (Hequet et al., 2007). The purpose of this research is to provide information that will evaluate the impact of using data generated from AFIS measurements in cotton breeding programs.

Improvements in fiber quality have long been a primary objective of cotton breeders. One major obstacle for early breeders was the lack of reliable methods to measure fiber characteristics. Those methods have become available with the advent of HVI in the late 1960s and AFIS in the 1980s. There is little information focusing on AFIS data and the benefits of using it in breeding programs. Previous research recognized the need for additional information about AFIS properties and the potential role of AFIS in breeding programs (Meredith et al., 1996). Other researchers have questioned how selecting for individual HVI properties, specifically strength, affects other fibers properties such as short fiber content, length, and fineness (May and Jividen, 1999). There have been few studies comparing HVI data versus AFIS data for making selections in a breeding program.

HVI was developed for the U.S. Department of Agriculture (USDA) in 1969 (Hsieh, 1999; Ramey, 1999). It was designed to be used as a marketing tool with which to evaluate the quality of the fiber within a bale of cotton. HVI evaluates multiple fiber characteristics in a high volume of samples at a relatively high rate of speed in comparison to hand classing. HVI uses automated sampling techniques and measures fiber properties from a bundle of fibers. This system remains popular today for both marketing and breeding, because it is efficient in terms of time and cost. Even with such wide acceptance, there is still debate among breeders about its effectiveness for use as a breeding tool. The development of AFIS was the result of cooperative efforts between the USDA Agricultural Research Service at Clemson, SC and Schaffner Technologies, with research beginning in 1982 (Bragg and Shofner, 1993). One of the primary objectives in the early design of this instrument was the ability to measure trash and neps. This was followed by efforts to measure fiber dimension, number of short fibers, and eventually a complete fiber length distribution (Bragg and Shofner, 1993; Shofner et al., 1988, 1990). These properties were chosen because of their value in the fiber-to-yarn engineering process. This basic information about the fiber is useful for quality control and production efficiency in mills, as well as for providing information needed to improve product quality (Shofner et al., 1988, 1990).

HVI uses a fibrosampler to grab a portion of cotton from the whole sample. This subsample is used to create a beard of approximately parallel fibers that is optically scanned for relevant measurements such as upper-half mean length (UHML) and uniformity index. AFIS uses an aeromechanical separator to separate microdust, trash, and fibers within a sample. These three components follow different paths and measured separately using two electro-optical sensors, one for fibers and one for dust and trash. Unlike HVI, fibers are individualized before any measurements are taken. This technique is more aggressive than HVI, but might be considered an advantage because it is more representative of the opening and carding process but can result in some fiber breakage. Properties such as length and maturity are measured on each fiber using an infrared beam and electro-optical technology. In addition to reporting means, data for individual fibers are combined to create distributions. Providing such information to the textile industry was a major accomplishment of AFIS (Shofner et al., 1988, 1990). The intent of the AFIS design was not to correlate other fiber measurements with AFIS. Rather, AFIS was designed to provide unique fiber data (Shofner et al., 1988). Prior to AFIS, individual fiber analysis was neither timely nor practical for industry or other applications besides research conditions (Bragg and Shofner, 1993). It should be noted that AFIS does not measure tensile properties (tenacity and elongation) of fibers.

AFIS is still considered new technology and limited information is available about its effectiveness for use as a breeding tool. The current AFIS instruments measure 20 fiber properties, including maturity ratio and length distribution. Most of these properties were considered at some level of interest in this selection study.

F_2 progenies were followed through a series of plant-to-row selections to the F_5 line stage. These lines were derived from original selections considered superior according to both types of fiber quality evaluation. This information was used to evaluate advantages and limitations of the two methods. The data presented in this paper tested the following hypothesis: fiber length distributions can be modified through breeding using UHML and uniformity index for the HVI selection method and complete length distribution for the AFIS selection method. This study was designed to provide breeders with insight as to how to select genotypes with fiber profiles that are preferred by textile mills.

MATERIALS & METHODS

Population Development. The study began with 15 intraspecific F_2 populations from crosses made in 2004 for fiber quality. Fiber properties (HVI and AFIS) of parent lines were considered for both quality and diversity (Tables 1 and 2). Length distributions for the parent lines were considered diverse. Populations that were chosen appeared to have high quality fiber while still representing a range of values for various fiber properties and length distribution.

Fiber Analysis. A 60-g fiber sample was taken from each plot after ginning and submitted for fiber analysis. Starting with the F_3 generation, HVI analysis and AFIS analysis were conducted on all populations for both selection methods so comparisons could be made later. These data were for comparison only, HVI data were never evaluated during the AFIS selection method, and AFIS data were never evaluated during the HVI selection method.

Table 1. HVI measurements for parent lines of the original 15 crosses. F indicates female parent, and M indicates male parent.

Entry	2004 Cross	Parent	Micronaire	UHML (mm)	Uniformity (%)	Strength (kN m/kg)	Elongation (%)
1	G-187	F	4.7	33.02	85.2	379.5	4.2
		M	5.4	29.21	85.5	335.4	8.3
2	G-105	F	4.5	34.29	86.3	369.7	4.1
		M	4.3	29.46	86.4	281.5	10.4
3	G-243	F	5.3	27.18	81.2	295.2	5.9
		M	4.3	35.81	89.7	375.6	4.6
4	G-244	F	5.3	27.18	81.2	295.2	5.9
		M	4.1	34.04	84.7	394.2	4.5
5	G-241	F	5.3	27.18	81.2	295.2	5.9
		M	3.7	34.29	87.7	361.9	6.7
6	G-185	F	4.1	35.05	86.8	397.2	4.1
		M	5.4	29.21	85.5	335.4	8.3
7	G-237	F	4.3	34.29	88.0	360.9	6.8
		M	5.4	27.94	85.9	281.5	8.1
8	G-24	F	4.3	34.29	88.0	360.9	6.8
		M	3.8	34.04	88.0	324.6	8.0
9	G-26	F	4.3	34.29	88.0	360.9	6.8
		M	5.5	31.50	86.5	296.2	8.3
10	G-94	F	4.0	36.07	87.7	412.9	5.1
		M	4.4	32.00	86.1	284.4	8.1
11	G-95	F	4.0	36.07	87.7	412.9	5.1
		M	4.6	33.53	87.2	278.5	8.0
12	G-100	F	5.3	32.51	88.2	362.9	6.2
		M	4.4	32.00	86.1	284.4	8.1
13	G-101	F	5.3	32.51	88.2	362.9	6.2
		M	4.6	33.53	87.2	278.5	8.0
14	G-232	F	3.5	28.96	86.6	318.7	9.1
		M	4.6	33.53	87.2	278.5	8.0
15	G-83	F	3.6	34.54	86.6	298.1	8.1
		M	4.5	34.29	86.3	369.7	4.1

Fiber analyses were performed at the Fiber and Biopolymer Research Institute (FBRI) at Texas Tech University in Lubbock, Texas. The same two instruments, an Uster HVI 900A and Uster AFIS pro (Uster, Knoxville, TN), were used for the duration of the study. Even after calibration, there can be variation between instruments. Therefore, it was important to use the same machines across years to minimize the effect of instrument discrepancies on fiber quality data. HVI samples from the 2005, 2006, and 2007 test plots were evaluated using two replications for uniformity index, tenacity, and elongation measurements and one reading for micronaire measurements. In 2008, HVI samples from test plots were evaluated using two replicates for micronaire, four replicates for length and strength, and two replicates for color measurements. All AFIS testing was conducted using five replications of samples with 3,000 fibers.

Statistical Analysis. Yarn and fiber data for 2008 were analyzed using PROC ANOVA (SAS, 2008). Mean separation was performed using the Waller-Duncan test, and was not performed when F-values were nonsignificant (.05) for breeding lines (entry).

Principal Component Analysis (PCA) was performed to determine if there were distinct groups of fiber length distributions to compare average distributions for individual lines beyond visual observation of the distribution profile and comparing means of AFIS measurements. PCA is a widely used mathematical technique to reduce the dimensionality of the data from *n* variables (41 length bins in our case) to a fewer number of dimensions (Esbensen et al., 2002). The variability in each individual distribution relative to the mean of the population can be represented as a smaller set of values (axes) termed principal components (PCs). The effect of this process is to concentrate sources of variability in the data into the first few PCs.

Table 2. AFIS measurements for parent lines of the original 15 crosses. F indicates female parent, and M indicates male parent.

Entry	2004 Cross	Parent	Lw (mm)	UQLw (mm)	Ln (mm)	SFCn (%)	Fineness (mTex)	Maturity
1	G-187	F	25.40	30.99	20.57	24.4	171	0.93
		M	25.65	30.23	21.59	19.4	176	0.91
2	G-105	F	25.91	29.72	23.37	10.2	173	0.94
		M	26.16	29.97	22.86	13.2	178	0.90
3	G-243	F	22.61	26.67	19.56	20.0	187	0.91
		M	29.46	35.05	24.64	16.3	160	0.95
4	G-244	F	22.61	26.67	19.56	20.0	187	0.91
		M	29.46	35.56	24.13	18.2	155	0.94
5	G-241	F	22.61	26.67	19.56	20.0	187	0.91
		M	26.92	31.75	23.11	14.4	161	0.93
6	G-185	F	28.45	34.80	23.11	19.8	155	0.93
		M	25.65	30.23	21.59	19.4	176	0.91
7	G-237	F	27.94	32.77	24.13	13.9	159	0.92
		M	24.38	29.21	20.32	22.4	177	0.89
8	G-24	F	27.94	32.77	24.13	13.9	159	0.92
		M	26.16	31.24	21.84	20.2	155	0.88
9	G-26	F	27.94	32.77	24.13	13.9	159	0.92
		M	25.65	29.72	22.86	11.8	184	0.93
10	G-94	F	30.23	36.83	24.89	17.2	151	0.92
		M	26.92	31.75	22.86	16.5	151	0.82
11	G-95	F	30.23	36.83	24.89	17.2	151	0.92
		M	26.42	31.24	22.61	15.7	170	0.92
12	G-100	F	28.19	32.77	24.64	12.6	183	0.95
		M	26.92	31.75	22.86	16.5	151	0.82
13	G-101	F	28.19	32.77	24.64	12.6	183	0.95
		M	26.42	31.24	22.61	15.7	170	0.92
14	G-232	F	22.35	26.16	19.05	20.9	162	0.87
		M	26.42	31.24	22.61	15.7	170	0.92
15	G-83	F	27.43	33.02	22.61	21.4	157	0.90
		M	28.45	33.53	24.64	13.4	164	0.97

Selection Process—Early Generations and Breeding Progression Results. The study resulted in 15 F_2 populations, 64 $F_{2:3}$ progeny rows, and 303 $F_{2:3:4}$ progeny rows. Figure 1 summarizes the 4-yr study. For the first three generations, there were two separate tests with the same statistical design, one for each selection method. The pedigree breeding method was used throughout the study. Both family and individual plant fiber data were used for the selection process in early generations. One method used only HVI data for progeny selections, whereas the second used only AFIS data. Fiber properties of primary interest in this study measured by HVI included micronaire, UHML, uniformity index, strength, and elongation. AFIS measurements of interest were mean length by number, short fiber content, fineness, and maturity ratio. AFIS also provides fiber length distributions that were used as a critical part of the selection criteria for this research. Only fiber data (no yield components)

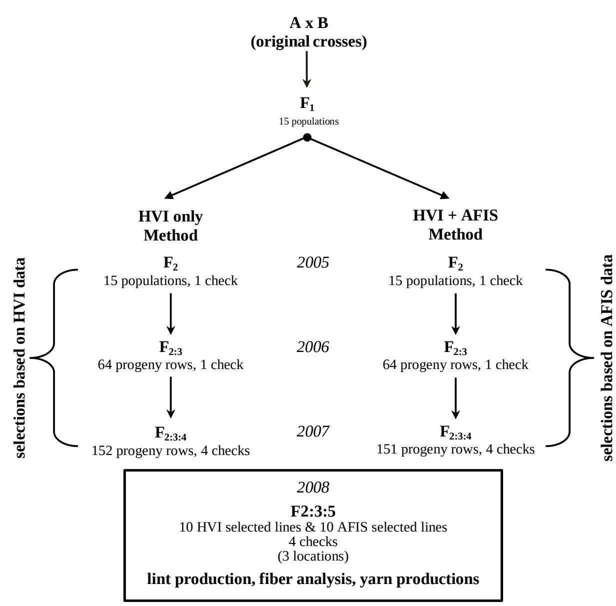

Figure 1. A summary of the study from the F_1 generation through the F_5 generation.

were considered during the selection process. Once the majority of family values were established as high quality, only individual plant data were used for selection. The first year of the study, 2005, consisted of two separate, identically designed field tests. The tests were planted side-by-side in a field at the Texas AgriLife Research and Extension Center in Lubbock, TX. Soil type at this location was an Acuff loam. Fifteen F_2 populations and one commercial cultivar were planted in a randomized complete block design utilizing four replications with two-row plots. Each plot was thinned to approximately five plants per meter about 30 d after emergence. Tests were irrigated and plot lengths were 9 m long and row width was 1.02 m. In the F_2 generation, samples used to determine progeny row means were collected by harvesting and bulking one boll per plant in each plot (Table 3). Individual plants were selected within the plots based on visual appeal of agronomic performance.

After harvest, selections were made based on fiber data. Selections were made in two phases for both field trials. First families and then individual plants within those selected families were chosen. Family selections were made based on the average fiber characteristics of the bulk family sample across replications as measured by HVI in one field trial and by AFIS in the other field trial. Plant selections were based on fiber characteristics of the individual plant in comparison to other plants within that same family. The AFIS-selection method utilized AFIS data including length distributions generated by AFIS as the main selection criterion. It should be noted that fiber samples in the AFIS test were measured by HVI as a comparison to standard technology, but only AFIS data were used in selection. Figure 2 illustrates differences between a desirable and undesirable length distribution (by number) based on the assumed desirable profile for high quality yarn production. A desirable length distribution was defined as having a low short fiber content and longer than average mean length by number signifying good fiber strength and maturity. There should be a single, well-defined peak that indicates length uniformity. Each set of material for the two selection methods was considered separately, resulting in two unique sets of selected plants for advancement: one selected on fiber characteristics measured by AFIS and the other selected on fiber characteristics measured only by HVI. Each selection method and the resulting entries were considered a separate test for the duration of the trial.

Table 3. Means, minimums, maximums and standard deviations for the 2005 F_2 progeny row boll samples for each selection method.

Fiber Property	Selection Method	N	Mean	Min.	Max.	Std.Dev.
micronaire	HVI	64	4.3	3.6	5.0	0.4
UHML (mm)	HVI	64	31.20	28.40	33.80	1.30
uniformity (%)	HVI	64	84.8	81.6	87.0	1.3
strength (kN m/kg)	HVI	64	316.8	290.3	353.1	15.7
elongation (%)	HVI	64	7.2	4.6	9.8	1.0
Lw (mm)	HVI	64	n/a	n/a	n/a	n/a
UQLW (mm)	HVI	64	n/a	n/a	n/a	n/a
SFCw (%)	HVI	64	n/a	n/a	n/a	n/a
Ln (mm)	HVI	64	n/a	n/a	n/a	n/a
SFCn (%)	HVI	64	n/a	n/a	n/a	n/a
fineness (mTex)	HVI	64	n/a	n/a	n/a	n/a
maturity	HVI	64	n/a	n/a	n/a	n/a
micronaire	AFIS	64	4.3	3.7	4.9	0.3
UHML (mm)	AFIS	64	31.00	27.70	34.30	1.50
uniformity (%)	AFIS	64	84.9	81.2	87.2	1.3
strength (kN m/kg)	AFIS	64	323.6	269.7	365.8	17.7
elongation (%)	AFIS	64	7.3	4.7	8.9	1.0
Lw (mm)	AFIS	64	27.20	24.60	31.00	1.50
UQLW (mm)	AFIS	64	33.00	30.00	37.30	1.80
SFCw (%)	AFIS	64	6.8	4.2	9.7	1.5
Ln (cm)	AFIS	64	2.21	1.91	2.57	0.15
SFCn (%)	AFIS	64	22.4	16.0	30.0	3.8
fineness (mTex)	AFIS	64	167	155	185	7
maturity	AFIS	64	0.90	0.85	0.97	0.03

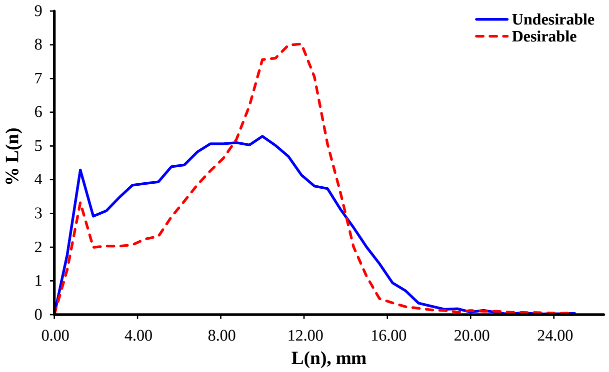

Figure 2. An example of a desirable and undesirable length distribution (by number).

In 2006, the F_3 generation was evaluated. Two tests with 64 $F_{2:3}$ progeny rows and two commercial cultivars were planted in a randomized complete block design with two replications and one-row plots. Each test consisted of only two replications with plot lengths of 6.1 m on 1.02-m rows. Plots were thinned to approximately five plants per meter around 30 d post-emergence. In the F_3 generation, progeny row fiber quality means were determined and individual plants were selected within the plots using the same method as in the F_2 generation. Selections in the F_3 generation were based on a higher standard for fiber quality because of the caliber of fiber quality compared to the previous year. For example, 2006 progeny row mean values for fiber strength averaged more than 350.0 kN m kg^{-1} for both sets of populations and had a minimum fiber strength value of 289.3 kN m kg^{-1} (Table 4). The average UHML in the HVI-selected lines was 34.11 mm. The UHML average for the AFIS-selected lines was 32.71 mm with the average length by number of 25.0 mm (Table 4). In 2005, the mean UHML for the HVI-selected lines was 31.20 mm (for boll samples) with a mean strength of 316.8 kN m kg^{-1} (Table 3). UHML of AFIS boll samples in 2005 was 31.00 mm with a mean strength of 323.6 kN m kg^{-1} (Table 3).

In 2006, there were not two distinct phases of selection. Progeny row means were of such high fiber quality, no lines were discarded based on progeny row means alone. All individual plants from all progeny rows were considered for advancement. Individual plants were selected by process of elimination, using the test average as a guideline. Plants that had fiber qualities below the test average in one or more traits were discarded until 152 HVI-selected plants and 151 AFIS-selected plants were chosen for advancement into the 2007 series of field trials.

Table 4. Means, minimums, maximums, and standard deviations for the 2006 $F_{2:3}$ progeny row boll samples for each selection method.

Fiber Property	Selection Method	N	Mean	Min.	Max.	Std.Dev.
micronaire	HVI	132	4.4	3.7	5.2	0.3
UHML (mm)	HVI	132	34.11	27.94	37.85	1.80
uniformity (%)	HVI	132	85.7	83.2	88.0	0.9
strength (kN m/kg)	HVI	132	357.2	297.2	438.4	27.1
elongation (%)	HVI	132	5.7	4.1	7.4	0.7
Lw (mm)	HVI	132	30.50	25.40	33.80	1.50
UQLW (mm)	HVI	132	36.30	29.70	40.10	2.00
SFCw (%)	HVI	132	4.1	2.5	6.5	0.8
Ln (cm)	HVI	132	2.54	2.13	2.84	0.13
SFCn (%)	HVI	132	16.3	11.2	23.7	2.6
fineness (mTex)	HVI	132	171	154	192	9
maturity	HVI	132	0.95	0.90	1.00	0.02
micronaire	AFIS	132	4.5	3.5	5.5	0.4
UHML (mm)	AFIS	132	32.71	27.43	37.85	2.00
uniformity (%)	AFIS	132	85.7	82.9	88.7	1.1
strength (kN m/kg)	AFIS	132	351.6	289.3	426.6	24.9
elongation (%)	AFIS	132	6.1	4.6	8.6	0.8
Lw (mm)	AFIS	132	29.55	25.15	33.78	1.60
UQLW (mm)	AFIS	132	34.73	28.70	40.13	2.10
SFCw (%)	AFIS	132	3.9	1.7	6.2	0.8
Ln (mm)	AFIS	132	25.00	21.60	28.20	1.40
SFCn (%)	AFIS	132	15.3	7.6	21.0	2.4
fineness (mTex)	AFIS	132	172	153	196	9
maturity	AFIS	132	0.95	0.87	1.02	0.03

Final Selection of Lines. In 2007, no boll samples were taken and no individual plant selections made in the field. There were 152 HVI-selected and 151 AFIS-selected $F_{2:3:4}$ progeny plots and four commercial cultivars planted in two separate field trials (one for each selection method). Each test was a randomized complete block with two replications, with one-row plots that were 9.4 m (row width, 1.02 m). Progeny rows were harvested using a mechanical stripper. We chose the 10 best lines from each set of populations based on fiber quality. Evaluations were based on the mean performance of the F_4 progeny row. The following fiber properties were used as selection criteria and considered in the following qualifying order for the HVI selected genotypes: micronaire, UHML, uniformity index, strength, and elongation. Plants were discarded with fiber values less than 3.8 micronaire, UHML of 32.00 mm, 84% uniformity index, 324.0 kN m kg^{-1} strength, and 7.5% elongation. Pedigrees were considered in the final selection criteria. Only one sister line from each family was advanced.

Selections for the AFIS method began with the evaluation of length (by number) distribution. In the first step, all lines with extremely undesirable length distributions were discarded. This consisted of length distributions with a high percentage of short fibers and an undefined peak (Fig. 2). Secondly, progeny rows were sorted by mean length by number (Ln) and short fiber content by number (SFCn). Lines with the longest fiber length combined with the lowest short fiber content were chosen for further assessment and eventual selection if fiber had a desirable length distribution. To further reduce the number of lines, a secondary criterion was established placing more emphasis on SFCn and fineness. The maximum fineness value was 175 mTex and the uppermost SFCn was 21.8%. Length distribution had to be superior, with a minimal number of short fibers and a well-defined peak, and no genotypes shorter than Ln 22.40 mm were selected. Pedigrees were considered in an effort to increase genetic diversity within the AFIS-selected lines.

Both HVI and AFIS selection methods resulted in lines with high fiber quality (Table 5). Individual lines had fiber strength as high as 379.04 kN m kg^{-1} and UHML of 34.67 mm. Lines from each selection method were advanced to the 2008 study.

F_5 Generation. In 2008, our goal was to produce enough lint for spinning trials rather than plant or plot evaluations. Therefore large plots were planted at Texas Tech University Research Farm in Lubbock, TX, on 13 May, a producer's field in Brownfield, TX on 13 May, and the Ag-CARES Farm in Lamesa, TX on 30 May. Soil type at Texas Tech University Research Farm was Acuff-Urban land complex. Brownfield and Ag-CARES soils were Amarillo fine sandy loam. Instead of tests for each selection method, there was a single trial with lines from both selection methods. The trial was composed of 24 entries, including 20 experimental $F_{2:3:5}$ lines (10 from AFIS selection and 10 from HVI selection) and four commercial cultivar checks. The commercial cultivars were 'FiberMax 958' (PI 619096), 'FiberMax 989' (PI 639508), 'DeltaPine 491' (PI 618609), and 'All-Tex Atlas' (PI 561579). The design was a randomized complete block with four replications. Each plot consisted of four rows with the following lengths: Brownfield , 10 m; Lubbock, 8.8 m; and Lamesa , 7.6 m. The row width was 1.02 m at all locations. Trials at the Texas Tech University research farm and Lamesa were grown with subsurface drip irrigation. The trial at Brownfield was grown under a center pivot irrigation system. Due to the timing of the first freeze in 2008, no harvest aids were applied. The two center rows of each plot were harvested using a mechanical stripper. The trial at the Texas Tech University research farm was harvested 5 November 2008. Trials at Lamesa and Brownfield were harvested 18 and 19 November respectively.

Samples were ginned individually by location and by plot. Ginning was performed in two phases because of large sample size, gin availability, and time constraints. In the first phase, samples were deburred using a two-saw cylinder stick machine and feeder-extractor at the Texas AgriLife Research and Extension Center in Lubbock, TX. In the next step, seed cotton samples were ginned at the USDA-ARS Cotton Production and Processing Research Unit in Lubbock, TX, with a modified 16-saw gin (Continental Gin Co., Birmingham, AL) equipped with extractor feeder (Continental Moss Gordin, Pratville,AL) and saw lint cleaner (Continental Gin Co.). Seed weight, lint weight, and ginning time were recorded for seed cotton from each plot. A 60-g fiber sample was taken from each plot after ginning. All lint from a plot stored and transported in a bale bag. Fiber samples were analyzed at the FBRI.

Table 5. Means, minimums, maximums, and standard deviations for the 2007 $F_{2:3:4}$ selected progeny rows for each selection method and the means for all selected whole rows.

Fiber Property	Selection Method	N	Mean	Min.	Max.	Std. Dev
micronaire	HVI	10	3.9	3.8	4.1	0.1
UHML (mm)	HVI	10	33.27	32.64	33.78	0.40
uniformity (%)	HVI	10	84.9	83.9	85.6	0.6
strength (kN m/kg)	HVI	10	341.23	324.12	367.76	13.09
elongation (%)	HVI	10	8.0	7.5	8.6	0.3
Lw (mm)	HVI	10	29.07	28.58	29.85	0.39
UQLW (mm)	HVI	10	35.22	34.29	36.07	0.49
SFCw (%)	HVI	10	5.9	5.2	6.6	0.5
Ln (mm)	HVI	10	23.14	22.23	24.00	0.58
SFCn (%)	HVI	10	22.3	19.2	25.0	1.8
fineness (mTex)	HVI	10	160	156	168	4
maturity	HVI	10	0.92	0.90	0.95	0.02
micronaire	AFIS	10	4.1	3.7	4.8	0.4
UHML (mm)	AFIS	10	31.81	28.45	34.67	1.84
uniformity (%)	AFIS	10	84.7	83.8	86.1	0.7
strength (kN m/kg)	AFIS	10	348.49	319.22	379.04	20.87
elongation (%)	AFIS	10	8.4	7.5	9.6	0.6
Lw (mm)	AFIS	10	28.40	26.42	29.85	1.04
UQLW (cm)	AFIS	10	33.71	30.61	35.81	1.59
SFCw (%)	AFIS	10	5.1	4.8	5.7	0.4
Ln (mm)	AFIS	10	23.42	22.23	24.26	0.57
SFCn (%)	AFIS	10	19.0	16.8	21.8	1.7
fineness (mTex)	AFIS	10	161	146	175	10
maturity	AFIS	10	0.91	0.89	0.94	0.02
micronaire	Both methods	20	4.0	3.7	4.8	0.3
UHML (mm)	Both methods	20	32.54	28.45	34.67	1.50
uniformity (%)	Both methods	20	84.8	83.8	86.1	0.6
strength (kN m/kg)	Both methods	20	344.86	319.22	379.04	17.36
elongation (%)	Both methods	20	8.2	7.5	9.6	0.5
Lw (mm)	Both methods	20	28.73	26.42	29.85	0.84
UQLW (mm)	Both methods	20	34.46	30.61	36.07	1.38
SFCw (%)	Both methods	20	5.5	4.8	6.6	0.6
Ln (mm)	Both methods	20	23.38	22.23	24.26	0.58
SFCn (%)	Both methods	20	20.6	16.8	25.0	2.4
fineness (mTex)	Both methods	20	161	146	175	7
maturity	Both methods	20	0.91	0.89	0.95	0.02

RESULTS

Fiber Analysis of Selected Lines. Results from this study include fiber analysis from F_5 lines generated using two fiber quality measurement methods throughout the selection process. Results of the F-test for entry were significant (.05 level) at all three locations for each of the following fiber properties: micronaire, UHML, uniformity, strength, elongation, mean length by weight (Lw), upper quartile length by weight (UQLw), short fiber content by weight (SFCw), length by number (Ln), short fiber content by number (SFCn), fineness, maturity, and standard fineness (Hs). A difference in the level of fiber quality was observed at each location. Average fiber micronaire of lines at Brownfield was lower (2.8) than was observed from lines tested at Lamesa and the Texas Tech research farm that had average micronaire of 3.5 and 3.9, respectively (Table 6). Differences among locations were evident in SFCn with means ranging from 22.3 to 31.9 (Table 6). A decline in fiber properties of individual lines was observed in response to environmental effect (Tables 7-12). Such variation in fiber quality was not unexpected (May and Jividen, 1999; Meredith et al., 1996; Wakelyn, 2007). For example, Entry 1 had an average Ln of 22.90 mm and

SFCn of 20.0 at the Texas Tech University research farm (Table 8) but Ln of only 20.10 mm and SFCn of 29.6 at Brownfield (Table 12). Such differences in fiber quality might be attributed to a decline in fiber maturity as indicated by micronaire and maturity ratio averages. Earlier studies recognized fiber maturity as a component of fiber strength and high correlations between fiber maturity and short fiber content (Meredith et al., 1996; Ulloa, 2006).

In addition to examining variation of fiber quality across environments, fiber properties were averaged for each selection method. According to HVI measurements, the HVI-selected lines were on average longer and stronger than the AFIS-selected lines. Length uniformity and micronaire were similar for both sets of lines. AFIS measurements indicate the HVI-selected lines have higher short fiber contents and are similar in length to the AFIS-selected lines when looking at mean length by number (Tables 13 and 14). Both groups of experimental lines (HVI and AFIS) proved to be better quality than the commercial cultivar checks for most fiber properties. Most of these trends are similar to those found in previous years.

At all locations, fiber from experimental lines was longer according to HVI and AFIS measurements and stronger than fiber from the commercial checks (Tables 13 and 14). Having stronger cottons based on HVI for all experimental lines could be surprising at first glance because we did not use tensile properties as a selection criteria for the AFIS-only test. These findings suggest that by improving fiber length distributions fiber strength was indirectly improved. Consistent with earlier generations, HVI-selected lines have UHML values higher than AFIS-selected lines entries. This is logical because for the HVI test we used UHML as selection criteria, whereas for the AFIS test we used the mean length. Data from samples from Lamesa had an average UHML of 33.20 mm for HVI-selected lines and an average UHML of 32.04 mm for the AFIS-selected lines (Tables 13 and 14).

The uniformity index means were similar for the two selection methods. Samples from Brownfield had an average uniformity index of 83.7 for both methods, whereas the uniformity index means varied no more than 0.1 for samples from the other locations. Average maturity ratios as measured by AFIS are identical between the selection methods in all locations as are the Ln values. Differences are evident when looking at short fiber content both by weight and number, with the HVI group having a greater short fiber content than the AFIS selected lines (Tables 13 and 14). It should be noted that cotton with longer fibers generally have fewer short fibers; however, our data revealed a better length distribution improvement for the AFIS-selected lines in comparison to the HVI-selected lines. The average UHML for the HVI group was longer with greater short fiber content than the AFIS group. Mean values for UQLw, Ln, and SFCn (Table 14) indicated greater variability (i.e., wider range) of fiber length in the HVI-selected lines than for AFIS-selected lines. The Ln was similar for both groups, but the longest fibers (upper 25%) for HVI-selected lines were longer than those for the AFIS-selected lines; however, HVI-selected lines also had more fibers shorter than 12.7 mm. Based on these mean values, it was expected that the AFIS-selected lines would have a more narrow length distribution than the HVI-selected lines. Despite the theoretical differences between the two measurement methods, selection criteria for both methods were stringent. The intensity of selection resulted in a high level of fiber quality regardless of selection method.

Table 6. Fiber property means, minimums, and maximums of fiber properties for the F_5 generation at each of the 2008 locations.

Fiber Property	N	Tech Farm			Lamesa			Brownfield		
		Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.
micronaire	96	3.9	3.2	4.4	3.5	2.6	4.2	2.8	2.3	3.5
UHML (mm)	96	32.49	29.72	34.54	32.31	29.97	34.54	31.77	29.21	33.78
uniformity (%)	96	84.8	82.1	86.0	84.1	80.8	85.7	83.4	80.2	85.2
strength (kN m/kg)	96	315.6	281.5	345.2	321.3	292.2	348.1	314.9	275.6	343.2
elongation (%)	96	8.7	7.7	9.9	8.4	7.6	9.4	8.6	7.5	9.8
Ln (mm)	96	22.85	19.05	24.89	21.70	17.78	24.38	19.73	16.26	21.84
SFCn (%)	96	22.3	14.3	32.7	25.3	18.7	36.7	31.87	26.30	43.10
fineness (mTex)	96	158	143	171	151	133	164	138.6	124.0	153.0
maturity	96	0.88	0.85	0.92	0.85	0.79	0.90	0.82	0.77	0.85
Hs (mTex)	96	178.3	164.4	190.0	176.3	162.2	188.5	169.23	155.00	182.14

Table 7. Entry means for HVI measurements of all $F_{2:3:5}$ lines at the 2008 Texas Tech farm location.

Entry	Method	Micronaire	UHML (mm)	Uniformity (%)	Strength (kN m/kg)	Elongation (%)
1	AFIS	4.1	30.92	84.9	296.9	9.1
2	AFIS	3.8	32.13	84.9	307.4	8.8
3	AFIS	3.8	32.26	85.3	308.9	9.3
4	AFIS	4.0	31.43	84.3	309.7	9.0
5	AFIS	3.8	33.27	85.6	333.2	8.4
6	AFIS	3.5	33.72	85.1	320.0	9.1
7	AFIS	4.0	30.99	83.9	304.0	8.9
8	AFIS	3.7	33.53	85.7	322.7	9.3
9	AFIS	4.2	30.10	84.7	312.4	9.1
10	AFIS	3.7	33.46	85.1	321.9	8.7
11	HVI	3.5	33.78	84.2	320.0	8.7
12	HVI	3.6	33.66	84.8	307.4	9.0
13	HVI	3.7	33.53	85.1	326.1	8.4
14	HVI	3.9	33.02	85.3	323.6	8.6
15	HVI	3.9	32.96	84.8	318.2	8.8
16	HVI	3.8	33.78	85.7	328.8	8.8
17	HVI	3.8	32.89	85.0	334.4	8.2
18	HVI	4.0	32.96	85.5	327.8	8.4
19	HVI	3.8	34.29	85.3	318.7	8.9
20	HVI	3.8	33.08	84.9	319.7	8.6
21	Commercial	4.0	31.50	84.6	308.2	8.1
22	Commercial	3.9	30.73	83.3	300.1	8.2
23	Commercial	4.2	30.80	83.9	309.2	8.6
24	Commercial	3.9	30.86	82.6	295.2	8.2
Test Mean		3.9	32.49	84.8	315.6	8.7

Table 8. Entry means for AFIS measurements of all $F_{2:3:5}$ lines at the 2008 Texas Tech farm location.

Entry	Method	Lw (mm)	UQLw (mm)	SFCw (%)	Ln (mm)	SFCn (%)	Fineness (mTex)	Maturity	Hs (mTex)
1	AFIS	27.94	33.21	5.5	22.86	20.0	163	0.88	185.8
2	AFIS	28.70	34.04	5.1	23.56	18.9	162	0.88	183.0
3	AFIS	28.58	33.85	4.7	23.88	17.7	157	0.87	180.2
4	AFIS	28.07	33.66	6.0	22.61	21.7	158	0.88	179.5
5	AFIS	29.40	35.50	5.9	23.30	22.7	159	0.90	176.6
6	AFIS	29.91	36.13	5.8	23.56	22.5	147	0.87	169.3
7	AFIS	27.69	33.27	6.7	21.97	23.6	162	0.88	183.9
8	AFIS	29.72	35.62	5.4	23.75	21.4	154	0.89	173.5
9	AFIS	26.54	31.62	6.4	21.65	22.0	164	0.89	184.2
10	AFIS	29.59	35.50	5.1	23.81	20.1	153	0.90	170.9
11	HVI	29.46	36.07	6.6	22.99	24.1	146	0.87	167.8
12	HVI	29.15	35.75	6.6	22.92	23.9	153	0.87	177.2
13	HVI	29.53	35.56	5.7	23.50	21.9	154	0.89	172.3
14	HVI	29.34	35.31	5.9	23.37	22.3	159	0.88	180.1
15	HVI	28.96	35.12	6.2	22.86	23.2	159	0.89	179.2
16	HVI	29.34	35.12	5.5	23.56	21.1	159	0.89	178.7
17	HVI	28.83	35.18	6.9	22.35	25.6	154	0.89	172.3
18	HVI	28.07	34.16	7.2	22.16	25.0	160	0.88	180.7
19	HVI	30.10	36.45	5.6	23.88	21.7	153	0.88	173.7
20	HVI	28.83	34.93	6.3	22.73	23.6	156	0.88	177.6
21	Commercial	27.69	33.40	6.6	22.03	23.5	162	0.90	181.0
22	Commercial	26.80	32.39	6.9	21.46	23.4	163	0.89	183.9
23	Commercial	27.05	32.45	6.7	21.78	23.0	165	0.89	184.6
24	Commercial	27.43	33.40	7.1	21.84	23.8	160	0.88	182.3
Test Mean		28.61	34.49	6.1	22.85	22.3	158	0.88	178.3

Table 9. Entry means for HVI measurements of all $F_{2:3:5}$ lines at the 2008 Lamesa location.

Entry	Method	Micronaire	UHML (mm)	Uniformity (%)	Strength (kN m/kg)	Elongation (%)
1	AFIS	3.8	31.18	84.8	308.7	8.6
2	AFIS	3.3	31.62	84.1	308.9	8.3
3	AFIS	3.7	31.62	84.7	316.5	9.1
4	AFIS	3.7	31.43	84.3	315.8	8.4
5	AFIS	3.6	33.02	85.0	341.0	8.1
6	AFIS	3.4	34.23	84.9	327.8	8.9
7	AFIS	3.7	30.54	82.9	306.0	8.5
8	AFIS	3.4	33.72	85.2	324.1	8.9
9	AFIS	3.9	30.04	84.1	331.0	8.6
10	AFIS	3.2	32.96	84.5	328.5	8.3
11	HVI	3.3	33.53	84.0	320.9	8.3
12	HVI	3.4	33.59	84.5	317.7	9.0
13	HVI	3.5	33.59	83.9	328.0	8.3
14	HVI	3.4	33.21	85.1	331.2	8.2
15	HVI	3.3	32.51	83.6	326.6	8.3
16	HVI	3.7	33.46	84.9	333.7	8.5
17	HVI	3.2	32.89	83.9	331.7	8.3
18	HVI	3.6	32.64	84.7	329.8	8.4
19	HVI	3.6	34.16	85.0	324.1	8.8
20	HVI	3.1	32.39	84.1	325.1	8.4
21	Commercial	3.5	31.50	83.9	320.4	7.9
22	Commercial	3.1	30.80	82.6	305.2	7.8
23	Commercial	3.7	30.67	83.7	310.1	8.3
24	Commercial	3.1	30.16	80.9	298.4	8.0
Test Mean		3.5	32.31	84.1	321.3	8.4

Table 10. Entry means for AFIS measurements of all $F_{2:3:5}$ lines at the 2008 Lamesa location.

Entry	Method	Lw (mm)	UQLw (mm)	SFCw (%)	Ln (mm)	SFCn (%)	Fineness (mTex)	Maturity	Hs (mTex)
1	AFIS	27.62	33.08	6.3	22.48	20.9	159	0.86	184.3
2	AFIS	26.99	32.83	7.2	21.65	23.3	151	0.84	178.6
3	AFIS	27.50	33.15	6.8	22.23	22.6	153	0.86	179.2
4	AFIS	27.62	33.66	7.0	21.97	23.8	153	0.86	178.2
5	AFIS	28.64	35.05	7.0	22.35	25.0	153	0.87	176.2
6	AFIS	29.34	35.81	6.3	23.05	23.1	144	0.86	168.2
7	AFIS	26.23	31.94	8.0	20.76	25.6	156	0.85	183.8
8	AFIS	29.15	35.37	6.4	23.05	23.1	146	0.84	173.0
9	AFIS	26.92	32.32	6.9	21.65	23.0	158	0.87	180.8
10	AFIS	28.26	34.54	7.0	22.16	24.1	141	0.85	165.3
11	HVI	28.51	35.18	7.9	21.78	26.7	146	0.86	169.6
12	HVI	28.58	35.37	7.5	22.16	26.0	150	0.86	175.2
13	HVI	28.64	35.24	7.3	22.10	25.7	147	0.86	171.1
14	HVI	28.45	34.99	7.2	22.16	25.3	151	0.86	176.6
15	HVI	27.24	33.66	8.7	20.89	28.1	149	0.85	174.6
16	HVI	29.02	35.50	6.5	22.86	23.7	156	0.87	179.1
17	HVI	27.88	34.29	7.7	21.65	25.7	143	0.85	169.0
18	HVI	27.94	33.85	6.6	22.29	23.2	156	0.87	179.3
19	HVI	29.27	35.69	6.3	23.05	22.9	154	0.86	179.4
20	HVI	27.56	33.97	8.1	21.34	26.7	146	0.84	173.2
21	Commercial	26.48	32.58	8.9	20.38	28.3	154	0.86	179.5
22	Commercial	25.53	31.94	10.5	19.49	30.6	146	0.83	176.9
23	Commercial	26.42	32.13	8.0	20.83	25.9	157	0.86	182.3
24	Commercial	24.57	31.18	12.4	18.42	34.1	146	0.82	178.9
Test Mean		27.68	33.89	7.6	21.70	25.3	151	0.85	176.3

Table 11. Entry means for HVI measurements of all $F_{2:3:5}$ lines at the 2008 Brownfield location.

Entry	Method	Micronaire	UHML (mm)	Uniformity (%)	Strength (kN m/kg)	Elongation (%)
1	AFIS	3.1	30.73	83.9	301.3	9.1
2	AFIS	2.9	31.37	83.5	304.0	8.6
3	AFIS	2.9	31.24	84.0	312.4	9.2
4	AFIS	2.9	30.80	83.3	313.1	8.7
5	AFIS	2.7	32.19	84.1	334.2	8.4
6	AFIS	2.8	33.08	83.8	328.0	8.9
7	AFIS	3.1	30.29	82.8	305.0	8.5
8	AFIS	2.7	32.83	84.3	313.6	9.1
9	AFIS	2.8	29.53	83.4	317.0	9.3
10	AFIS	2.6	32.26	83.6	317.7	8.6
11	HVI	2.8	33.46	83.2	319.2	8.7
12	HVI	2.8	33.27	84.1	314.8	9.3
13	HVI	2.9	33.27	83.8	324.3	8.6
14	HVI	2.8	32.70	84.4	329.3	8.5
15	HVI	2.6	31.94	82.6	313.3	8.4
16	HVI	2.8	32.77	83.9	328.0	8.6
17	HVI	2.8	32.45	83.9	330.3	8.9
18	HVI	2.9	32.39	84.3	328.8	8.5
19	HVI	2.7	33.15	83.3	325.3	9.1
20	HVI	2.7	32.19	83.3	320.4	8.4
21	Commercial	2.6	30.73	82.8	304.0	8.1
22	Commercial	2.4	30.23	81.5	288.1	8.0
23	Commercial	3.0	30.35	82.9	304.0	8.5
24	Commercial	2.4	29.72	80.6	283.4	7.7
Test Mean		2.8	31.77	83.4	314.9	8.6

Table 12. Entry means for AFIS measurements of all $F_{2:3:5}$ lines at the 2008 Brownfield location.

Entry	Method	Lw (mm)	UQLw (mm)	SFCw (%)	Ln (mm)	SFCn (%)	Fineness (mTex)	Maturity	Hs (mTex)
1	AFIS	26.10	32.13	9.6	20.00	29.6	145	0.83	176.1
2	AFIS	26.48	32.70	9.2	20.38	28.9	143	0.82	174.2
3	AFIS	26.48	32.58	9.2	20.32	28.8	140	0.82	170.4
4	AFIS	25.78	32.26	10.4	19.62	31.1	141	0.82	171.9
5	AFIS	26.80	33.72	10.1	20.00	31.6	139	0.83	167.4
6	AFIS	27.88	34.99	9.2	20.83	30.2	134	0.83	161.4
7	AFIS	25.40	31.56	10.8	19.05	32.4	147	0.83	178.5
8	AFIS	27.50	34.23	9.4	20.64	30.4	136	0.82	165.7
9	AFIS	24.64	30.29	10.1	19.18	29.6	141	0.82	171.7
10	AFIS	26.61	33.27	10.3	19.88	31.6	127	0.81	157.1
11	HVI	27.37	34.86	10.4	19.94	33.1	134	0.83	162.7
12	HVI	27.50	34.61	9.5	20.64	30.3	140	0.83	169.1
13	HVI	27.52	34.63	9.7	20.32	31.5	139	0.84	165.7
14	HVI	27.37	34.35	9.7	20.51	30.9	141	0.82	171.1
15	HVI	26.10	33.21	11.9	18.92	35.5	138	0.81	170.3
16	HVI	27.56	34.42	9.4	20.64	30.4	139	0.83	167.3
17	HVI	26.73	33.59	10.3	19.81	32.2	134	0.82	163.2
18	HVI	27.05	33.85	9.9	20.26	31.3	141	0.83	169.3
19	HVI	27.18	34.42	10.5	20.00	32.7	140	0.82	169.6
20	HVI	26.35	33.21	10.9	19.37	33.5	138	0.82	167.7
21	Commercial	25.08	31.69	11.7	18.73	33.2	137	0.80	170.4
22	Commercial	24.45	31.18	13.2	18.03	36.0	134	0.79	170.5
23	Commercial	25.46	31.56	10.4	19.30	31.3	146	0.82	177.2
24	Commercial	23.75	30.67	15.0	17.21	39.0	135	0.79	172.3
Test Mean		26.37	33.07	10.5	19.73	31.9	139	0.82	169.2

Table 13. Mean values of HVI measurements for each selection method in the F_5 generation and commercial varieties at each of the 2008 locations.

Location	Method	Micronaire	UHML (mm)	Uniformity (%)	Strength (kN m/kg)	Elongation (%)
Brownfield	AFIS	2.8	31.43	83.7	314.6	8.8
Brownfield	HVI	2.8	32.75	83.7	323.4	8.7
Brownfield	Commercial	2.6	30.26	81.9	294.9	8.1
Brownfield	All	2.8	31.77	83.4	314.9	8.6
Lamesa	AFIS	3.6	32.04	84.4	320.8	8.6
Lamesa	HVI	3.4	33.20	84.3	326.9	8.4
Lamesa	Commercial	3.4	30.78	82.8	308.6	8.0
Lamesa	All	3.5	32.31	84.1	321.3	8.4
Texas Tech farm	AFIS	3.9	32.18	84.9	313.7	9.0
Texas Tech farm	HVI	3.8	33.39	85.0	322.5	8.6
Texas Tech farm	Commercial	4.0	30.97	83.6	303.2	8.3
Texas Tech farm	All	3.9	32.49	84.8	315.6	8.7

Table 14. Mean values of AFIS measurements for each selection method in the F_5 generation and commercial varieties at each of the 2008 locations.

Location	Method	Lw (mm)	UQLw (mm)	SFCw (%)	Ln (mm)	SFCn (%)	Fineness (mTex)	Maturity	Hs (mTex)
Brownfield	AFIS	26.37	32.77	9.8	19.99	30.4	139	0.82	169.4
Brownfield	HVI	27.06	34.10	10.2	20.03	32.1	138	0.82	167.7
Brownfield	Commercial	24.69	31.27	12.6	18.32	34.9	138	0.80	172.6
Brownfield	All	26.37	33.07	10.5	19.73	31.9	139	0.82	169.2
Lamesa	AFIS	27.83	33.78	6.9	22.14	23.4	151	0.86	176.8
Lamesa	HVI	28.31	34.77	7.4	22.03	25.4	150	0.86	174.8
Lamesa	Commercial	25.75	31.96	10.0	19.78	29.7	151	0.84	179.5
Lamesa	All	27.68	33.89	7.6	21.70	25.3	151	0.85	176.4
Texas Tech farm	AFIS	28.61	34.24	5.7	23.09	21.1	158	0.88	178.7
Texas Tech farm	HVI	29.16	35.36	6.2	23.03	23.2	155	0.88	175.9
Texas Tech farm	Commercial	27.24	32.91	6.8	21.78	23.4	162	0.89	183.0
Texas Tech farm	All	28.61	34.49	6.1	22.85	22.3	158	0.88	178.3

DISCUSSION

A total of 24 lines were selected for spinning tests in 2008. The lines included 20 F_5 lines, 10 from each selection method, plus four commercial check cultivars. Based on fiber data from 2005 through 2007, fiber length distributions were modified through breeding. Both selection methods resulted in a reduction of short fiber content and an increase in fiber maturity compared to the checks and lines from earlier generations. Modification in these and other fiber properties was evident in 2008 fiber data including length distribution.

At all locations, the average length distribution for breeding lines was more desirable than fiber from the commercial cultivars tested in this study (Figs. 3, 4, and 5). Breeding lines exhibited longer Ln and a lower percentage of short fiber in comparison to the commercial cultivars. Average length distributions varied across locations; Texas Tech Research farm had the most desirable and Brownfield had the least desirable length distributions. Length distributions for Brownfield exhibited the effects of lower micronaire and maturity ratios. Distributions had higher short fiber contents, shorter mean length, and a less defined peak than the other locations (Fig. 5).

PCA revealed length distribution of fibers fell into two distinct clusters: group 1 includes most of the HVI-selected lines, whereas group 2 includes most of the AFIS-selected lines (Figs. 6, 7, and 8). At the Texas Tech University Research farm, PC1 and PC2 accounted for 98% of the total length distribution variation and could be used to distinguish between length distributions for each of the selection methods and commercial cultivars. Means for AFIS fiber properties of the two selection methods were similar, Ln and maturity ratios were not different between the groups at all locations and SFCn never differed more than 2.1% among selection methods. Yet, PCA analysis demonstrated differences among the average length distribution of the groups (HVI, AFIS, and commercial cultivars). These differences were most evident at the Texas Tech University Research Farm (Fig. 6).

There were three distinct groups of length distributions: HVI-selected lines, AFIS-selected lines, and check cultivars (Fig. 6). There were two HVI-selected lines located among the AFIS-selected lines that indicated the length distributions of these lines were more like the AFIS-selected lines than other HVI-selected lines. It was also interesting to note HVI-selected lines were on the negative side of the PC1 axis, the same as the commercial cultivars. Groupings were not as clear at Lamesa (Fig. 7) and Brownfield (Fig. 8), but some separation did occur. At Lamesa, HVI-selected lines were in a tighter cluster than AFIS-selected lines or commercial cultivars. Average length distributions at Brownfield did not separate into three distinct groups, but differences among the two selection methods and commercial cultivars could be seen. This might be a result of lower fiber maturity at Brownfield in comparison to the other locations (Krifa, 2006). Fiber maturity affects length distribution, because immature fibers are more likely to break during ginning. This fiber breakage changes the original length distribution. The effect of maturity on length distribution was observed when PCA results were contrasted across locations. Cotton fiber from the Texas Tech University Research Farm, which had the greatest fiber maturity, also had differences among lines for fiber length distribution. At Brownfield, fiber had the lowest fiber maturity and the least distinction among the three groups for fiber length distributions of any location. When low fiber maturity occurs, differences among fiber length distributions are often the result of environmental effects more than genetic differences. This is related to fiber maturity being highly influenced by the growing environment as reported by May and Jividen (1999).

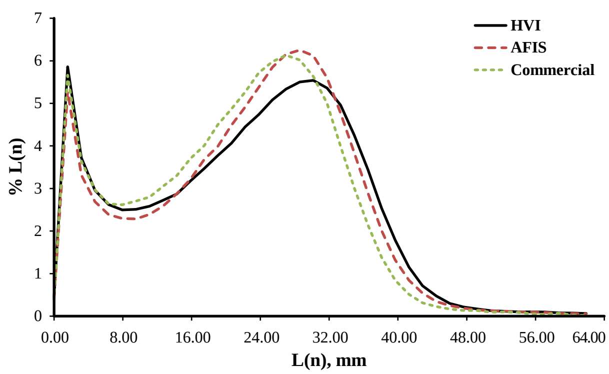

Figure 3. Average length distribution (by number) for each selection method and the commercial cultivars at the Texas Tech University Research Farm in 2008.

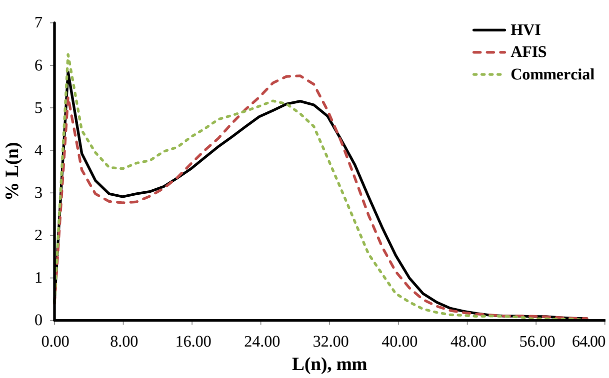

Figure 4. Average length distribution (by number) for each selection method and the commercial cultivars at Lamesa, TX, in 2008.

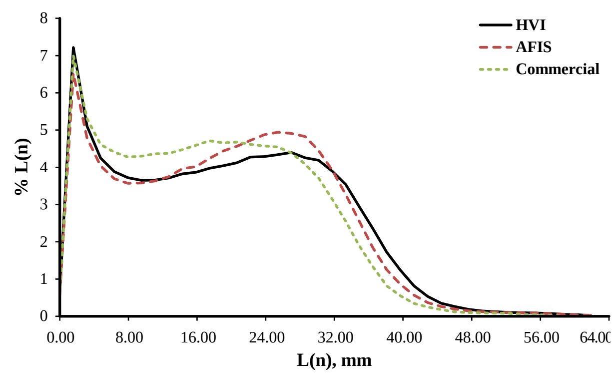

Figure 5. Average length distribution (by number) for each selection method and the commercial cultivars at Brownfield, TX, in 2008.

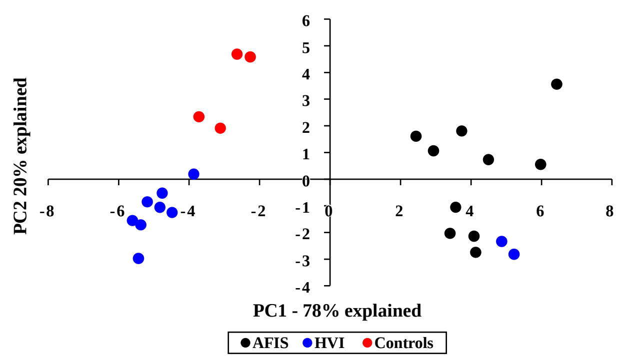

Figure 6. Principal component analysis for average length distributions of HVI-selected lines, AFIS-selected lines, and commercial cultivars at the Texas Tech University Research Farm in 2008.

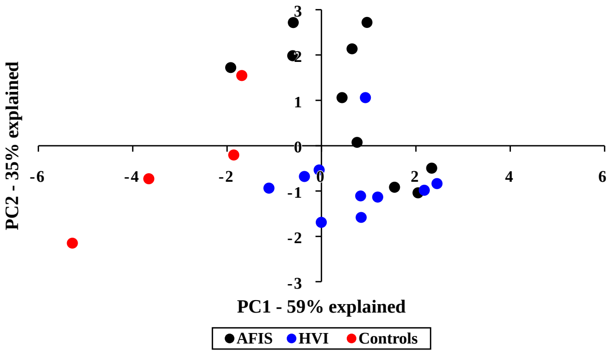

Figure 7. Principal component analysis for average length distributions of HVI entries, AFIS-selected lines, and commercial cultivars at Lamesa, TX, in 2008.

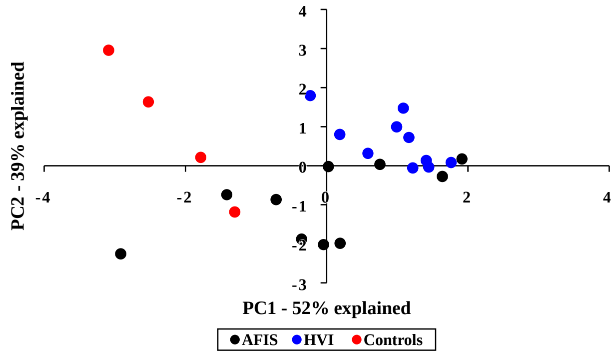

Figure 8. Principal component analysis for average length distributions of HVI-selected lines, AFIS-selected lines, and commercial cultivars at Brownfield, TX, in 2008.

CONCLUSIONS

According to data from this research, it is possible to modify cotton fiber length distribution through plant breeding efforts. Fiber length distribution for F_5 breeding lines for both selection methods was better than fiber length distribution of commercial check cultivars, and the distribution improved over the F_2 averages. Short fiber content was reduced and fiber length and fiber maturity were increased using both selection methods. It was also determined that selecting for an improved fiber length distribution, as was accomplished in the AFIS method, indirectly selects for improvement of other fiber properties such as fiber maturity and strength, explaining why an HVI strength improvement occurred for the AFIS selections despite it not being a trait under direct selection. Other studies have looked at gene action controlling fiber length distribution and heritability of length uniformity (Braden, 2005; Smith et al., 2010). The results support the hypothesis that fiber length distribution is heritable and could be altered through breeding efforts. However, these studies did not examine the ability to select for desirable fiber length distribution within a breeding program or the effect this could have on textile performance.

Differences in fiber quality were minimal between the two selection methods even though selection criteria for each method were different. These results were unexpected given the additional detailed fiber information offered by AFIS measurements, but might be explained by the way the fiber data was interpreted. The HVI method had less data available than the AFIS method; however, by focusing on length uniformity in addition to UHML and fiber strength, the HVI method enabled us to modify fiber length distributions. The effectiveness of HVI selection was comparable to using fiber length distributions provided by AFIS measurements. Knowledge of AFIS data and fiber length distributions were used to interpret and apply HVI data during the selection process. This approach was different from only using fiber length and strength data as selection criteria. Both selection methods focused on selecting lines with a balanced fiber quality profile. Cottons with balanced fiber profiles should exhibit superior spinning performance and yarn quality. These findings illustrate the importance of fiber data interpretation and application in a breeding program, regardless of the source.

Future Work. A second hypothesis for this research was the possibility of improving spinning performance and yarn quality by selecting for a favorable fiber length distribution. If this is true, the experimental lines should exhibit spinning performance and yarn quality superior to the commercial cultivars in this study. The effect of a balanced fiber profile on spinning performance and yarn quality for F_5 lines from each of these selection methods will be explored by this research team.

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