1555 Improving the Efficiency of Breeding Programs for Fiber and Yarn Quality

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Abstract

The purpose of this selection study is to compare the use two selection methods, one using HVI data only and one using HVI plus AFIS data. The study begins with fifteen intraspecific F_2 populations that will undergo a series of selections through the F_4 generation. Fiber data from the second year of the study are presented and progress of the two selection methods is discussed.

Introduction

Traditionally cotton breeders have used HVI (High Volume Instrument) as their only source of fiber quality data when making plant selections. Because the demands that breeders face and the expectations concerning fiber quality are intensifying, this method of determining which plants to keep needs further evaluation. Breeding programs must prove to be efficient and up to date if they are going to remain competitive as an integral part of the cotton industry. As the cotton industry changes, breeders must think globally and continually strive to be proactive rather than reactive. The purpose of this study is to provide data that will encourage the inclusion of AFIS (Advanced Fiber Information System) data in breeding programs as well as demonstrate the value of such data.

The efficiency of selections made in breeding programs using two different methods will be compared. One method uses only HVI data for progeny selections, and the second method uses both HVI and AFIS data for progeny selection. Length measurements based on number as opposed to weight, short fiber content, fineness, and maturity ratios are all measurements that are offered by AFIS and not offered by HVI. More specifically, AFIS provides fiber length distributions that will be used as a critical part of the selection criteria for this test.

There are data supporting the theory that AFIS may be an effective tool in predicting spinning performance and yarn quality (Hequet et al., 2007). The ability to select for end performance would be a valuable tool for breeders. Evaluating end performance of the lines is a long-term goal of this study, but only the first two years of research will be presented in this paper.

Literature Review

Fiber traits of raw cotton and their relationship with yarn characteristics is a popular and controversial topic among breeders. For many years, there have been attempts to predict the spinning performance and yarn quality of raw cotton. Latimer, Wallace, and Calhoun (1996) acknowledge this need to evaluate cotton fiber. Producing cotton fiber of a certain "type" has been a goal for some time, for both producers and breeders. Not until recently has it been so important that the "type" of fiber produced be the kind sought after by the textile industry. Deussen (1992) reveals that there is a "growing awareness" in the U.S. that the welfare of the cotton production industry is very closely related to the welfare of the textile industry. This is an important relationship for all who are involved in the cotton industry, but especially important to breeders.

Improving fiber quality is a popular objective for breeding programs, but is not usually the primary objective (Culp and Harrell, 1973; May and Jividen, 1999; Calhoun and Bowman, 1999). For most breeders, improving yield is the first priority (Bowman, 2000). Studies report that some breeders do focus their research on fiber quality and its importance to the textile industry (Meredith et. al, 1991; May & Taylor, 1998; May & Jividen, 1999; Meredith et. .al, 1996; El-Zik & Thaxton, 1992; Calhoun and Bowman, 1999). Even though most breeders are aware of the need for high quality fiber with good textile performance, most breeding programs are still incomplete in this area. There are also areas of research that are incomplete and needing more attention (Hequet, 2007). Studies regarding fiber quality and the measurement of it do exist, and they do offer some valuable information. However, there are still many unanswered questions. Another problem is many of the studies available are lacking in the understanding and appreciation of certain fiber properties (Hequet, 2007).

A study done by May and Taylor (1998) focused on genetically improving yarn tenacity by selecting for a given set of fiber properties. The goal was to determine which fiber properties constituted the best selection criteria either in combination or individually. The Stelometer, Fibronaire, Fibrograph, and Arealometer measured the fiber properties being compared. This research pointed out that selecting for fiber tenacity alone is not always the answer to higher yarn tenacity. At the time of this study, it was reported to be the first study of this kind. They also discussed the economic significance of predicting yarn quality based on fiber properties. Testing of fiber properties is much cheaper than testing of yarn properties. This makes it much more feasible for breeders to do fiber testing at early stages and save yarn testing for only a limited amount of cottons in the later stages of a program. Heritability values of the fiber properties were also calculated and compared. It was found that 50% span length was the best single fiber prediction of yarn tenacity. They discussed that selecting for one trait indirectly selects for other correlated traits. High elongation values were said to show the least amount of gain in yarn tenacity (May and Taylor, 1998). Although not discussed in the paper, this negative relationship of elongation and yarn tenacity may be the result of fiber immaturity. Immature fibers tend to have high elongation values, but are lacking in strength that is needed to produce high yarn tenacity. Their conclusion was that selecting for low micronaire, long 50% span length, and high tenacity fiber, resulted in the most gain in yarn tenacity. The authors mention the AFIS and some of its measurements as being valuable tools for improving yarn tenacity. They state that AFIS measurements should be examined further, and be considered for use as selection criteria. Green and Culp (1990) researched the ability to simultaneously improve yield, fiber quality, and yarn strength. This study looked at combining ability (specific and general), parent selection, and choice of fiber measurement instruments. The instrument comparisons were between standard laboratory instrumentation (SLI) measurements and High Volume Instrument (HVI) measurements. One objective of the study was to demonstrate which method of fiber evaluation would be more valuable for population improvement in breeding programs. Their data showed that there is no significant general combining ability affects for any of the HVI traits. HVI did not appear to be capable of detecting small differences in fiber traits. Because of this, it was concluded that HVI was not useful for improving quantitative traits (Green and Culp, 1990). A conclusion from this study was that HVI was not as valuable to breeders as it was to the textile industry for which it was designed. This conclusion was probably valid in 1990, but is probably not valid today. Indeed, HVI technology was not yet mature at that time.

Studies such as those previously mentioned are of value and interest because they do show attempts to predict yarn quality based on raw fiber characteristics. Although these studies compared the various fiber properties and their ability to predict yarn tenacity, there were no definitive answers. There is still the ongoing question of which fiber properties should a breeder select for in order to improve yarn quality. When discussing yarn quality, it is important to note that tenacity is not the only attribute that should be addressed. Unfortunately, most of the previous research has only been concerned with yarn tenacity. Textile mills must meet different demands for yarn quality depending on the end product. Yarn tenacity is important, but there are additional yarn characteristics that are as important, such as thick and thin places (Price, Calamari, and Tao, 1999; Calhoun and Bowman 1999,). It is crucial to be aware of what the textile mills need to meet their concerns that go beyond yarn quality, for example efficiency of processing. The impact of raw fiber properties upon yarn properties and spinning performance should be addressed if breeders are going to develop cottons that will be desirable to the textile industry.

Another study conducted by Meredith et. al (1996) compared the association of fiber properties measured by AFIS and those considered conventional breeder's measurements. Seven conventional measurements considered were yarn tenacity, bundle strength, 2.5 %

span length, uniformity, micronaire, Arealometer maturity, and Arealometer perimeter. AFIS measurements presented were nep number, nep size, 2.5% span length, short fiber content, micronaire, maturity ratio, and diameter. Another objective was to determine the variance components for the different fiber properties. The authors did infer that AFIS data has a high genetic repeatability. There were both negative and positive correlations found among fiber traits. The authors point out that selecting for finer fibers (the unit for fineness is millitex = mass in mg of 1,000 meters of fibers) would result in an increase in neps and short fibers. This problem of neps is more likely related to fiber maturity than it is to fiber fineness. Many times fibers appear to be very fine when they are not. Instead, they are very lightweight, immature fibers. The authors did state that AFIS could be useful for selecting cottons with lower short fiber content. The recognition of AFIS as a viable tool for selection was an important part of this study.

Earlier studies (Culp and Harrell, 1973) were interested in improving fiber quality. However, at this time, fiber length and strength, with the emphasis being on strength, were the fiber properties receiving the most consideration. Studies that are more recent have begun to acknowledge the importance of additional fiber properties (May and Jividen, 1999). Awareness of other fiber properties is the result of relationships that were known but often ignored by many breeders. Meredith et. al (1991) states that much of the fiber property variations found at the textile mill have genetic origins. Therefore, it is essential that breeders improve fiber quality in addition to yield in order to have cottons that are appealing to the textile mills. Having high quality fiber is the key to U.S.

cotton's competitive edge, and attractiveness in today's global market (Braden and Smith, 2004; Deussen 1992).

In the early 1970's, the opinion of certain researchers was that producing high quality cotton was not a priority, because the financial incentives to do so were considered inadequate. They felt that this was something that might be a future priority for the cotton industry in years to come (Baker and Verhalen, 1973). However, this "future" time has arrived and it is time to be very concerned about producing cottons with premium fiber. There have been advances in the quality of cotton produced, but the demands placed on fiber quality are also constantly intensifying. This intensity of rising demands comes from improvements in spinning technology and the competitiveness of the world market. Improvements have been made for the fiber quality traits that are currently evaluated, so current and past methods of breeding are considered to be successful thus far (Benedict, Kohel, and Lewis, 1999). Nevertheless, breeding programs must prove to be efficient and effective while striving to meet the demands of producers and the textile industry if they are going to remain competitive as an integral part of the cotton industry.

There is a paucity of information focusing on the use of AFIS data and the benefits of using it in breeding programs. However, previous research recognizes 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). No studies were available which compared using HVI only and versus the combination of HVI and AFIS data for making selections in a breeding program. It was also difficult to find studies with the objective of improving multiple yarn properties, not just tenacity, in a breeding program.

Objectives

The objective of this project is to compare the efficiency of a breeding program using only HVI versus using HVI and AFIS data when making plant selections, starting with the F2 generation. Selections will be made and lines will be evaluated through the spinning process. In the final stages of the project, the progress of each selection method (one set of fiber data vs. two sets) will be compared.

Materials and Methods

The first year of the study, 2005, consisted of two separate, but identical (in design) field tests. Fifteen intraspecific 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 one plant every 203.2 mm (8 in.). Plot lengths were 9 meters (29.5 ft). Bolls samples for family means were obtained by picking one boll per plant. Individual plant selections (IPS), sixteen per plot, were made based on agronomic performance and appearance. The harvested samples, both boll samples and individual plants were ginned on a small, table-top, saw gin. Check samples were ginned every fifty samples to evaluate the consistency of gin function. Humidity and temperature readings were taken in the ginning area once every minute. Ginning performance was tested and environmental conditions were documented due to the possible affects both could have on fiber quality results. Fiber samples from one test underwent fiber analysis on both the Advanced Fiber Information System (AFIS) and High Volume Instrument (HVI). The other set of fiber was only tested with HVI. All fiber analyses were done by the Texas Tech University International Textile Center at Lubbock, TX. Selections were made in two phases, first families, and then individual plants within the selected families. Family selections were made based on the average fiber characteristics across replications. Plant selections were based on key fiber characteristics of the individual plant in comparison to other plants (both within a family and across families). The test utilizing both HVI and AFIS data included length distributions as selection criteria in addition to the other AFIS data. Each of the two tests was considered separately, resulting in two unique sets of selected plants for advancement. Each selection method and the resulting entries will be considered a separate test for the duration of the trial.

In 2006, sixty-four F_3 populations and two commercial checks were planted in a randomized complete block design with two replications and one-row plots. Plots were thinned to approximately one plant every 203.2 mm (8 in.). Replication number and plot size were small due to limited seed supply. Each test consisted of only two replications with plot lengths of 6.1 meters (20 ft.). Again, boll samples were harvested for family means, and individual plants were selected. More emphasis was put on the agronomic performance of plants; therefore, there was not a predetermined amount of plants selected per row. Ginning and fiber analyses were conducted using the same protocol as the previous year. Fiber analyses differed some from the previous year. All fiber samples from both tests underwent both HVI and AFIS analyses. The AFIS data were needed for the HVI only test so comparisons could be made. The AFIS data for the HVI only test were not used for selections. It was only used for comparisons after selections were made. The selections based on fiber characteristics were done differently than the previous year, because of the caliber of fiber quality that was present. For example, 2006 family values for strength averaged 353.1 kN m kg^{-1} (36 g/tex) for both tests with a minimum of 289.3 kN m kg^{-1} (29.5 g /tex). The average upper half mean length (UHML) for families in the HVI only test was 34.04 mm (1.34 in.). The UHML average for the HVI plus AFIS test was 32.77 mm (1.29 in.) with the average length by number being 24.89 mm (.98 in.). In 2006, there were not two distinct phases of selection. Family means were of such high quality, no family was discarded based on family means alone. Therefore, all individual plants from all families were considered for advancement. At this point, plant selection was made by a process of elimination. The appropriate fiber characteristics (for each method) for individual plants were used for a series of selections. Plants that performed below average in one or more traits were discarded until a manageable number of lines were chosen for the 2007 test. There were 151 plants selected for the HVI and AFIS method, and 153 plants chosen for the HVI only method.

Results and Discussion

Two important questions that can be addressed with the current data available are, 1) Is there a difference in fiber quality between the two tests?, and 2) Have the selections been successful up to this point in terms of improving fiber quality?. To illustrate apparent differences, distributions of fiber traits have been presented for both the subset of selected plants and the entire population of all plants prior to selection. Chi-squared tests were used to identify statistical differences between the two test distributions for each fiber trait.

<u>Length & Related measurements (weight based)</u>

One major difference between HVI and AFIS is that several measurements recorded by HVI are weight based, as where AFIS provides additional measurements that are based on number of fibers. Weight based measurements provided by AFIS are upper quartile length by weight (UQLW) and mean length by weight (LW). HVI provides upper half mean length (UHML) and length uniformity index (uniformity, UI). When looking at the length measurements based on weight (UQLW, LW, and UHML) as illustrated in Figures 1 and 2, the HVI only test appears to have better plants in terms of length. This difference is visible in both data sets (all plants, and selected plants), but is more obvious in the selected plants. Chi-squared values (Table 1) indicate there are significant differences between the distributions for the two tests, both for the original plant set and the selected plant set, for the UHML, LW, and UQLW values. The UQLW distribution for the HVI only tests shows more change between the original plant set and the selected plants than the HVI plus AFIS test. This is not surprising because UHML was the only length measurement used for the HVI only selections and UQLW and UHML are very highly correlated. The other two weight based measurements related to length are length uniformity and short fiber content (SFCW). For these traits, there are more plants with favorable values in the HVI plus AFIS test. This test has more plants with lower SFCW and fewer plants with a low uniformity index. This is also true when considering all plants, but is more apparent after selections were made, as illustrated by the SFCW histogram in Figures 3 and 4. It is notable that in the distribution of selected plants there are no plants in the bottom three uniformity bins or the upper six SFCW (Figure 4) bins for either test. Plants within an undesirable range for these traits were eliminated. Of greater interest, is the fact that more plants were eliminated from a larger range in the HVI plus AFIS test. There are not any plants with SFCW values above 6.5 % while the HVI only test has plants in all bins up to 8.0 %. Regarding uniformity, there are fewer plants in the HVI plus AFIS test with values below 85.5 % than are in the HVI only test. This is of interest because plants were not discarded solely because of either of these measurements. Since these two traits were not individually considered as selection criteria. Plants with high SFCW were eliminated because of poor fiber length distributions, while plants with low UI were probably eliminated indirectly through the elimination of low micronaire plants.

Length & Related measurements (number based)

Plant distributions for the other length and short fiber measurements based on number are different than the ones obtained from the by weight measurements. These length parameters, length by number (LN) and short fiber content by number (SFCN) show the HVI plus AFIS test to be better. Once again, this development is apparent in both plant sets, but is more evident in the selected set. For the selected plants, the dominant group in the HVI only test is the 24.89 mm (.98 in.) bin with 16% of the plants, while the largest group in the HVI plus AFIS test is the 25.4 mm (1.00 in.) bin with 25% of the plants. Another obvious difference between the two tests is that there is a lower upper limit for SFCN in the selected plants with no plants having more than 21.5 % short fibers by number. There is also a visible difference in the lower limit for LN for the two tests.

The Chi-squared values (Table 1) were significant for both SFCN and LN for the selected plants. Therefore, there were differences for those two traits between tests. These differences are the result of the two selection methods since neither measurement was available in the HVI only test. The original plant set was only significantly different between tests for the SFCN values. This difference between the two tests before selections is an indication that the previous years' selections had been successful. The HVI plus AFIS test having fewer plants with high SFCN supports the idea that this trait is heritable and can effectively be used as a selection criteria. If this continues, the 2007-2008 population will have an even lower SFCN average. It is critical to notice the different performance of each test depending on which group of measurements is considered (by weight versus by number). Progress from previous selections is evident when comparing all plants for both tests, because of a difference in length properties between the two tests. This year's improvements are apparent when comparing the selected plants to the original set of plants.

Strength and Elongation

The HVI measurements of strength and elongation were used as selection criteria for both tests. Both tests were given a lower limit for strength of 304 kN m kg^{-1}(31 g/tex). This is apparent when comparing the entire plant population in Figure 5 to the selected population in Figure 6. No definite patterns were seen with elongation values, other than the selected plants had fewer plants in the lower ranges. These two traits showed very little variability between tests. For these two measurements, little discrepancy between the two tests is expected because the HVI measures them both and AFIS does not offer an individual measurement that is comparable. Differences that occurred in the plant distribution were possibly a result of selecting for other traits such as fiber maturity. A mature fiber generally is stronger than a similar fiber with less maturity. Maturity and other related measurements may explain many of the observations previously discussed.

<u>Fiber Maturity</u>

One trait that is of particular interest, because of developments that occurred in these data, is fiber maturity. Improving fiber maturity is especially important to the Texas High Plains cotton industry. Many times cottons grown in this area have fiber properties that would be appealing to a textile mill if it were not for the low micronaire values. As seen in Figure 7, it is not uncommon for a large percentage of the cotton grown in this area to have low micronaire. Improving fiber maturity, in addition to other fiber traits being superior, would give West Texas cotton a much needed competitive edge. There were obvious differences between tests for several maturity related measurements. In the beginning, micronaire was the sole trait used for the first round of elimination for both tests. Any plant with a micronaire value below 3.5 was discarded. In the HVI only test, plants with a micronaire above 5.0 were also rejected. In the HVI plus AFIS test, some plants above 5.0 were selected based on other measurements. In Figure 8, there are a higher percentage of selected plants with micronaire values in the 3.5-4.0 range in the HVI only test than remain in the HVI plus AFIS test. This range is not considered discount, but these values are low enough to indicate the possibility of fiber immaturity. This becomes evident when looking at the maturity ratios for the selected plants (Figure 9) in the HVI only test. There are a high percentage of plants that should not have been selected because of their maturity ratios. It is important to remember, that for selection purposes, micronaire was the only means of determining maturity for the HVI only test. Micronaire is an indicator but not a direct measurement of maturity. Therefore, several of the plants with the same micronaire may have had different maturity ratios. This explains the lack of high maturity ratios in the HVI only test. The most important result that was seen in these data is an overall increase in maturity for the HVI plus AFIS test. Even before this years selection process, the HVI plus AFIS test had a higher percentage of plants with high maturity ratios than the HVI only test. This increase in maturity is not only coming from direct selection of high maturity ratios, but is also a result of selecting for good length (by number) distributions. Plants with mature fibers tend to have better length distributions than plants with less mature fibers. When discussing fiber maturities, there are two other related fiber traits that should be considered, fineness and standard fineness.

Fiber Fineness

Fineness values for all plants from both tests do not exhibit obvious differences. However, chi-squared values in Table 1 showed that the two tests are significantly different. The selected plant's data (Figure 10) show that the HVI only test has more plants with finer fibers. It is important to remember these fineness measurements may be skewed by differences in fiber maturity, which means these plants may not truly have finer fibers. The fineness measurement is based on weight; therefore, an immature fiber will have a lower fineness value. Instead of having finer fibers, the HVI only test may have more plants with less mature fibers. Maturity is also a likely explanation for why the lower fineness limit differs between all plants and the selected plants. There are no selected plants with fineness values below 148 for either test, because anything lower was indirectly eliminated based on micronaire or maturity values. Fineness values were not used as an individual selection criterion and were not available for the HVI only selection process. Because of the concerns with fineness values, it is important to look at standard fineness. Standard fineness (Hs = fineness/maturity) gives and indication of fiber fineness while accounting for maturity. For this trait, there was no significant difference between the two tests for all plants. However, there was an obvious visual and statistically significant difference between the two tests for the selected plant set (Figure 11). Once again, the HVI only test appears to have more plants with finer fibers than the HVI plus AFIS test. Since maturity is accounted for with Hs, these low values may be accurate and a result of selecting for other traits. Often, longer and stronger fibers have the tendency to be genetically finer (smaller fiber diameter). This relationship between traits most likely explains the distribution of fineness for the HVI only plants. Because the main traits that were emphasized for selection in this test were length, strength, and micronaire, it is probable that some of these plants would also have finer fibers.

Length Distribution

One selection criteria that has been mentioned in relation to most other fiber quality parameters is the length (by number) distribution. Length by number distribution is made available by AFIS and played a very important role in the selection process for the HVI plus AFIS test. Plants were judged primarily on this fiber characteristic before consideration was given to any other traits, because so many fiber properties contribute to the shape of the distribution. Figure 12 illustrates examples of a good and a bad length distribution. If a plant was lacking in any particular area such as length, strength, maturity, or amount of short fibers, this weakness would become evident in the length distribution. If a plant had a poor distribution it was discarded, regardless of other measurements. Very rarely would a plant have a bad distribution, as illustrated in Figure 12, and still have any other desirable characteristics. The length distribution might be described as a summary for the plants overall fiber quality. Having this one characteristic to consider during the selection process is easier than considering multiple values for various traits simultaneously. The length (by number) distribution is also thought to be useful in predicting the spinning performance of fibers.

Note: AFIS also provides a length by weight distribution. However, it was not used because of problems related to weight based measurements that were mentioned previously.

Conclusions and Perspectives

For now, we know that there is differentiation between the two tests for the two selection methods. The majority of the fiber traits show both selection methods to be effective in eliminating plants with lesser fiber quality. More importantly, the HVI plus AFIS test is showing improvements for different traits than are seen in the HVI only test. When looking at the data prior to selection for several traits, it is obvious that past selections have been successful. Based on these data, it appears that selecting for a desirable length distribution (by number) indirectly improves fiber properties such as maturity and strength that directly influence the length distribution. Differences between spinning performance are the greater interest, but cannot be determined yet. However, these data have provided enough information to suggest that there will be differences in spinning performance between the two tests.

A comparison of the progress made by each of the selection methods will be conducted in the final phase of the project. Spinning and yarn analyses will be available for the final comparisons. This information as well as the fiber quality of the lines will be used as an indication of which selection method is more effective. The final questions will be: 1. Did we accomplish more using both HVI & AFIS, compared to using HVI alone?, and 2.How well were we able to choose genotypes that performed well in spinning and the production of quality yarns? Breeders need to know that they can select genotypes that will be sought by the textile mills, and this research should offer hope that they can do just that if they have the appropriate resources. The challenge of producing cotton that can compete in a world market must be met from several angles, and the quality of the lines found in breeding programs is an excellent place to start.

References

1. Baker, J.L., and L.M. Verhalen. 1973. The inheritance of several agronomic and fiber properties among selected lines of upland cotton, *Gossypium hirsutm* L. Crop Sci. 13: 444-450.

2. Benedict, C.R., R.J. Kohel, and H.L. Lewis. 1999. Cotton Fiber Quality. Pages 269-288 in C.W. Smith and J.T. Cothren, eds. Cotton: origin, history, technology, production. John Wiley & Sons, Inc. New York, NY.

3. Bowman, D.T. 2000. Contemporary Issues: Attributes of public and private cotton breeding programs. Journal of Cotton Science. 4:130-136.

4. Braden, C. A., and C.W. Smith. 2004. Fiber length development in near-long staple upland cotton. Crop Sci. 44:1553-1559.

5. Calhoun, S., and D.T. Bowman. 1999. Techniques for Development of New Cultivars. Pages 361-414 in C.W. Smith and J.T. Cothren, eds. Cotton: origin, history, technology, production. John Wiley & Sons, Inc., New York, NY

6. Culp, T.W. and D.C. Harrell. 1973. Breeding methods for improving yield and fiber quality of upland cotton (*Gossypium hirstutum* L.).Crop Sci.13:686-689.

7. Deussen, H. 1992. Improved cotton fiber properties – the textile industry's key to success in global competition. P. 43-63. *In* C.R. Benedict and G.M. Jividen (ed.) Cotton Fiber Cellulose: Structure, Function and Utilization Conference 1992. Natl. Cotton Council, Memphis, TN.

8. El-Zik, K.M., and P.M. Thaxton. Simultaneous improvement of yield, fiber quality traits, and resistance to pests of MAR cottons. P. 315 – 331. *In* C.R. Benedict and G.M. Jividen (ed.) Cotton Fiber Cellulose: Structure, Function and Utilization Conference 1992. Natl. Cotton Council, Memphis, TN.

9. Green, C.C., and T.W. Culp. 1990. Simultaneous improvement of yield, fiber quality, and yarn strength, in upland cotton. Crop Sci. 30:66-69.

10. Hequet, E. 2007. Personal Communication. International Textile Center, Texas Tech University, Lubbock, Texas.

11. Hequet, E., N. Abidi, J. Gannaway. 2007. Relationships between HVI, AFIS, and yarn textile properties. World Cotton Research Conference-4, Lubbock,TX. 10-14 Sept. 2007.

12. Latimer, S.K., T.P. Wallace, and D.S. Calhoun. 1996. Cotton breeding: High volume instrument versus conventional fiber quality testing. P. 1681. *In* P.

Dugger and D.A. Richter (ed.) Proc. Belt. Cotton Res. Conf., New Orleans, LA. 9-12 Jan. 1996. Natl. Cotton Council, Memphis, TN.

13. May, O.L. and G.M. Jividen. 1999. Genetic modification of cotton fiber properties as measured by single- and high-volume instruments. Crop Sci. 39:328-333.

14. May, O.L., and R.A. Taylor. 1998. Breeding cottons with higher yarn tenacity. Textile Res. J. 68:302-307.

15. Meredith, W.R. , Jr., T.W. Culp, K.Q. Robert, G.F. Ruppenicker, W.S. Anthony, and J.R. Williford. 1991. Determining future cotton variety fiber quality objectives. Textile Res. J. 61:715-720.

16. Meredith, W.R. Jr., P.E. Sasser, and S.T. Rayburn. 1996. Regional high quality fiber properties as measured by conventional and AFIS methods. P 1681-1684. *In* P. Dugger and D.A. Richter (ed.) Proc. Belt. Cotton Res. Conf., New Orleans, LA. 9-12 Jan. 1996. Natl. Cotton Council, Memphis, TN.

17. Price, J.B., T.A. Calamari, and W.Y. Tao. 1999. Yarn Preparation, Fabric Formation, and Finishing. Pages 751-791. in C.W. Smith and J.T. Cothren, eds. Cotton: origin, history, technology, production. John Wiley & Sons, Inc., New York, NY.

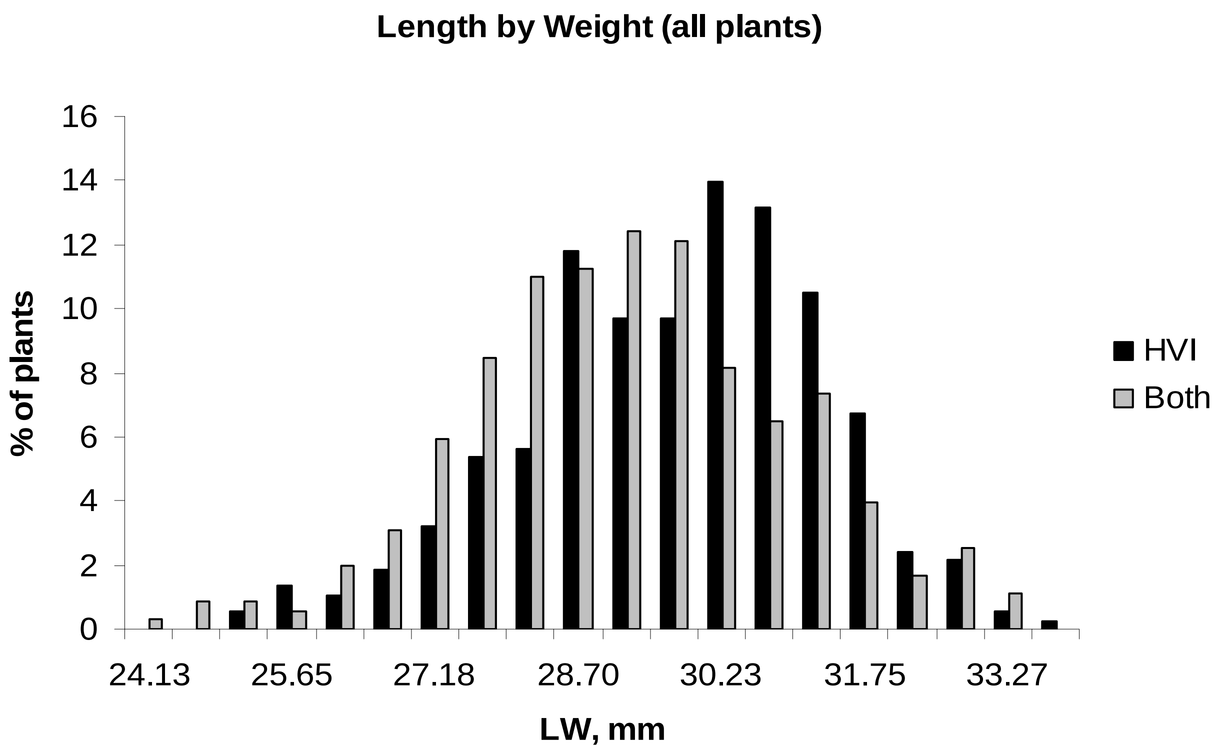

Figure 1. Histograms of length by weight values for all individual plants (selected for agronomic traits in the field) in the HVI only test and the HVI + AFIS test.

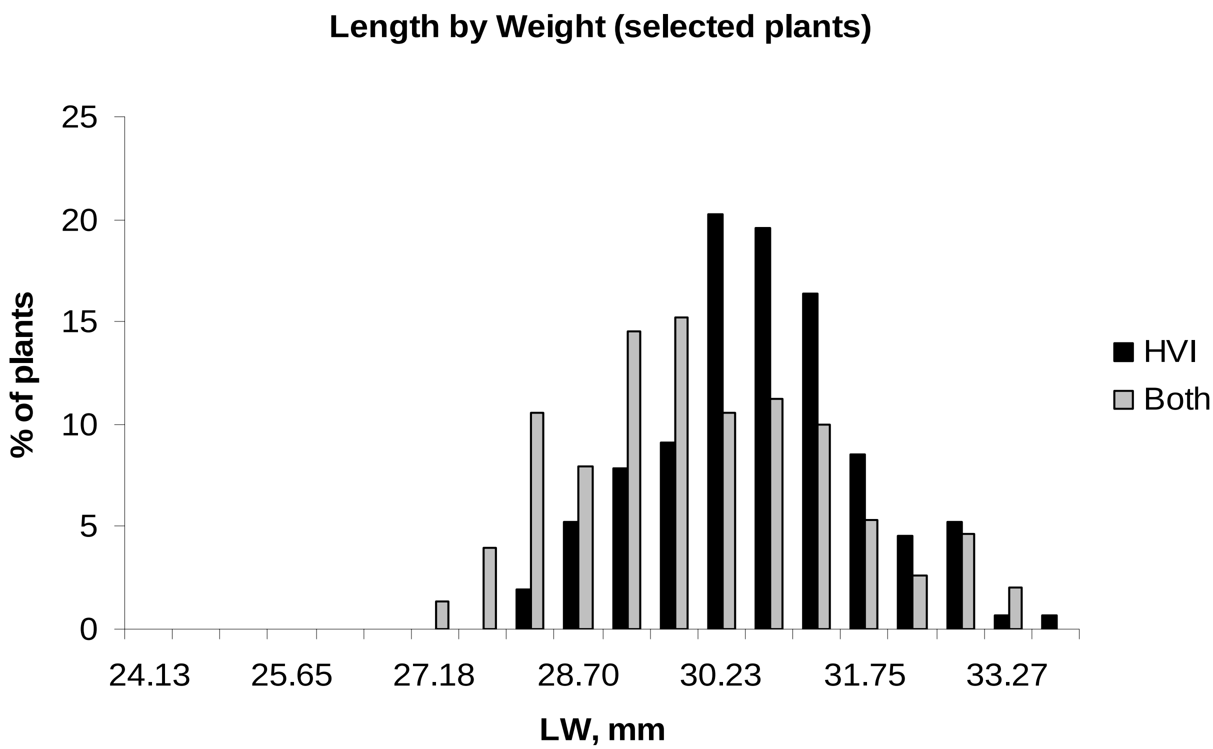

Figure 2. Histograms of length by weight values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

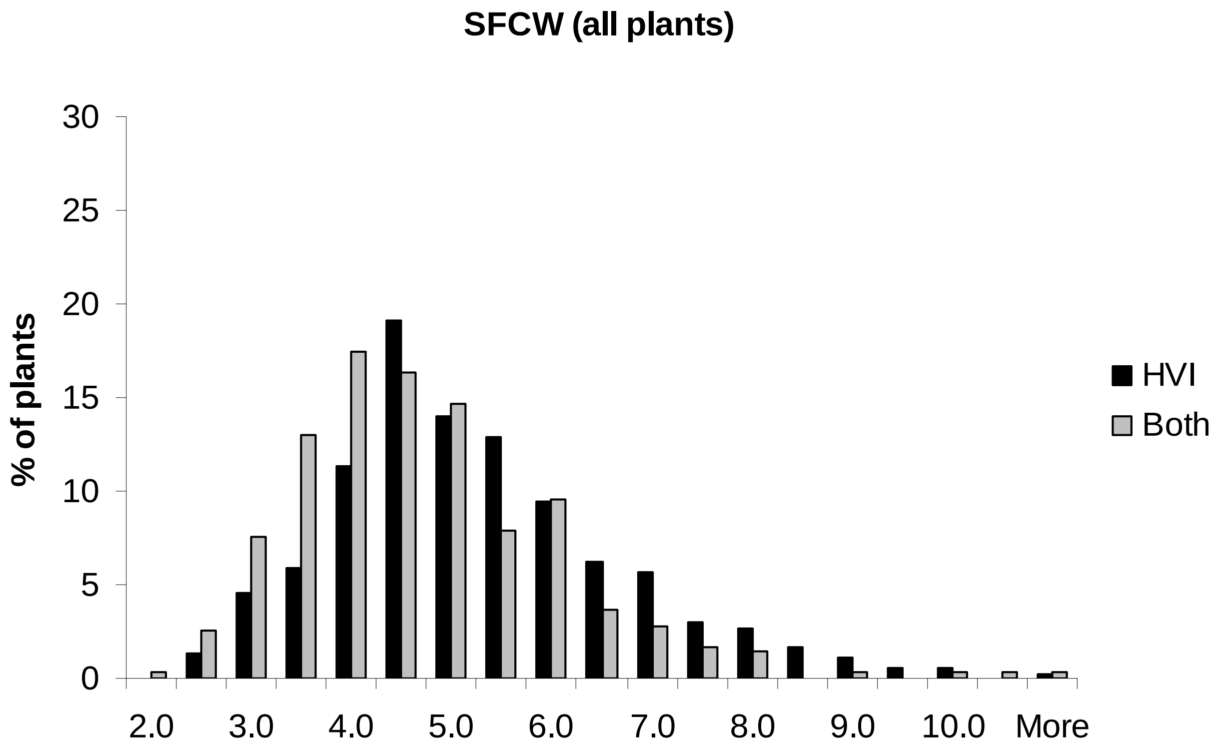

Figure 3. Histograms of short fiber content by weight values for all individual plants (selected for agronomic traits in the field) in the HVI only test and the HVI + AFIS test.

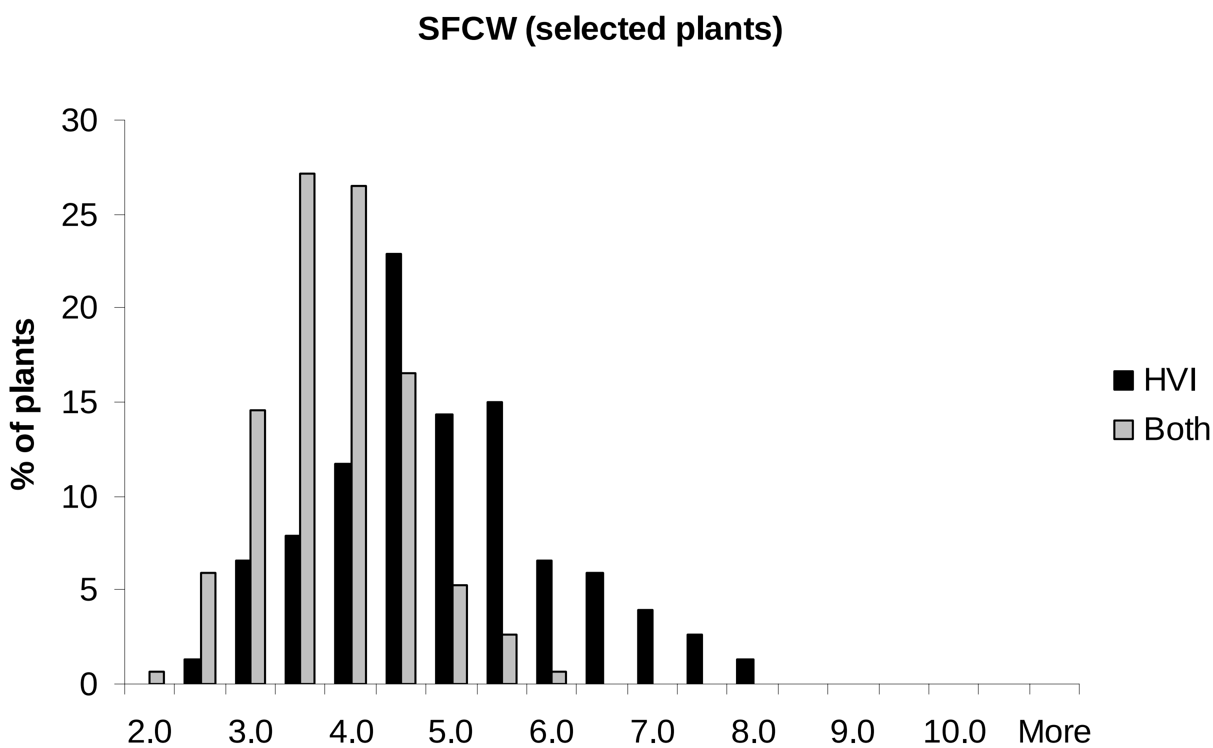

Figure 4. Histograms of short fiber content by weight values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

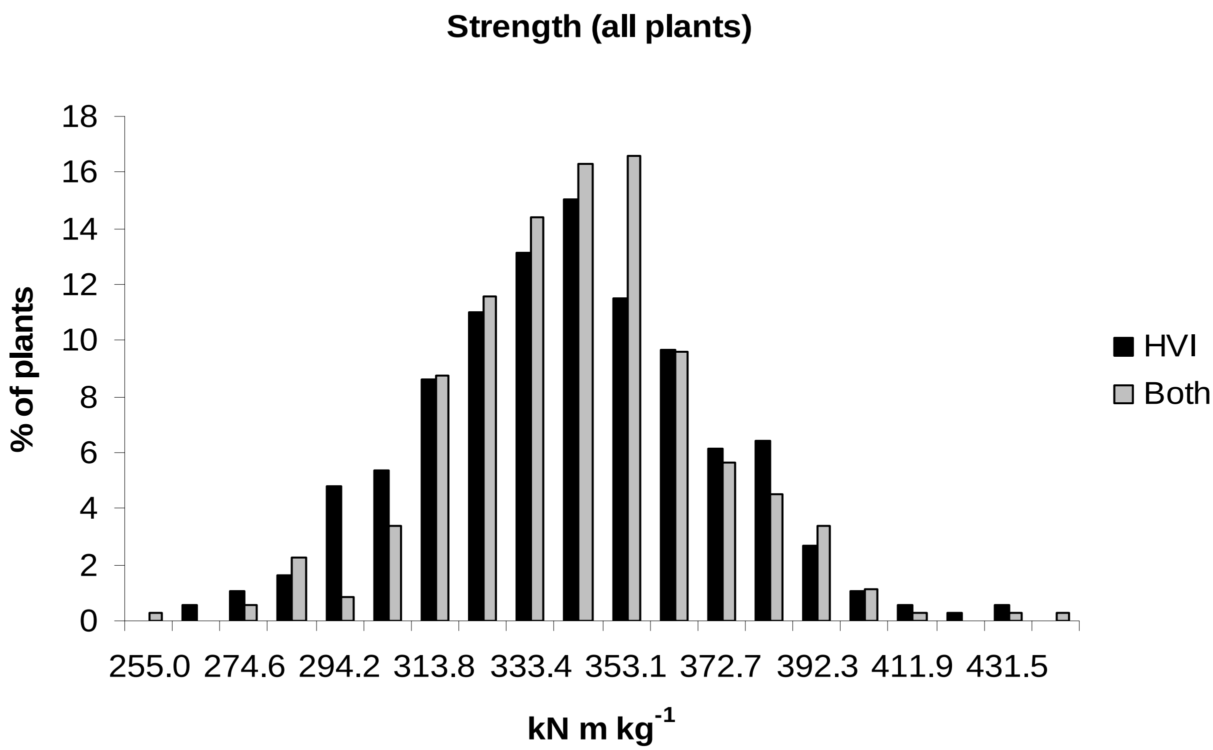

Figure 5. Histograms of strength values for all individual plants (selected for agronomic traits in the field) in the HVI only test and the HVI + AFIS test.

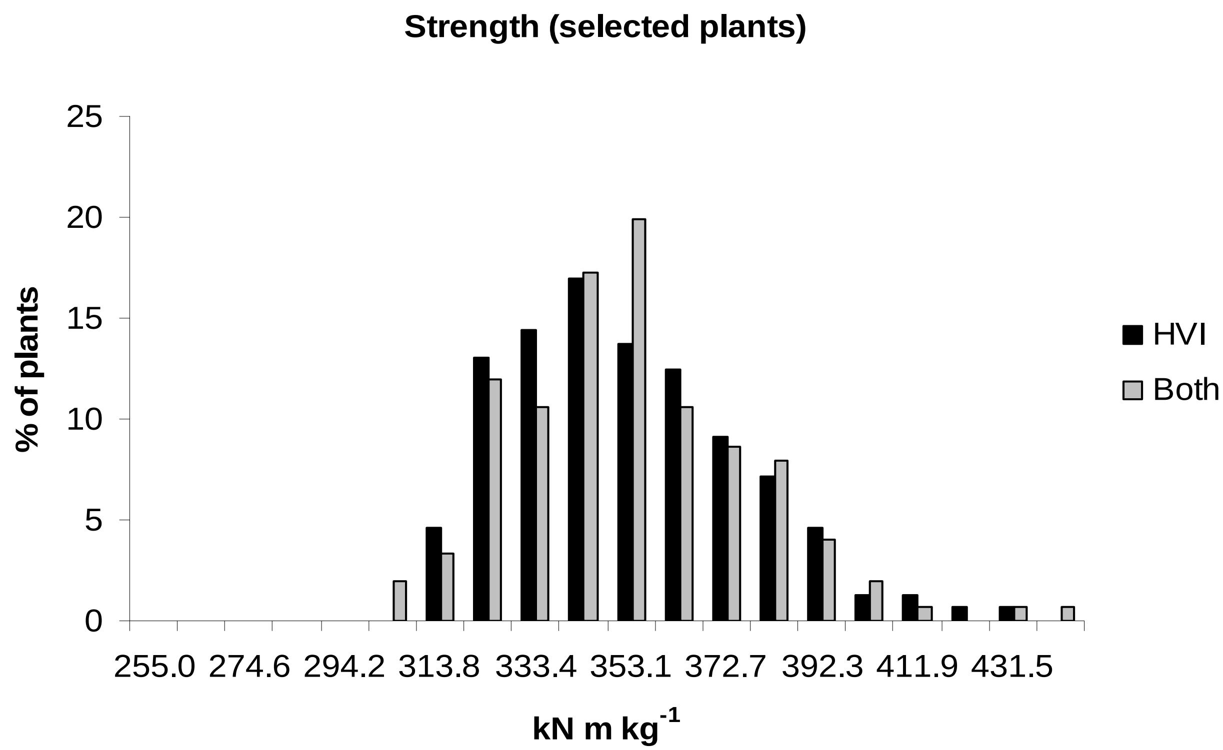

Figure 6. Histograms of strength values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

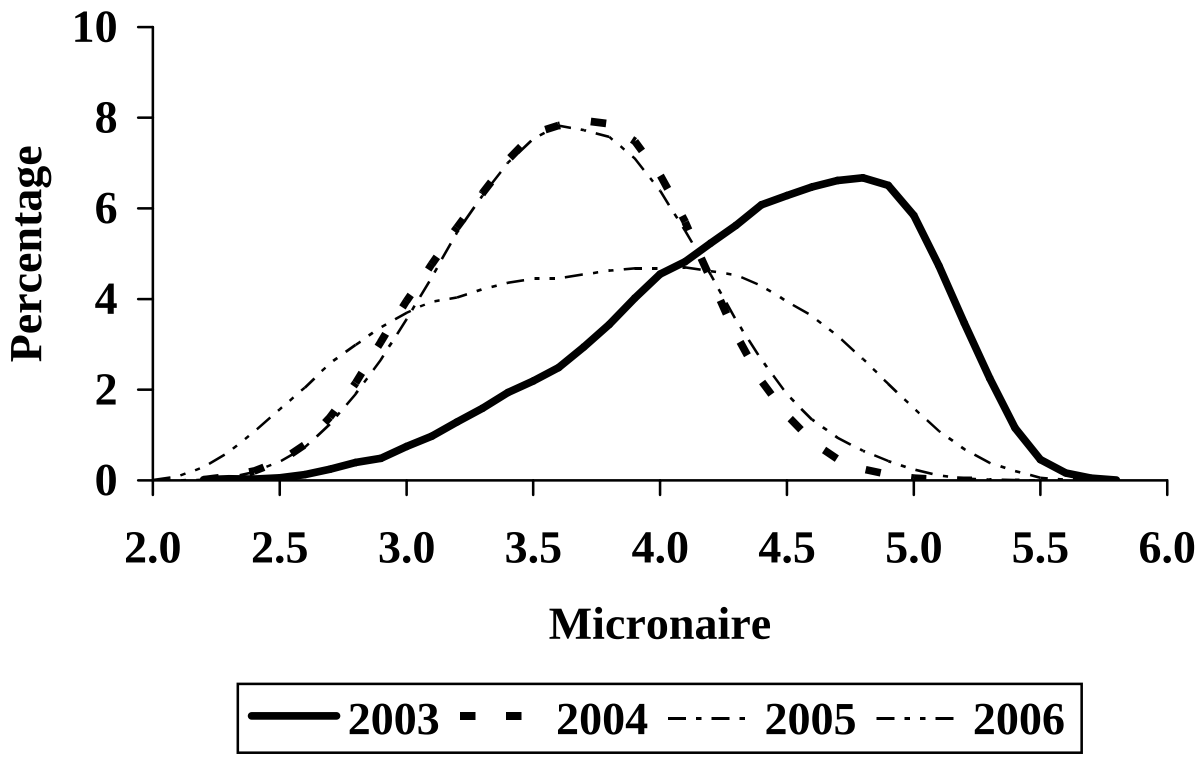

Figure 7. Micronaire values from the Lubbock classing office. Percentage of total bales classed for a given micronaire.

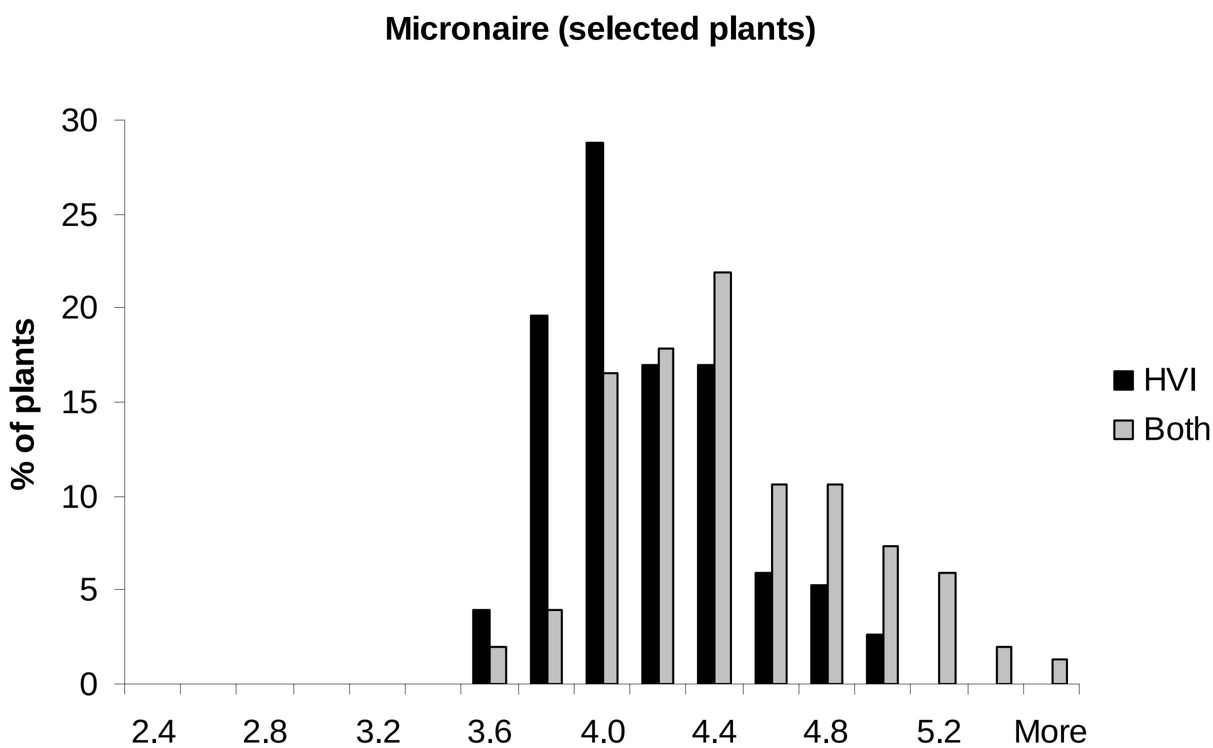

Figure 8. Histograms of micronaire values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

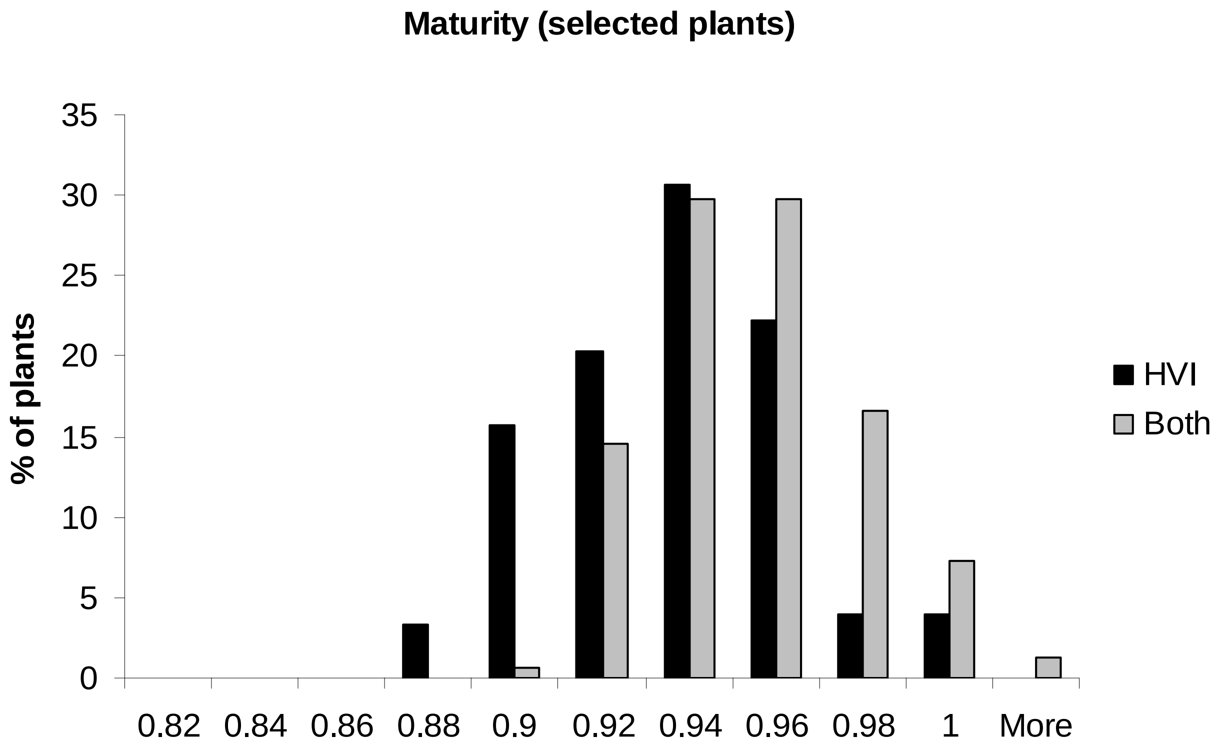

Figure 9. Histograms of maturity ratios for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

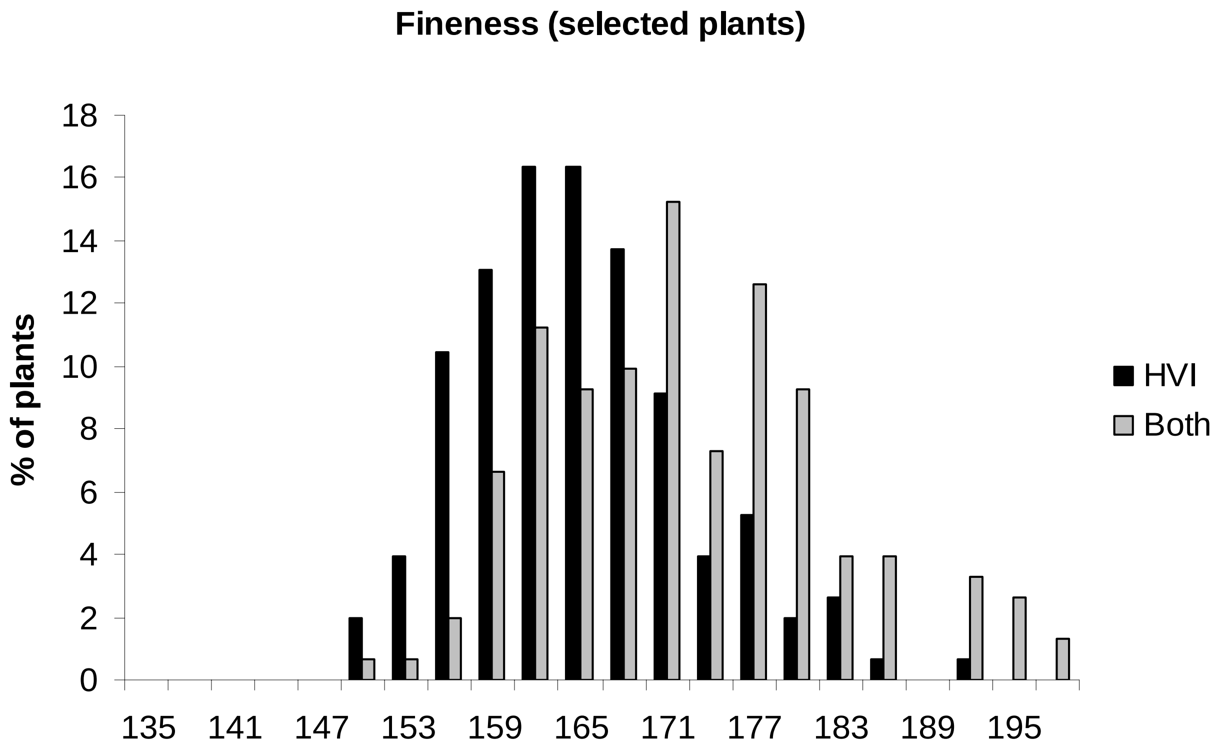

Figure 10. Histograms of fineness values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

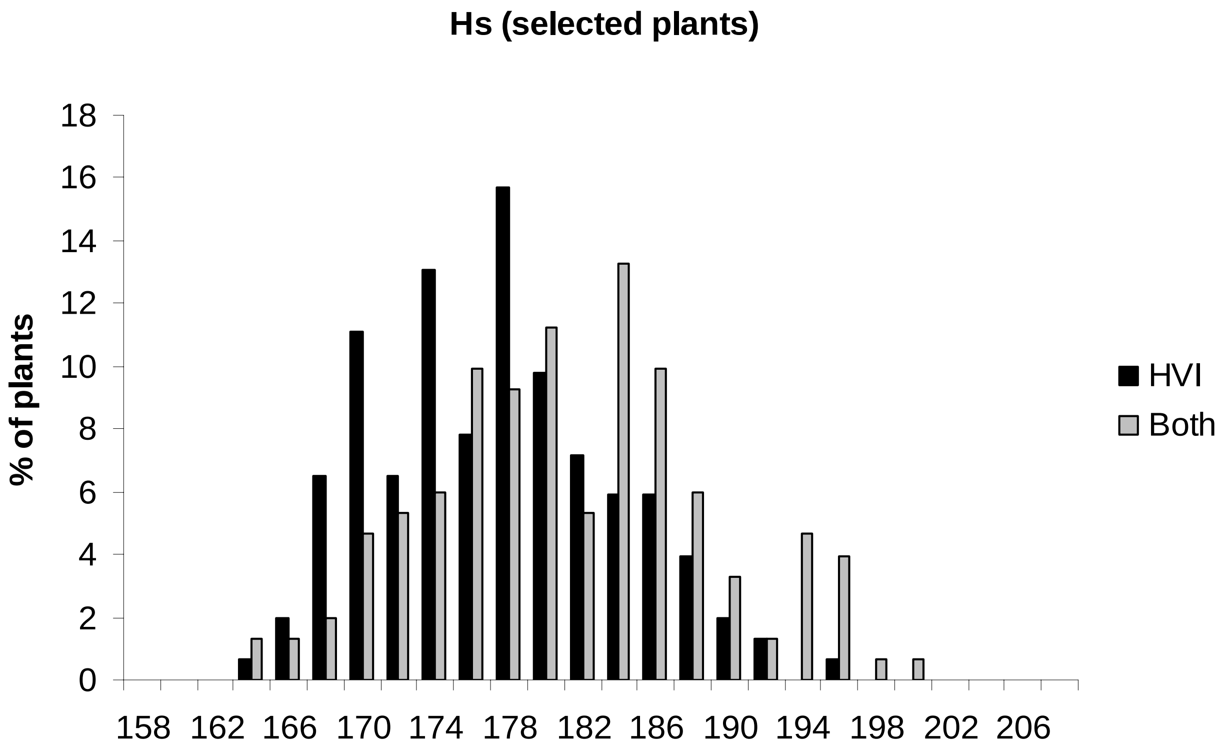

Figure 11. Histograms of standard fineness values for selected plants (selected for fiber quality) in the HVI only test and the HVI + AFIS test.

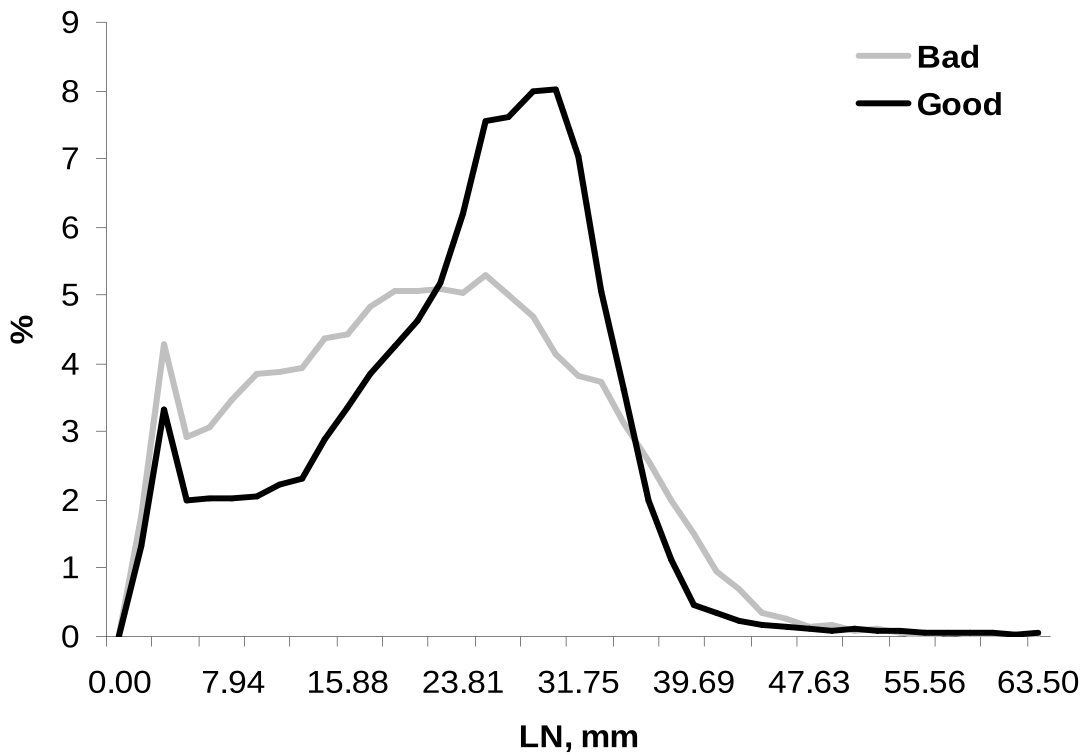

Figure 12. Examples of what would be considered a good, or bad length (by number) distribution.

	All Plants			Selected Plants		
	Test Average		Chi Squared Test	Test Average		Chi Squared Test
	HVI	HVI & AFIS	x^2	HVI	HVI & AFIS	x^2
Micronaire	4.1	4.1	0.08	4.1	4.4	0.00*
Upper Half Mean Length (mm)	33.53	32.51	0.00*	34.54	33.02	0.00*
Uniformity	85.9	86.1	0.03*	86.3	86.6	0.00*
Strength (kN m kg^{-1})	336.4	339.3	0.21	348.15	348.15	0.84
Elongation	6.7	6.8	0.11	6.6	6.6	0.73
Length by weight (mm)	29.72	29.21	0.00*	30.48	29.97	0.00*
Upper Quartile Length by Weight (mm)	35.56	34.29	0.00*	36.58	35.05	0.00*
Short Fiber Content (w)	5.1	4.5	0.00*	4.7	3.6	0.00*
Length by number (mm)	24.13	24.38	0.56	24.89	25.4	0.01*
Short Fiber Content (n)	19.2	17.0	0.00*	18.7	14.6	0.00*
Fineness	165	168	0.01*	164	171	0.00*
Maturity	.92	.93	0.21	.93	.95	0.00*
Standard Fineness (Hs)	178.4	181.0	0.20	176.3	180.3	0.01*

* Significantly different at the 0.05 confidence level

Table 1. Average values for the given set of plants and chi-squared values for comparison of histograms.