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Inheritance of Fiber Strength and Fiber Elongation in F 3 of a Cross Between Two Varieties of Upland Cotton.

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INHERITANCE OF FIBER STRENGTH AND FIBER ELONGATION IN F3 OF A CROSS BETWEEN TWO VARIETIES OF UPLAND COTTON

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Philosophy

in

The Department of Agronomy

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENT</td>
<td>ii</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>iv</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>v</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>vi</td>
</tr>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>REVIEW OF LITERATURE</td>
<td>5</td>
</tr>
<tr>
<td>MATERIALS AND METHODS</td>
<td>28</td>
</tr>
<tr>
<td>RESULTS AND DISCUSSION</td>
<td>40</td>
</tr>
<tr>
<td>Inheritance of Fiber Strength</td>
<td>42</td>
</tr>
<tr>
<td>Inheritance of Fiber Elongation</td>
<td>61</td>
</tr>
<tr>
<td>Association Among Traits</td>
<td>75</td>
</tr>
<tr>
<td>SUMMARY AND CONCLUSIONS</td>
<td>85</td>
</tr>
<tr>
<td>LITERATURE CITED</td>
<td>89</td>
</tr>
<tr>
<td>AUTOBIOGRAPHY</td>
<td>94</td>
</tr>
</tbody>
</table>

iii
LIST OF TABLES

Table | Description | Page
--- | --- | ---
1. | Frequency distribution of fiber strength for the parents and F3 lines | 43
2. | Frequency distribution of fiber elongation for the parents and F3 lines | 62
3. | The association of fiber strength and fiber elongation with some important economic traits | 81
## LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>A scatter diagram showing fiber strength for 69 F2 plants and the means of the 69 F3 lines derived from them.</td>
<td>59</td>
</tr>
<tr>
<td>2.</td>
<td>A scatter diagram showing fiber elongation for 69 F2 plants and the means of the 69 F3 lines derived from them.</td>
<td>74</td>
</tr>
<tr>
<td>3.</td>
<td>A scatter diagram showing the association between fiber strength and fiber elongation in 69 F3 lines.</td>
<td>78</td>
</tr>
</tbody>
</table>
ABSTRACT

The inheritance of fiber strength and fiber elongation was studied in the parents and 69 F3 lines of a cross between 2 varieties of Upland cotton, *Gossypium hirsutum*. Cleveland Short Sympodia had low fiber strength (12.8 grams/tex) and high fiber elongation (12.3 percent). AHA 6-1-4 had high fiber strength (22.8 grams/tex) and low fiber elongation (5.4 percent).

The F3 lines along with progenies of each parent were planted in small plots replicated 3 times. The fewest number of plants evaluated for any one F3 line was 20; and maximum number was 24. The number of plants evaluated for each parent was 72. The 69 F3 lines evaluated were assumed to have represented a random population.

Fiber strength and fiber elongation were determined on an individual plant basis using the Stelometer at the 1/8" gauge.

The continuous distribution of F3 line means indicated that both characters were quantitatively inherited.

Analysis of variance of the F3 line means and the parental means for both characters indicated that none of the F3 lines could be considered as a probable parental recovery. Two separate estimates of the number of effective factor pairs suggested that the difference between the parents was controlled by at least 11 to 17 pairs of genes.
for fiber strength. Lower minimum estimates of 5 to 7 pairs were concluded to control the difference between the 2 parents for fiber elongation.

Partitioning of the variance among F3 line means indicated that the major portion of the genotypic variance in case of fiber strength was additive in nature. The genotypic variance in case of fiber elongation was all attributed to additive effect of genes.

Heritability for fiber strength, using the regression of F3 line means on F2 parental plants, was estimated at 59 percent while heritability estimate based on the ratio of the additive genetic variance to total variance was 52 percent. A very high estimate of heritability of 80 percent was obtained for fiber elongation. These high estimates of heritability indicate that selection for fiber strength or fiber elongation on an individual plant basis would have been highly effective.

A highly significant negative correlation coefficient ($r = -0.60^{**}$) was obtained between fiber strength and fiber elongation. This association was found to be genetic in nature; however, further studies are needed to determine the cause of the genetic association.

Fiber strength was found to be negatively associated with lint percentage ($r = -0.43^{**}$) and positively associated with fiber length ($r = +0.60^{**}$). Fiber elongation was not associated with either lint percentage or fiber length.
INTRODUCTION

Despite the recent invention of synthetic fibers (nylons, rayons, etc.) the cotton plant is, and probably will remain, the chief source of textiles. However, to face the increasing and continuous competition of synthetic fibers, cotton breeders have been concerned with the development of superior varieties.

Until recently, increased yield has been the ultimate aim of most cotton breeders. Because of the direct relationship between fiber properties and the rate of spinning efficiency, the improving of fiber qualities has been the purpose of many studies.

According to several workers fiber strength accounts for a large degree of yarn strength. Yarn strength has been found to be the principal criteria for determining yarn qualities.

After the development of fiber strength testers around 1940 many cotton breeders began to study the inheritance of this economic trait. The rather limited genetic studies of fiber strength before 1940 could be attributed to the slow and inaccurate methods of determining this fiber quality. Most of the studies that have been conducted established the fact that fiber strength is a quantitative character governed by multiple factors.
In 1953 Hertel at the University of Tennessee developed the Stelometer. This instrument was the result of an attempt to develop an instrument that would accurately give the breaking strength as well as the breaking extension. Since that time workers began to study fiber elongation as a measure of fiber quality.

The few studies that have been conducted on this character indicate that fiber elongation behaves as a typical quantitative character. The mode of inheritance of fiber elongation and its relation to yarn qualities still require extensive study.

Quantitative characters such as fiber strength and fiber elongation are studied in terms of variance. Total variance may be separated into components attributable to either environmental or genotypic causes. Furthermore, the genotypic variance may be partitioned into additive and non-additive components. This partitioning has proven to be useful both in describing types of gene action and in estimating the magnitude of various types of gene action.

Other information usually sought in genetic analysis of quantitative characters are estimates of their heritability, estimates of the number of genes by which the parents differ for the characters under investigation and the association among the various traits under study. Estimates of heritability are of value to plant breeders in providing
a measure of the effectiveness of selection on an individual plant basis in the early segregating generations. An estimate of the number of pairs of genes by which the parents differ for the traits under study provides the plant breeder with an indication of the relative frequency by which plants and lines equal in their expression to the parents will occur in the cross under investigation. A knowledge of the nature and magnitude of the association among various economic traits indicates to the plant breeder whether it will be easy or difficult to combine the desirable expressions of 2 or more traits within a single line or strain.

The present investigation was conducted to study the inheritance of fiber strength and fiber elongation in an intervarietal cross of American Upland cotton, *Gossypium hirsutum*. The specific objectives in this study were:

1. To determine the mode of inheritance of these 2 characters.
2. To partition the total variance among F$_3$ lines into its environmental and genotypic components and to further partition the genotypic variance into its additive and non-additive variances.
3. To estimate the number of effective factor pairs by which the parents differ for the 2 characters.
4. To obtain estimates of heritability for both characters.

5. To determine the magnitude and nature of association between fiber strength and fiber elongation and, also, the association of each of these 2 characters with lint percentage and fiber length.
The design of instruments to determine strength of fiber was undertaken a number of years ago. The Chandler bundle method, using a pendulum-type Scott tester, was the best of the older methods, and was a standard for some years (7). In 1940 at the Arizona Agricultural Experiment Station, Pressley designed an instrument for determining fiber strength (35). This instrument measures, in pounds, the force required to break a bundle of cotton fibers cut to the width of special clamps used in breaking the bundle. The number of pounds indicated by this machine divided by the weight of the broken bundle, in milligrams, gives a value known as the Pressley index.

In 1953 Hertel (21), working at the Fiber Research Laboratory, University of Tennessee, designed an instrument for measuring breaking extension (elongation) and breaking strength. This instrument, called a Stelometer, is a pendulum-type breaker designed to measure breaking strength and breaking elongation at 2 gauge lengths, zero and 1/8". After this machine was developed attention has been given to fiber elongation by some cotton workers.

Lawson (25) conducted a study to determine the reason why cotton appears to be stronger when tested on the Pressley tester than when tested on the Stelometer. Efforts were
made in the study to control as many of the other variables that effect fiber strength measurements as possible. In her study an apparatus was devised to operate the Pressley tester at uniform rates of loading for part of the testing. At comparable operating speeds, she found that the 2 instruments gave the same tenacity readings on cotton. She concluded that no significant difference occurred between tenacity determined by the 2 instruments if the rates of loading are uniform and equal and if the results are corrected for overshoot. When she compared both instruments at the recommended rate of loading, she found that the tenacity of cotton was about 16 percent higher when tested on the Pressley tester than on the Stelometer. She indicated also that approximately half of the increase was due to overshoot on the Pressley tester and the other half to the higher rate of loading used for the Pressley tester.

The relationship between fiber strength, as measured at different gauge lengths, and yarn strength have been studied by many workers. Kerr (24) studied the association between yarn strength and fiber strength as measured at both zero and 1/8" gauge. He used cottons originating from a trispecies hybrid (G. arboreum X G. thurberi) X G. hirsutum, American-Egyptian, Hopi-Acala and commerial Acala cottons. A high positive correlation coefficient of +.81 was obtained between fiber strength measured at 1/8" gauge and 22's yarn
skein strength. This value was appreciably higher than the correlation coefficient obtained between fiber strength at the zero gauge and yarn strength ($r = +.59$). He concluded that the measurement of fiber strength at the 1/8" gauge should be more valuable in breeding programs because of its closer relationship to yarn strength.

Burley and Carpenter (10) studied the relationship between 22's yarn strength and fiber strength as measured at gauge lengths of 0, 2, 3, and 4 mm. They also evaluated available types of cotton fiber testers. Materials consisted of 75 samples selected to include a wide range of fiber and spinning properties. The results indicated that fiber strength values at the 3 mm. gauge spacing showed a high association with the 22's strength carded yarn than any of the other gauge lengths. A curve of "r" values showed that the highest relationship was beyond the 3 mm. gauge, approximately at 3.2 mm. or 1/8". When comparing the results obtained from the Stelometer with those obtained by the Pressley tester, they concluded that both instruments were highly effective and accurate in testing fiber strength at the 1/8" gauge.

Burley and Rouse (9) studied the effect of atmospheric conditions on the testing of certain cotton fiber properties. The experimental materials consisted of 5 Upland cotton varieties. All samples were conditioned overnight before being tested at the specific conditions. Their study
consisted of 2 separate phases. One phase was to study the
effect of varying levels of relative humidity at a constant
temperature. The other phase was to study the effect of
varying levels of temperature at a constant relative humidity.
Strength determinations were made on the Pressley strength
tester at zero gauge. Results for each variety separately
indicated that strength values increase with an increase
in either temperature or relative humidity. However, the
amount of increase in strength differed with different
varieties. An increase in relative humidity from 55 percent
to 85 percent resulted in an average increase of 6.2 percent
of the mean value at 55 percent relative humidity.

Morris (30) studied the effect of temperature and
relatively humidity on fiber bundle strength measurements
at the 1/8" gauge. Tests were carried out at 4 levels of
relative humidity between 53 percent and 81 percent and
at 2 temperature levels of 70° and 80°F. Fiber bundle
strength increased with the rise in either temperature or
relative humidity. He found that an increase in relative
humidity had a greater effect on strength than a comparable
increase in temperature. An increase from 57 percent to
81 percent relative humidity resulted in an average increase
of 16.2 percent of the fiber bundle strength at the 57
percent relative humidity. In comparing his results with
those obtained by the other workers where fiber strength
was measured at the zero gauge, he concluded that the effect of relative humidity was greater at the longer test lengths.

The effects of various fiber qualities on yarn characteristics have been the subject of many studies. Cotton spinners have emphasized the need for fibers having desirable length, strength, fineness and maturity to permit an increase in spinning rate. Fiber strength and yarn strength are known to be closely associated to the extent that the former accounts for a large percentage of yarn strength.

Simpson et al (41) obtained a highly significant correlation value of +.91 between fiber strength and yarn strength. Their determinations of fiber strength were made at the 1/8" gauge using the Stelometer.

Brown et al (8) evaluated the properties of yarn spun from the lint of the trispecies hybrid (G. arboreum X G. thurberi) X G. hirsutum. This trispecies hybrid had high strength with a Pressley index of 11.5. The yarn made of fibers from this trispecies hybrid was compared with those made of 5 Upland varieties, having Pressley indices ranging from 7.6 to 10.5, and with the Egyptian cotton, G. barbadense (var. Karnak), having a Pressley index of 9.5.

They reported that yarns made from the trispecies hybrid were similar in strength and uniformity to those
made from the much longer and finer Karnak. Those yarns were also stronger than yarns of commercial Upland varieties. They concluded that fiber strength was more important to yarn strength than either fineness or fiber length.

Fiori et al (16) studied the effect of cotton fiber strength on single yarn properties and processing behavior. They concluded that high strength cotton could be spun into stronger yarn for all yarn number and twists. They also found that fiber strength did not affect yarn elongation.

Sands et al (37) studied the physical properties of print cloth produced from 3 cottons differing primarily in flat bundle strength. They found that the strongest-fibered cotton produced the strongest fabrics in the warp direction of the grey, bleached, and bleached and dyed materials. However, in the filling direction this relationship did not hold for the bleached, and bleached and dyed treatments. They concluded also that elongation at break of fabric was apparently influenced more by mechanical treatment during chemical processing than by fiber properties.

According to Sands et al (37) strength of yarn produced from blends of high strength and low strength fibers was in direct proportion to the percentage of strong and weak fibers. A direct relationship between elongation of fiber and elongation of fabrics was observed.
Jenkins (23) studied the relationship between fiber properties and the performance of resin treated and non-resin treated fabric. Fabric tensile strength and tear strength were higher in the low elongation cottons before and after resin treatments. A negative association was found between fiber elongation and fabric tensile strength. According to her discussion this negative association was due to differences in fiber strength rather than fiber elongation since the low elongation cottons were slightly higher in fiber strength than the high elongation cottons. Fabric elongation was higher for the high elongation cottons.

Camell (11) studied the effect of fiber elongation on the laboratory performance of sheeting fabrics. The fabrics used in her study were made from 4 selected cottons including Stardel, a commercial variety and 3 of unknown variety. The selected cottons were matched as nearly as possible for the 3 properties, fiber length, fiber strength and fiber fineness. The percent elongation of the 4 varieties were 6.6, 6.4, 9.9 and 10.1 percent elongation on the Stelometer at the 1/8" gauge. Tear resistance, breaking resistance strength and abrasion resistance were used as criteria to measure the serviceability of cotton sheeting made from the 4 selected cottons.

The author concluded that differences in strength were found among the mean tear resistance and breaking resistance
values for the fabrics made of the 4 cottons. She also concluded that the variance in tear resistance and breaking resistance strength was due to fiber elongation. These differences were greater at the initial interval and decreased throughout the wear-laundering intervals. No difference in abrasion resistance between the fabrics made from high and low elongation was reported.

Although she concluded that the variance was due to fiber elongation, it should be mentioned that differences in fiber strength could have accounted for these results as the high fiber elongation cotton had lower fiber strength than the low elongation cottons.

Pillay (34) found that yarn elongation was influenced by changes in fiber elongation as well as changes in twists. The maximum increase in yarn elongation due to fiber elongation was 120 percent whereas that due to twist was 108 percent. He concluded that fiber elongation may be one of the more important factors controlling yarn elongation. He stated also that since differences in elongation of as much as 100 percent are known to exist among cottons, this fiber property may be extremely important in determining the elastic behavior of yarns.

Barre (4) reported on the influence of fiber structure on fiber strength. He reported that the more crystalline cellulose deposited in the secondary wall, and the smaller
the angle of the spiral structure, the greater the tensile strength. Berkley et al (5) studied the relationship between fiber strength and cell wall structure as determined by x-ray diffraction patterns. The material consisted of samples of Sea Island, American Egyptian (G. barbadense) and American Upland (G. hirsutum). Highly significant correlation coefficients were found between fiber strength as determined by the Pressley index at the zero gauge and x-ray angle.

Wakeham and Spicer (47) studied the relationship of reversal frequency with fiber strength. The materials studied consisted of several species and varieties of cotton. They found that the fiber breaks more readily at the site of the reversal than between the reversal. They found that the reversal sites were the weakest points along the fiber. The authors concluded that selection of cotton with few reversals might contribute to the improvement of strength of fiber.

Betrabet et al (6), working with different species and varieties of cotton, found that high strength cottons have few convolutions and lower x-ray angles than weak fibers.

The effect of environmental and cultural factors on fiber strength has been reported by many workers. The effect of environment on fiber quality in 10 varieties of Upland cotton was reported by Hancock (19). The experiments
were of a randomized block design with 5 replications of each variety. The varieties were tested at 3 locations for 2 years. The determinations of fiber strength were made on a Pressley strength tester at the zero gauge under controlled conditions of temperature and relative humidity. He found highly significant differences between varieties, locations and years. The various possible interactions among varieties, seasons and locations were studied. The results indicated that both locations and seasons affected fiber strength more than varieties. It also indicated that fiber strength was sensitive to small differences in soil heterogeneity in some of the tests.

Hancock (20), in another study involving 3 Upland varieties, conducted experiments to investigate the effect of flowering dates, locks per boll and node number of fruiting branches on lint properties. The flowering periods were the ascending, the peak and descending period. Fiber strength was measured by the Pressley strength tester at the zero gauge. Flowering period significantly affected fiber strength while no significant affect on fiber strength was found due to either the node number of fruiting branch or to the number of locks per boll for the same period of flowering.

March et al (27) studied the influence of weathering prior to harvest on some properties of cotton fibers.
Weathering decreased both fiber strength and fiber-elongation. Less than 1 percent of the original strength and elongation was lost per week. Weathering caused a loss in yarn strength with about .8 percent of the original strength per week.

Nelson (32) conducted an experiment over a period of 3 years to study the effect of nitrogen, phosphorus and potash on lint and seed properties of cotton. Strength was measured with the Pressley strength tester at the zero gauge. He found that potash applications increased wall thickness and lowered fineness and strength. Strength of fibers was not affected by phosphorus. A negative association between fiber strength and x-ray angle was observed. Potash increased the x-ray angle while a decrease in x-ray angle was shown by the applications of nitrogen. Spinning samples revealed that applications of potash reduced picker and card waste, lowered the number of neps and slightly improved the grade of yarn. Small but consistent decreases in yarn strength were obtained from applications of potash.

Spooner et al (42) studied the effect of different irrigation treatments and nitrogen levels on various fiber properties. Fiber strength showed no effect from adequate moisture applied by irrigation. Only in one location was fiber strength significantly decreased by high levels of irrigation. Nitrogen levels had no significant effect on fiber qualities measured.
Eaton and Ergle (12) studied the influence of moisture supply and fruitfulness on fiber properties, carbohydrates and nitrogen levels of cotton plants. Plants deflorated to 2 bolls per plant were compared with fully loaded plants under 2 levels of water supply. They found that the treatments that increased the carbohydrate level (2 bolls and drought) also increased fiber strength. A large and highly significant positive correlation of +0.94 was reported between carbohydrate level in the stem and fiber strength.

Eaton and Ergle (13) studied the effect of light intensity and partial defloriation on fiber properties. A remarkable stability in the properties of fibers was noted. Even under the influence of the somewhat drastic treatments represented by heavy shading and the cutting away of half of each leaf, the effects on fiber properties were minor.

Murray et al (31) studied the effect of fertilizers upon fiber characteristics. Their experiments were arranged in a randomized block design with 4 replications in 3 years. The fertilizers used were urea, treble superphosphate and muriate of potash. Fiber samples were taken from each replication every year for quality determinations. Fiber length was measured on the Digital Fibrograph, fineness was measured with the Micronaire and strength with the Stelometer at 1/8" gauge. Their results indicated that lint yield responded to nitrogen and
phosphorus but no consistent effect of fertilizer treatments on length, strength or fineness of the fiber was found.

Ware and Harrel (48) studied the inheritance of fiber strength in $F_1$, $F_2$ and $F_3$ populations and in the first and second backcross generations of a cross between 2 varieties of Upland cotton. Strength determinations were made by the Pressley strength tester at zero gauge. They found that fiber strength behaved as a typical quantitative character. The $F_1$ population was intermediate between its parents with a slight tendency of the weak fiber to be partially dominant. The $F_2$ population of 87 plants gave a mean slightly below the average of the 2 parents. Strength in $F_3$ progenies did not show as much uniformity as the parents. Season affected strength to some degree.

Stroman et al (45) studied the association between fiber strength and lint percentage in materials consisting of plants originating from early Acala selections. Correlation coefficients between fiber strength and lint percentage were small and significant ($r = -.37$ in 1944 and $-.24$ in 1946). He stated that the association might have resulted from multiple factors related to each other.

Gonzales (18) studied the inheritance of lint qualities in an $F_2$ generation of a cross between 2 strains of Upland cotton. Strength determinations were made with the Pressley strength tester at the zero gauge. The parents were only
slightly different in fiber strength as one had a Pressley index of 6.9 and the other had a Pressley index of 6.4. A population of 203 plants showed a normal frequency curve. The author concluded that fiber strength was quantitatively inherited and determined by multiple factors. No association was observed between fiber strength and lint percentage or between fiber strength and length.

Stafford (43) studied the inheritance of fiber strength in a cross between Wilds and Half and Half, both varieties of Upland cotton. Strength was measured with the Pressley strength tester at the zero gauge. He reported that fiber strength behaved as a typical quantitative character. Partial dominance for weak fiber was present. The number of genes segregating for strength was studied in 2 crosses. In cross I, the means of the parents differed by 2.0 Pressley index units for strength and an estimate of 4 pairs of genes were obtained. In cross II, the means of the parents differed by 1.4 Pressley index units and an estimate of 2 pairs of genes was obtained.

Continuing his work with cross I, Stafford measured fiber strength for 107 F3 lines grown from selected F2 plants. The results in F3 agreed with the conclusion derived from the F2 result. These results indicated that more than 3 pairs of genes appeared to control the difference between the parents for fiber strength. He concluded
that the most probable number appeared to be 4 pairs of genes. Heritability values of 63 percent and 65 percent were obtained in F\textsubscript{2} for the 2 crosses. The regression of F\textsubscript{3} means on their F\textsubscript{2} corresponding plants was 0.386, indicating a moderate heritability for fiber strength.

Stafford calculated simple correlation coefficients for strength with 9 other characters in 211 F\textsubscript{2} plants of cross I. He explained that he used this cross for his correlation studies since a wider genetic range existed between the parents in strength and most of the other characters studied. His results indicated that no significant correlation coefficients were found between fiber strength and any of the 9 other characters. Therefore, he concluded that strength was independent of lint index, lint percentage, lint density index, length of fiber, wall thickness of fiber, weight fineness of fiber and immaturity of fiber in its inheritance. He concluded also, that the breeder should have no particular difficulty in combining strength with any one of these fiber properties in a single variety.

Self and Henderson (38) studied the inheritance of fiber strength in a cross between AHA 50 and Half and Half, both Upland varieties. AHA 50 had a mean strength of 9.6 Pressley index, while Half and Half had a mean strength of 7.1 Pressley index. The F\textsubscript{1} had a mean strength of
8.2 Pressley index, a value intermediate between the 2 parents, but slightly lower than the arithmetic average of the parents. The F₂ population of 806 plants had a continuous range from 6.6 to 9.9 Pressley index with a mean of 8.1. An estimate of 5 pairs of genes conditioning the difference between the parental means was observed using the Castle-Wright formula.

From the 806 F₂ plants in their study, 66 were selected and progeny tested in F₃. The F₂ plants taken into F₃ were selected to represent the complete range found among the entire 806 plants. Among the 66 F₃ lines they obtained 3 lines which had means as low as that of the low strength parent. They concluded that these lines possibly represented recoveries of the Half and Half genotype. It was pointed out by the authors that the apparent frequency in which the parent genotypes were recovered in F₂ was somewhat higher than would be expected from the segregation of 5 pairs of genes and suggested that 4 pairs was a more probable number.

The estimates of heritability obtained by Self and Henderson were high. A heritability estimate of 86 percent from the F₂ data was obtained. The heritability estimate using the regression of F₃ means on their corresponding F₂ plant values was 53 percent. The authors stated that selection for fiber strength on an individual plant
basis in the $F_2$ and later segregating generations would have resulted in lines high in fiber strength.

Stith (44) studied the inheritance of some quantitative characters in a cross between 2 varieties of Upland cotton. He found that fiber strength was quantitatively inherited. No evidence of transgressive segregation was observed. Absence of dominance was obtained for fiber strength. Heritability estimates were obtained from the genotypic variance of the $F_2$ population and from the variance components among $F_3$ lines. He obtained a heritability estimate of 54.1 percent from the $F_2$ population, whereas a heritability estimate of 87.3 percent was obtained from the variance components among $F_3$ lines.

In his study Stith obtained negative phenotypic and genotypic correlations between fiber strength and lint percentage in the $F_2$ population. He found also that fiber strength and fiber length were related to the extent that selection for longer fibers would result in stronger and finer fibers.

Al-Jibouri (1), in an interspecific cross, reported a strong negative association between fiber strength and fiber elongation as measured at both zero and 1/8" gauge.

Fryxell et al (17) studied fiber quality in several $F_1$ hybrids in crosses between different strains of $G. \text{hirsutum}$ and $G. \text{barbadense}$ (American Egyptian and Sea Island). The results indicated that the hybrids having
Sealand 542 as one of the parents were intermediate in their fiber elongation. Twenty-seven of the 30 hybrids having *G. barbadense* as one of the parents had greater fiber elongation than either of their parents.

Al-Jibouri et al (2) reported a high degree of association between fiber strength and lint percentage in a cross between an Upland variety and a strain of interspecific origin. A phenotypic correlation coefficient of -.58 was obtained while the genotypic correlation was -.53. They also obtained a very low and non-significant correlation between fiber strength and fiber length.

In 3 separate intervarietal crosses of *G. hirsutum* Miller et al (29) reported low associations between fiber strength and lint percentage. In the 3 populations studied, correlation ranged from -.07 to -.24. They also found that phenotypic correlations between fiber strength and fiber length ranged from -.23 to +.33 while the values for the genotypic correlations ranged from -.23 to +.25. All of these correlations were low and in most cases non-significant.

Worley (51) studied the inheritance of fiber strength in the F1, F2 and F3 of an interspecific cross between DPL 15 (*G. hirsutum*) and Sea Island (*G. barbadense*). Fiber strength was measured with the Pressley tester at the zero and 1/8" gauge. Fiber strength was reported to have behaved as a quantitative character in this study. Partial dominance
for low Pressley index (weak fiber) occurred; however, fiber strength at the 1/8" gauge showed absence of dominance.

Attempts were made in his study to estimate the number of genes segregating for fiber strength. The parental means differed by 2.81 units Pressley index at zero gauge and 2.27 units of 1/8" strength index. Data indicated that the parents differed by only a few pairs of genes for this wide parental difference. According to his results there appears to be more genes segregating for the 1/8" strength index than for Pressley index.

Worley reported high estimates of heritability for this character. At the 1/8" gauge, heritability estimates based on F$_2$ data was 85 percent; the regression of F$_3$ line means on F$_2$ plant values was 0.61. At the zero gauge, heritability in the F$_2$ population was estimated at 90 percent and the regression of F$_3$ line means on F$_2$ plant values was .69. He concluded that selection in F$_2$ for high strength would have been valuable in obtaining high strength lines.

The association of fiber strength with lint percentage was also studied by Worley. He calculated the correlation coefficients among F$_2$ plants and among F$_3$ lines. In F$_2$ he obtained a correlation coefficient of -.06 and -.09 between lint percentage and fiber length at zero and 1/8" gauge respectively, while in the F$_3$, a correlation coefficient of -.21 was obtained between these 2 characters at the 1/8" gauge.
Shepherd (39) in a study of the first cycle of recurrent selection of an interspecific hybrid between Sea Island (G. barbadense) and DPL 15 (G. hirsutum), obtained a highly significant negative correlation of -.57 between fiber strength and lint percentage. It was suggested that this strong negative correlation was probably the result of partial linkage between these 2 characters. He also indicated that the occurrence of several lines moderately high in both characters showed the possibility of combining high expression of both characters through additional cycles of recurrent selection.

In a study of the second cycle recurrent selection of the same cross, Shepherd (40) obtained a low but highly significant negative correlation of -.26 between fiber strength and lint percentage for the total intercross population. However, the extent of association varied with different line intercrosses. In some cases a very low correlation coefficient was obtained between the 2 characters; whereas in other line intercrosses high negative correlation coefficients as high as -.65 was found. He concluded that some degree of linkage probably occurred between genes from these 2 characters for several of the line intercross combinations.

Ware (49) studied the inheritance of x-ray diffraction pattern and its relation with lint characteristics in a cross
between 2 Upland varieties. One of the parents had a low x-ray angle of 32.15° while the other had a very wide x-ray angle of 44.43°. The average x-ray angle for the F₁ was 38.5°. The frequency distributions of F₂ and backcross generations were more widely spread than in the parents or F₁, forming a normal curve. The author concluded that x-ray angle behaved as a typical quantitative character. A highly significant correlation coefficient of -0.65 was obtained between x-ray angle and Pressley index at the zero gauge among the 252 F₂ plants studied.

Thomas (46) studied the inheritance of fiber strength and fiber elongation in a cross between Cleveland Short Sympodia and Stardel, both varieties of Upland cotton. The Cleveland Short Sympodia parent had low fiber strength (12.85 grams/tex) and high fiber elongation (10.87 percent). The Stardel parent had a high fiber strength (18.22 grams/tex) and low fiber elongation (7.32 percent). The Stelometer at the 1/8" gauge was used for determining both characters.

Thomas reported that fiber strength behaved as a typical quantitative character. The frequency distribution of the 301 F₂ plants studied was continuous and smooth toward the mean of the population. Several pairs of genes were concluded to have controlled fiber strength.

In his study, attempts were made to obtain estimates of the number of pairs of genes segregating for fiber
strength. An estimate of 12 to 14 pairs of genes was obtained using the Castle-Wright and Wright formulae. A heritability estimate of 59 percent was obtained for fiber strength in F2 data.

Thomas also reported that fiber elongation behaved as a typical quantitative character. He obtained an estimate of 5 to 6 pairs of genes segregating for fiber elongation. A heritability estimate of 36 percent was obtained for fiber elongation from F2 data.

The association between fiber strength and fiber elongation was studied by Thomas. A moderately significant negative correlation of -.39 was obtained. Due to the low environmental correlations between these 2 characters in his investigation, he concluded that the association between fiber strength and fiber elongation was genetic in nature.

El-Sharkawy (14), in the F2 study of a cross between Cleveland Short Sympodia and AHA 6-1-4, reported that fiber strength behaved as a typical quantitative character. A small degree of partial dominance for weak fiber strength was obtained in his study. He reported that neither parental type was recovered in the F2 population of 315 plants. The Castle-Wright and Wright formulae gave estimates of 12 to 13 pairs of genes segregating for fiber strength. He obtained a very high heritability estimate of 87.3 percent for fiber strength from the F2 data.
In studying the inheritance of fiber elongation, El-Sharkawy reported that it behaved as a typical quantitative character. A small degree of partial dominance for low fiber elongation was obtained. Using the Castle-Wright and Wright formulae he obtained an estimate of 4 to 5 pairs of genes segregating for fiber elongation. A very high heritability estimate of 90 percent was obtained for fiber elongation from the F₂ data. He concluded that selection of individual plants with high elongation would have been highly effective in establishing lines with high expression of this character.

El-Sharkawy studied also the association between fiber strength and fiber elongation in the F₂ population. He reported a highly significant negative correlation of -0.57 between the 2 characters. Since the correlations between these 2 characters in the parents were low and non-significant, he concluded that this association might be due to genetic causes.
MATERIALS AND METHODS

The materials used in this study consisted of parents and F₃ lines of a cross between Cleveland Short Sympodia and AHA 6-1-4, both varieties of Upland cotton, G. hirsutum.

Cleveland Short Sympodia has low strength and high elongation. It was obtained from the Regional Collection of Upland cotton at Stoneville, Mississippi in 1959 as Accession Number 98. AHA 6-1-4, on the other hand, has high strength and low elongation. It was originally obtained from the Regional Collection of Upland cotton at Stoneville, Mississippi as Accession Number 464. Since that date it has been maintained as an inbred line at Baton Rouge, Louisiana.

The original cross was made in the field in the summer of 1959 using Cleveland Short Sympodia, plant 3, as the female parent and AHA 6-1-4, plant 3, as the male parent. Self-fertilized seed were obtained from each parent plant for future progeny testing.

In the fall of 1959, hybrid seed (F₁) were harvested and sent to Iguala, Mexico where several F₁ plants were grown and self-fertilized during the winter of 1959-1960. The F₂ seeds harvested from individual F₁ plants were kept separate and sent to Baton Rouge in time for planting in the spring of 1960.
The parents, F₁ generation and 3 F₂ families (obtained from 3 different F₁ plants) were planted in 1960 at the Perkins Road Farm in Baton Rouge. Several flowers on each F₂ plant were self-pollinated. The self-fertilized seeds of each F₂ plant were harvested separately and used to grow F₃ lines.

From each F₂ family, 25 plants were chosen at random without any selection; however, one requirement was that a minimum of 75 selfed seeds should be available for planting F₃ progeny.

Before planting the area was fertilized with 500 pounds of a 12-12-12 mixture per acre. Soil was fumigated with one gallon of 50 percent emulsifiable concentrate of Nemagon mixed with 9 gallons of water applied as a spray in a band in the center of the bed 6 to 8 inches deep. The purpose of this treatment was to control the Fusarium wilt-reniform nematode disease complex.

The F₃ lines along with both parents were planted on May 4, 1961, in a split-plot design with 3 replications at Perkins Road Agronomy Farm. The 3 families were randomized in each block as the main plots. The 25 F₃ lines of each family along with both parents were then randomized as sub-plots. Three sub-plots of each parent were planted in each of the 3 replications giving a total of 72 plants each. Approximately 12 hills were planted to each sub-plot.
with at least 2 seeds per hill. A good stand was obtained and plants grew normally and produced well.

Prolonged rains during the fall prior to harvest caused a considerable amount of boll rot. In some cases almost all the bolls on a particular plant were rotted. However, the bolls which opened during the last week of September and the month of October were undamaged. A number of plants had what was considered to have been an insufficient number of good bolls. Because of this it was decided to harvest only the first 8 plants in each plot with at least 5 undamaged bolls per plant. Some plots had less than 8 such plants, in which case less than 8 plants were harvested.

Six F3 lines had fewer than 6 plants per sub-plot in one or more replications. These were eventually eliminated from the study. Thus the total number of F3 lines studied was 69. The fewest number of plants evaluated for any one F3 line was 20; the maximum number per line was 24.

Seed cotton was ginned on a Porter-Morrison laboratory gin (16 saws with 5 inches diameter). Ginning was done by an experienced laborer at the Agronomy Farm. Lint and seed of each plant were collected in separate sacks. The materials were then stored in a room in the Agriculture Center for about 18 months prior to weighing and subsequent determinations of lint percentage and fiber properties.

Beginning at this point the author took over this study in July of 1963. The following determinations were made:
1. **Lint Percentage**

The lint and the seeds of each plant were weighed separately to the nearest tenth of a gram on a K-5 Mettler balance. Lint percentage was obtained by the following formula:

\[
\frac{\text{weight of fiber}}{\text{weight of fiber} + \text{weight of seeds}} \times 100
\]

2. **Fiber Properties**

Approximately 10 grams of lint were pulled at random from the lint of each plant and placed in a small Kraft paper bag with its proper number.

Fiber strength and fiber elongation were determined in the Fiber Testing Laboratory in Room 122 in the Agriculture Center. Controlled conditions of temperature (70° ± 2°F), and relative humidity (65 percent ± 2 percent) were maintained.

The Stelometer, a direct reading pendulum type fiber breaker, was used at the 1/8" gauge length for the determination of both strength and elongation. The cotton samples were conditioned in the fiber laboratory at least 2 days before testing. The instrument was checked for accuracy of strength and elongation before testing and at 3 hour intervals. Determinations were made for lint samples of a check cotton of known value for strength and elongation at the beginning of each work period or for every 2 sub-plots.
The check used was a long staple selection of Acala obtained from the United State Department of Agriculture, having a known strength of 19.3 grams/tex and elongation of 7.7 percent. Before the supply of this check was almost exhausted another check cotton (Stardel grown in 1963) was used. Based on 120 paired measurements of the Long Staple Acala check and Stardel, the values for the Stardel check were established. These values were 19.5 grams/tex for strength and 6.3 percent elongation.

A flat bundle Pressley type sample was prepared in an especially designed vise which allows one to accomplish the testing without having to touch the cotton with one's hand. The breaking strength of the sample was read from a direct reading scale calibrated from 2 to 7 kilograms. The breaking load was calculated in terms of kilograms required to break one milligram of lint (Stelometer index). These readings were made to the nearest $\frac{1}{100}$ of a kilogram.

The Stelometer index was multiplied by the standard length of the sample, 1.5 cm., in order to obtain strength values as grams/gre. This was then multiplied by 10 to get grams/tex.

The elongation for 1/8" gauge break was read from a separate scale calibrated from 0 to 20 percent. The percent elongation was read to the nearest 1/10 of a percent.

Two determinations were made for each sample. If the 2 determinations lay within a tolerance of 1.20 grams/tex
for fiber strength and 0.8 percent for elongation they were averaged. When this tolerance was exceeded, a third determination was made and all determinations were averaged if they were within the range of twice the specified tolerance. If the range was exceeded by the 3 determinations but 2 of the determinations were within the range of the specified tolerance, these determinations were averaged.

After strength and elongation determinations were made for all plants, 100 plants were selected at random from the plants previously determined and were used as spot checks on the accuracy of the original determinations. A correlation coefficient was calculated between the values of the original and the second determinations.

Fiber length determinations were made at the Fiber Testing Laboratory at Gourier Lane by a trained fiber technician using the Model 230 Digital Fibrograph. This instrument gives a fast, accurate and efficient measurement of length and distribution of length of fibers in a clamped sample of cotton. Both 50 percent span length and 2.5 percent span length were determined. The 50 percent span length is a distance from the clamps on the fiber test beard to a point where only 50 percent of the fibers extend. The 2.5 percent span length is a distance from the clamp on the fiber test beard to a point where only 2.5 percent of the fibers extend. The 2.5 percent span
length is comparable to the U.H.M. measured by the Servo Fibrograph.

Statistical Analysis of the Data

The data collected from the various determinations were coded on standard 80 column IBM code sheets in order to use the facilities of the Louisiana State University Computer Center. Programs of the various types of analysis were available. The following statistical measurements were made:

1. Analysis of the F₃ data

Means, standard deviations and coefficients of variability were calculated for each F₃ line and for the parental lines. Lines that have means in the range of parental means and have the same coefficient of variability were considered to be probable parental recoveries. Analysis of variance of F₃ line means and parental means was made in order to determine if any of the F₃ lines had a mean equal to either of the parental means. The least significant difference was calculated at the 5 percent and 1 percent levels of probability.

2. Partitioning of the variance using F₃ data

Mather (28) presented and discussed several formulae which are used in partitioning the variance of F₂ and
successive generations into its components. These components are:

(a). Non-heritable variation resulting from the action of environmental agencies, this might include some effects of irremovable genic interaction.

(b). Fixable heritable component due to the additive effects of genes; it depends on the difference in average character expression associated with the 2 homozygotes for each of the gene pairs involved.

(c). Non-fixable heritable component; it arises from the difference between the expression of heterozygotes and the average of the 2 corresponding homozygotes. This, of course, depends on the degree of dominance. Such variation cannot be utilized in the selection of true breeding strains.

The formulae applied using the F3 data were:

(1). Variance of means of F3 progenies = 1/2D + 1/16H + E

(2). Covariance of F3 means and their corresponding F2 values = 1/2D + 1/8H

Where:

D = additive genetic variance

H = variance due to dominance

E = environmental variance

The variance of F3 line means was obtained from the analysis of variance data. The variance among parental
plot means was used as an estimate of the environmental variance \( (E) \) among \( F_3 \) lines. By subtracting \( (E) \) from the variance among \( F_3 \) line means, an estimate of \( 1/2D + 1/16H \) was obtained. This value was then subtracted from the covariance of \( F_3 \) means and their corresponding \( F_2 \) values \( (1/2D + 1/8H) \) which resulted in an estimate of \( 1/16H \). A value for \( H \) and subsequently an estimate for \( D \) was then calculated.

3. **The number of effective factor pairs**

Three methods were used to determine the minimum number of effective factor pairs segregating for fiber strength and elongation. The three methods were:

(a). The frequency of \( F_3 \) lines that could be considered as probable parental recoveries, assuming that the \( F_3 \) lines tested represented a random population.

(b). Using a method proposed by Mather (28) where the deviation of each parent from the mid-parent value is squared and divided by the additive genetic variance which is obtained from partitioning of variance.

(c). Using a method proposed by Panse (33) where heritable portions of the mean variance of \( F_3 \) lines is squared and divided by its variance.

4. **Estimates of heritability**

In a narrow sense, heritability may be defined as the ratio of additive genetic variance to phenotypic variance.
In this study estimates of heritability were obtained by 2 methods:

(1). The regression of $F_3$ line means on their corresponding $F_2$ plant values

$$b = \frac{\text{cov. } F_2 \ F_3}{V_{F_2}}$$

Where:

$b = \text{regression coefficient}$

$\text{cov. } F_2 \ F_3 = \text{the covariance of } F_2 \text{ plant values and } F_3 \text{ line means}$

$V_{F_2} = \text{the variance of } F_2$

(2). The method used by Warner (50)

$$\frac{1/2D}{V_{F_2}}$$

Where:

$D = \text{additive genetic variance}$

$V_{F_2} = \text{variance of } F_2$

The estimate of additive genetic variance was obtained from the partitioning of variance data.

5. Association among traits

The following phenotypic correlation coefficients were calculated among $F_3$ line means:

(1). Between fiber strength and fiber elongation.

(2). Between fiber strength and lint percentage.

(3). Between fiber strength and 2.5 percent span length.
(4). Between fiber strength and 50 percent span length.

(5). Between fiber elongation and lint percentage.

(6). Between fiber elongation and 2.5 percent span length.

(7). Between fiber elongation and 50 percent span length.

The formula used to calculate the simple phenotypic correlation was:

\[ r = \frac{\text{cov. } xy}{\sqrt{V_x \cdot V_y}} \]

Where:

- \( r \) = simple correlation
- \( \text{cov. } xy \) = phenotypic covariance between character x and character y
- \( V_x \) = variance of character x
- \( V_y \) = variance of character y

The following genotypic correlation coefficients were calculated:

(1). Between fiber strength and fiber elongation.

(2). Between fiber strength and lint percentage.

(3). Between fiber elongation and lint percentage.

The offspring-parent relationship was used to estimate the genetic correlation. The following formula was used as referred to by Falconer (15):

\[ r_A = \frac{\text{cov. } xy}{\sqrt{\text{cov. } xx \cdot \text{cov. } yy}} \]
Where:

- \( r_A \) = genetic correlation
- \( \text{cov. } xy \) = cross covariance
- \( \text{cov. } xx \) = offspring-parent covariance of each character separately
- \( \text{cov. } yy \) = character separately

The cross covariance was obtained from the product of the value of character \( x \) in parents (\( F_2 \) plant values) and the value of character \( y \) in offspring (\( F_3 \) line means).

Since the Cleveland Short Sympodia and AHA 6-1-4 parents were considered relatively homozygous, the phenotypic correlation within each parent for the several characters mentioned were calculated and used as an estimate of environmental correlations.
RESULTS AND DISCUSSION

The populations used in this genetic analysis consisted of the Cleveland Short Sympodia and AHA 6-1-4 parents and F$_3$ generation. Traits studied were fiber strength, fiber elongation, lint percentage, and fiber length.

The parents, each consisting of 72 plants, and 69 F$_3$ lines, each consisting of 20 to 24 plants, were analysed statistically. The analysis of variance indicated that there was no significant difference among the 3 families studied. This would indicate that they are samples of the same population. This is in agreement with results reported on F$_2$ (14). As a result, the 69 F$_3$ lines were treated as one population.

Reliability of Fiber Strength and Elongation Data

In order to obtain reliable data on fiber strength and elongation, it was necessary for the author to spend a period of time in training to learn the operating techniques of the Stelometer. After 4 weeks of such training, it was decided that the author was sufficiently proficient in the techniques involved to begin the determinations of strength and elongation of the materials involved in the study. So that these measurements would be as accurate as possible, frequent checks were made on the conditions within
the laboratory and on the accuracy of the equipment involved in the determinations. Determinations were made only when temperature and relative humidity within the laboratory were maintained at 70°F ± 2° and 65 percent ± 2 percent respectively. All equipment were checked for accuracy before testing and at 3 hour intervals; if any were found inaccurate, the testing was discontinued until the necessary adjustments were made. As a further guard against errors in measuring these 2 characters, frequent determinations were made of a check cotton of known value for strength and elongation. These determinations were made at the beginning of each work period and for every 2 sub-plots. If the check cotton deviated from the known value for either character, a corresponding adjustment was made to all plants tested during that period. However, test samples were not measured when observed values for the check deviated from its known value by more than 1.20 grams/tex or 0.8 percent elongation.

After determinations were made on all materials involved in the study, 100 plants were chosen at random for a second determination of fiber strength and elongation. The second determination was made in the same manner as the first. The first and second determinations were then compared for both strength and elongation in order to obtain an indication of the accuracy with which each character was measured. In case of fiber strength the original and second determinations were within the accepted tolerance of 1.20 grams/tex.
for 98 of the 100 plants. The other 2 plants were within the range of twice the specified tolerance.

In case of fiber elongation, the original and the second determinations were within the accepted tolerance of 0.8 percent elongation for 92 of the 100 plants. The remaining 8 plants were within the range of twice the specified tolerance. This suggests very good agreement between the first and second determinations for both characters. A further indication of the extent of agreement between the original and the second determinations for each character can be obtained by calculating correlation coefficients. This was done and the correlation coefficients obtained were 0.92 in the case of strength and 0.86 in the case of elongation. These are very high correlation coefficients and indicate that the original determinations were accurate and could be duplicated.

Inheritance of Fiber Strength

The frequency distribution of individual plants in both parents and in \( F_3 \) lines is shown in Table 1. Means and coefficients of variability for both parents and \( F_3 \) lines are indicated.

The 3 main plots of Cleveland Short Sympodia ranged in mean fiber strength from 12.7 to 12.9 grams/tex with an overall average of 12.8 grams/tex. The main plots of AHA 6-1-4 ranged in mean fiber strength from 22.4 to
Table 1. Frequency distribution of fiber strength for the parents and F3 lines

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N. = number of plants.
c.v. = coefficient of variability.

L.S.D. 0.9 grams/tex at the 5 percent level of probability
1.1 grams/tex at the 1 percent level of probability
23.2 grams/tex with an overall average of 22.8 grams/tex. The 2 parents differed by a substantial margin of 10.0 grams/tex. This constitutes a difference of 78 percent of the low strength parent and represents a very wide range for this character.

The 72 plants of Cleveland Short Sympodia fell in 4 strength classes, ranging from 11.0 grams/tex to 14.0 grams/tex, while plants of AHA 6-1-4 fell in 4 strength classes, ranging in fiber strength from 21.0 to 24.0 grams/tex. There was no overlapping in the distribution of plants of the 2 parents as the highest class of Cleveland Short Sympodia differed from the lowest class of AHA 6-1-4 by 6 strength classes.

Coefficients of variability for the Cleveland Short Sympodia ranged from 4.3 to 6.3 percent with an average of 5.1 percent. Coefficients of variability for the AHA 6-1-4 ranged from 3.0 to 5.2 percent with an average of 4.2 percent. The relative variation among plants of each parent was fairly low. The parents were presumably homozygous for fiber strength. Thus, the variation within the parents was assumed to have been due to environmental effect.

The F₃ line means are arranged in Table 1 in ascending order from lines with low means to those with high means. The 69 F₃ line means fell in continuous classes with means ranging from 14.8 to 19.3 grams/tex with a distribution
similar to that expected from a typical quantitative character. Distribution of plants within each F3 line was in most cases continuous and occupied several classes. This along with the F2 data reported by El-Sharkawy (14) indicates that fiber strength in the Cleveland Short Sympodia X AHA 6-1-4 cross behaved as a typical quantitative character.

The coefficients of variability of F3 lines ranged from a low of 2.9 percent to a high of 8.9 percent. Several F3 lines had a coefficient of variability equal to or lower than that of the parents. These lines appeared to be relatively homozygous. However, none of these lines had a mean equal to either of the parental means.

Analysis of variance of the data showed that each of the 69 F3 line means differed significantly from the mean of each parent. Also, the data are clear in indicating that F3 lines were characterized by real differences in mean strength. The least significant differences were 0.9 and 1.1 grams/tex at the 5 and 1 percent levels of probability respectively.

Partitioning of variance

As pointed out by Allard (3), the progress in plant breeding depends on the nature, magnitude and interrelations of genotypic and environmental variation. Variation among generations (parents, F1, F2, backcross, etc.) as reflected by mean variance, has been widely used as a source of information on the ways that genes combine to produce the total
effect of the genotype. Sub-division of the total genotypic variance into additive and non-additive components have been the subject of many studies before.

Additive genetic variance is the more important variance since it is the chief cause of resemblance between relatives. It refers to the average character expression associated with the homozygotes for each of the gene pairs involved. In selection, only the additive effects contribute to permanent gain. The non-additive includes both dominance and epistatic effects. Dominance variance arises from the difference between the expression of heterozygotes and the average of the 2 corresponding homozygotes. From the statistical point of view the dominance deviations are interactions between alleles. Epistatic effects are the results of non-allelic gene interactions.

The method used for partitioning of variance was that referred to by Mather (28). This partitioning of genotypic variance is based on certain assumptions to construct a genetic model. These assumptions are.

1. Regular diploid meiosis.
2. No multiple alleles.
3. No epistatic effect.
4. No linkage or equilibrium with respect to linkage relations.

Variance among F3 line means was partitioned into genotypic and environmental components. The variance
among means of the parental plots grown along with F3 was used as an estimate of the environmental variance among F3 lines. The remaining component was further sub-divided into additive and non-additive components using results from the covariance of F2 plants with F3 means. It was not possible in this study to separate the 2 components of non-additive variance. The following results were obtained:

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<th>Population</th>
<th>Components of variance</th>
<th>Observed variance</th>
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<tr>
<td>Genotypic variance</td>
<td>1/2D + 1/16H</td>
<td>.755</td>
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<td>Covariance F2/F3</td>
<td>1/2D + 1/8H</td>
<td>.784</td>
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\[
\begin{align*}
1/16H & = .029 \\
H & = .464 \\
D & = 1.452
\end{align*}
\]

Where:

- \( H \) = non-additive variance
- \( D \) = additive variance
- \( E \) = environmental variance

The additive portion of genotypic variance was about 3 times larger than the non-additive portion and about 4.5 times as large as the environmental variance. Thus, from these results it could be concluded that the major portion
of genotypic variance was due to additive effect of gene action.

The additive portion of genotypic variance is the portion that contributes to progress under selection. The non-additive and the environmental variances could upset the progress obtained by selection. However, in this population, their magnitude was low relative to the additive portion of the genotypic variance. This would indicate that selection for high fiber strength should be highly effective. The reliability of the conclusions derived from the method of partitioning of variance will depend on the validity of the genetic model. According to Comstock and Robinson (22, 36) the genetic models used for partitioning will usually be unrealistic in one or more respects.

The number of effective factor pairs

The effective factor has been described by Mather (28) as the smallest unit of hereditary material that is capable of being recognized by the methods of biometrical genetics. It may be a group of closely linked genes or at the lower limit a single gene.

Methods for determining the number of effective pairs controlling the expression of a quantitative character have been developed by several workers. These methods are based on certain assumptions to set up a genetic model that will
agree well with the observed data. Due to the fact that some of these assumptions are highly improbable, it should be pointed out that any estimation of the number of genes for a quantitative character is not completely accurate by any procedure.

In this study the first method used to obtain an estimate of number of factor pairs was the frequency of probable parental recoveries among F3 lines. Lines with means within the range of the parental means and with approximately the same coefficient of variability as the parents were to be considered as probable parental recoveries. Analysis of variance of fiber strength data showed that each of the 69 F3 line means differed significantly from the mean of each parent. Thus, not a single F3 line was considered to be a probable parental recovery. None of the F3 line means occurred in the range of the individual plant distribution of either parent.

Assuming that the F3 lines tested represented a random population, one would expect to recover, theoretically, each parental genotype from a population of 64 F3 lines in the case of 3 pairs of genes. Since none of 69 F3 lines was considered to be a probable recovery of either parent, it was concluded that the parents must have differed by more than 3 factor pairs.

In fact, of the total 1,731 plants studied only 1 plant (line 23-45) had a fiber strength value as low as or
lower than the mean of the low strength parent. The observed strength of this plant was 11.8 grams/tex. None occurred with a fiber strength value equal to or higher than the mean of the high strength parent. This extremely low frequency of individual F₃ plants with strength values equal to the mean of either parent would suggest that the parents differed by considerably more than 3 factor pairs for strength.

The second method for estimating the number of effective factor pairs was that used by Mather (28). In this method, the square of half the parental difference was divided by the additive portion of genotypic variance. This method is based on the following assumptions:

(1). All the (+) alleles are provided by one parent and all the (-) alleles are provided by the other parent.

(2). No linkage occurs between the contributing genes.

(3). All genes are equal in their effect.

The mid-parent value was found to be 17.8 grams/tex. The deviation of both parents from the mid-parent value was 5.00 grams/tex. Squaring this value and dividing by 1.452, the value for D (additive genetic variance), an estimate of 17 pairs of genes was obtained.

The estimate of the number of pairs of genes obtained by this method may be distorted in either or both of 2 ways.
One, is that the genes may not all give equal increments; the second is that the (+) and (-) alleles may not be distributed isodirectionally between the parents. Both difficulties must lead to a low estimate of the number of pairs of genes.

The third method used for estimating the number of effective factor pairs was the one proposed by Panse (33). In this method the heritable portion of the mean variance of F3 lines is squared and divided by its variance. In order to obtain the mean variance of F3, the variance among plants of each F3 line was calculated and averaged over all the lines. A value of 1.398 was obtained. The variance among plants within each parental line was calculated and averaged for use as an estimate of the environmental portion of the mean variance of F3. The value obtained for this estimate was .602. By subtracting the estimate of environmental variance from the mean variance of F3, a heritable portion of .796 was obtained. The variance of the mean variance of F3 was obtained by direct calculations and was found to be .059. By dividing the square of the heritable portion of the mean variance of F3 by its variance, an estimate of 11 pairs of genes governing the difference between the parents was obtained. The accuracy of the estimate obtained by this method depends on the number of F3 lines and the number of individual plants.
per line. According to Mather (28) estimates obtained from approximately 20 F3 lines should be reasonably reliable. Since 69 F3 lines were used in this study the method should have given a relatively reliable estimate of the number of effective factor pairs.

According to Mather (28) the estimate obtained by this method should overcome the difficulties of incomplete concentration and incomplete reinforcement which might distort the estimate obtained by the previous method. Thus, a larger estimate of the number of pairs of genes should have been obtained by this method in comparison with Mather's method. But this was not the case, as an estimate of 17 pairs of genes was obtained by the method used by Mather while 11 pairs were obtained by this method. The possibility of the variation due to non-heritable agencies of lowering the estimate of the number of effective factors, and that the variance of the mean variance of F3 being high or low could result in a lower estimate obtained by the third method.

From the results obtained by the 3 methods it appears that the parents differed by a large number of factor pairs for strength. This number ranged from 11 pairs, as estimated by the method proposed by Panse (33), to 17 pairs, as estimated by the formula used by Mather (28).

These results are in close agreement with those obtained in the F2 study of this cross (14). In F2 an estimate of
12 to 13 pairs of genes was obtained using Castle-Wright and Wright formulae. In another cross, involving one of the parents used in this study, Thomas (46) obtained an estimate in $F_2$ of 12 to 14 pairs of genes controlling a parental difference of 6.6 grams/tex.

In other studies, Stafford (43) obtained an estimate of 4 pairs of genes controlling a parental difference of 2.0 Pressley index units. Self and Henderson (38) reported 4 to 5 pairs controlling a parental difference of 2.5 Pressley index units.

The large number of effective factor pairs obtained in this study could be attributed to 2 reasons. The first is the substantially large difference between the 2 parents. Secondly, fiber strength was determined in the present study at the $1/8"$ gauge while in the studies by Stafford (43) and Self and Henderson (38), fiber strength was determined at the zero gauge. Worley (51) studied the inheritance of fiber strength measured at both the zero and $1/8"$ gauge for the same segregating population. He reported that the number of pairs of genes segregating for strength when measured at $1/8"$ gauge was larger than that segregating for strength when measured at zero gauge.

Estimates of heritability

Heritability expresses the proportion of the total variance that is attributable to the average effects of
genes. In a narrow sense Lush (26) defined heritability as the ratio of additive genetic variance to phenotypic variance. The importance of heritability in a genetic study of a quantitative character is its predictive role, expressing the reliability of the phenotypic value as a guide to the genotypic and breeding value. In this study heritability estimates indicate the effectiveness of selection among F2 individual plants.

The regression of F3 means on their corresponding F2 plants was the first method used to obtain an estimate of heritability. Since fiber strength was measured in F2 by another investigator, the 69 F2 plants were measured again for strength by the author. The original measurements and those made by the author were within the accepted tolerance of 1.20 grams/tex. A correlation coefficient of .91 was obtained between the original measurements and those made by the author. This very high correlation coefficient indicates a close agreement between the 2 sets of measurements. Thus, the 2 readings for each of the 69 F2 plants were averaged and used as the F2 parent value.

The regression of F3 line means on their F2 corresponding values is illustrated in Figure 1. A very close association between F3 means and F2 parental plants is indicated by a regression coefficient of .59 ± .065. F2 plants low in fiber strength tended to give F3 lines
Figure 1. A scatter diagram showing fiber strength for 69 F₂ plants and the means of the 69 F₃ lines derived from them.
lines likewise low in strength, and F² plants high in fiber strength tended to produce F³ lines high in strength.

The second method used to obtain an estimate of heritability was based on the partitioning of variance described in the previous section. Half of the additive genetic variance (D), was divided by the total variance in F². This method is based on the fact that the total variance in F² contains only one half of the additive genetic variance.

From the results obtained in this study 1/2D was found to be .726. The variance among the 69 F² plants was found to be 1.40. Thus a heritability estimate of 52 percent was obtained.

The heritability estimate computed on the basis of the additive genetic variance is heritability in a narrow sense. The heritability obtained by this method theoretically should be very accurate in indicating the degree to which the progeny of F² plants will resemble their parents. It should be pointed out, however, that the calculation of this estimate is subjected to a certain degree of error since there are several calculations involved and the variances are small in magnitude. Also, the partitioning of variance into its component is based on certain assumptions some of which may be highly improbable.

Although the estimate of heritability obtained by the regression of F³ means on their F² corresponding plant values might include a portion of the non-additive genetic variance
(the covariance of F3 means with F2 plant values is \(1/2D + 1/8H\)), it is a direct estimate of heritability and has proven to be very practical to plant breeders.

Estimates of heritability of fiber strength using both methods agreed very closely. Both gave relatively high estimates (59 and 52 percent respectively). These estimates suggest that effective selection could be practiced on an individual plant basis during the early segregating generations of this cross.

Estimates of heritability of fiber strength have been obtained in several other studies. Stafford (43) obtained a value of .39 for the regression of F3 means on their corresponding F2 plants. Self and Henderson (38), using the regression of F3 means on F2 plant values, obtained a heritability estimate of 53 percent. Worley (51) obtained an estimate of 69 percent for heritability at the zero gauge, while it was 61 percent at the 1/8" gauge. The present study, along with the results reported by other workers, indicate that heritability of fiber strength is relatively high. Thus, it may be generalized that selection for fiber strength on an individual plant basis would probably be highly effective in most populations having a genetic variability for this character.

Inheritance of Fiber Elongation

The frequency distribution of individual plants in both parents and the 69 F3 lines is shown in Table 2.
Table 2. Frequency distribution of fiber elongation for the parents and F₃ lines

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N = number of plants.

c.v. = coefficient of variability.

L.S.D. .73 percent elongation at the .05 level of probability
       .97 percent elongation at the .01 level of probability
Means and coefficients of variability for both parents and F3 lines are indicated.

The 3 main plots of Cleveland Short Sympodia ranged in mean fiber elongation from 12.2 to 12.4 percent with an overall average of 12.3 percent. The main plots of AHA 6-1-4 ranged in mean fiber elongation from 5.3 to 5.5 percent with an overall average of 5.4 percent. Thus, the 2 parents differed by a substantial margin of 6.9 units. This constitutes a difference of 128 percent of the low elongation parent and represents about the maximum range known to occur for this character in Upland cotton.

The 72 plants of Cleveland Short Sympodia fell in 5 classes, ranging from 10 to 14 percent elongation. The total plants of AHA 6-1-4 fell in 2 classes, ranging in elongation from 5 to 6 percent. Thus, there was no overlapping in the distribution of plants of the 2 parents since the lowest class of Cleveland Short Sympodia differed from the highest class of AHA 6-1-4 by 3 elongation classes.

Coefficients of variability for the Cleveland Short Sympodia parent ranged from 6.4 to 9.2 percent, with an average of 7.7 percent. Coefficients of variability of AHA 6-1-4 ranged from 5.9 to 7.2 percent, with an average of 6.4 percent. These are fairly high values for inbred lines. El-Sharkawy (14) reported much lower coefficients of variability for the same parents in his study of the
F₂ population of this cross, 4.1 and 3.2 percent for
Cleveland Short Sympodia and AHA 6-1-4 respectively.
However, his evaluations were based on 17 plants of each
parent which were grown in a single 30 feet plot. In
the present study, the coefficient of variability of each
parent was based on 72 plants and with each parent grown
in 9 plots of 8 plants each, randomly located throughout
the experimental area. The more extensive sampling of the
experimental area in this study could at least partially
account for the higher coefficients of variability observed
than that reported by El-Sharkawy.

The fact that the 2 studies were grown in different
years and conducted by different individuals may also have
a bearing on this point. However, since the parents had
been inbred for several generations and, presumably, were
relatively homozygous, these moderately high coefficients
of variability were assumed to have been due to environ­
mental causes.

The F₃ line means are arranged in Table 2 in ascending
order from lines with low means to those with high means.
The 69 F₃ line means fell in continuous classes with means
ranging from 6.3 to 11.3 percent. The distribution was
similar to that expected from a typical quantitative
character. Distribution of plants within each F₃ line
was also continuous and occupied several classes.
This, along with the F2 data reported by El-Sharkawy (14), indicates that fiber elongation in the Cleveland Short Sympodia X AHA 6-1-4 cross behaved as a typical quantitative character.

The coefficients of variability of F3 lines ranged from 5.9 to 18.8 percent. Some of the F3 lines had coefficients of variability equally as low as that of the parents. Thus, these lines appeared to have been relatively homozygous, but none had a mean equal to either of the parental means.

Analysis of variance of the data showed that each of the 69 F3 line means differed significantly from the mean of each parent. The analysis also indicated that the F3 lines differed appreciably among themselves in mean fiber elongation. The least significant difference calculated at the 5 percent level of probability was .73 percent elongation.

**Partitioning of variance**

As was the case of fiber strength data, the variance among F3 line means for fiber elongation was partitioned into its components. The variance among parental plot means was used as an estimate of environmental variance among F3 lines. The remaining component was further subdivided into additive and non-additive components using results from the covariance of F2 plants with F3 means.
The following results were obtained:

<table>
<thead>
<tr>
<th>Population</th>
<th>Components of variance</th>
<th>Observed variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variance among F₃ lines</td>
<td>1/2D + 1/16H + E</td>
<td>1.013</td>
</tr>
<tr>
<td>Environmental variance</td>
<td>E</td>
<td>.201</td>
</tr>
<tr>
<td>Genotypic variance</td>
<td>1/2D + 1/16H</td>
<td>.812</td>
</tr>
<tr>
<td>Covariance F₂/F₃</td>
<td>1/2D + 1/8H</td>
<td>.807</td>
</tr>
</tbody>
</table>

Since variances cannot have negative values, non-additive portion of genotypic variance was considered to be zero. Thus, all of the genetic variation for fiber elongation was considered to have been due to additive variance.

The number of effective factor pairs

The 3 methods used to estimate the number of effective factor pairs segregating for fiber strength were also used to determine the number in the case of fiber elongation.

The frequency of probable parental recoveries among F₃ lines was the first method used to obtain an estimate of the number of effective factor pairs. Lines with means within the range of the parental means and with approximately the same coefficient of variability were to be considered as possible parental recoveries. Six F₃ lines had means within
the range of the individual plant distribution of the high elongation parent (lines 20-25, 20-41, 27-21, 27-5, 22-5 and 20-6). Two F3 lines had means within the range of the individual plant distribution of the low elongation parent (line 23-17 and 20-51). However, analysis of variance of fiber elongation data showed that each of the 69 F3 line means differed significantly from the mean of each parent. Thus, not a single F3 line was considered to be a probable parental recovery.

Assuming that the F3 lines tested represented a random population, one would expect to recover, theoretically, each parental genotype from a population of 64 F3 lines in the case of 3 pairs of genes. Since none of the 69 F3 lines were considered to be probable parental recoveries of either parent, it was concluded that the parents must have differed by more than 3 factor pairs for elongation.

A few of the 1,731 individual F3 plants may have been parental recoveries. Three F3 plants had elongation values equal to or lower than the mean of the low elongation parent. These plants occurred in F3 line 20-51. Two F3 plants had elongation values equal to or above the mean of the high elongation parent. These plants occurred in F3 lines 22-51 and 20-6. The occurrence of these individual F3 plants with elongation values equal to the mean of the parents would suggest that the parents differed by fewer pairs of genes for fiber elongation than was the case for fiber strength.
The second method for estimating the number of effective factor pairs was that used by Mather (28). The mid-parent value for fiber elongation was found to be 8.85 percent. The deviation of both parents from the mid-parent was 3.45 percent elongation. Squaring this value and dividing by 1.62, the value for \( D \), an estimate of 7 pairs of genes was obtained.

The third method used for estimating the number of effective factor pairs was the one proposed by Panse (33). The mean variance of \( F_3 \) lines was found to be .952. The variance among plants within each parental line was calculated and averaged to use as an estimate of the environmental portion of the mean variance of \( F_3 \). The value obtained for this estimate was .411. By subtracting the estimate of environmental variance from the mean variance of \( F_3 \) a heritable portion of .541 was obtained. The variance of the mean variance of \( F_3 \) was obtained by direct calculation and was found to be .060. By dividing the square of the heritable portion of the mean variance of \( F_3 \) by its variance, an estimate of 5 pairs of genes governing the difference between the parents was obtained.

The estimates of the number of factor pairs obtained by the 3 methods agreed very closely. The frequency of probable parental recoveries suggests that the parents differed by more than 3 pairs of genes but fewer than was
the case for fiber strength. The second and the third method agreed very closely as they gave an estimate of 7 and 5 pairs respectively. In F2 study of this cross (14) a slightly lower estimate of 4 to 5 pairs of genes was obtained.

**Estimate of heritability**

The regression of F3 means on their corresponding F2 plants was the first method used to obtain an estimate of heritability. Since fiber elongation was measured in F2 by another investigator, the 69 F2 plants were measured again for fiber elongation by the author. The original measurements and those made by the author were all within the accepted tolerance of .8 percent elongation. A correlation coefficient of .90 was obtained between the original measurements and those made by the author. This very high correlation coefficient indicates a close agreement between the 2 sets of measurements. Thus, the 2 readings for each of the 69 F2 plants were averaged and used as the F2 parent plant value.

The regression of F3 line means on their corresponding F2 plant values is illustrated in Figure 2. A very close association between F3 means and F2 parental plants is indicated by a regression coefficient of .80 ± .057. F2 plants high in fiber elongation tended to give F3 lines high in elongation, and F2 plants low in elongation tended to produce F3 lines low in elongation.
Figure 2. A scatter diagram showing fiber elongation for 69 F₂ plants and the means of the 69 F₃ lines derived from them.
The second method was used to obtain an estimate of heritability in a narrow sense. In this method, half of the additive genetic variance obtained from the partitioning of variance data was divided by the variance among the 69 F2 plants. The variance among the 69 F2 plants was found to be 1.02, and as previously reported, 1/2D equals .81; thus, a heritability estimate of 79 percent was obtained.

Both estimates of heritability were essentially the same due to the fact that the total genetic variance was additive in nature. Both methods gave very high estimates of heritability for fiber elongation. These results indicate that selection for high elongation on an individual plant basis would be highly effective.

A heritability estimate of 90 percent was obtained by El-Sharkawy (14) in the F2 study of this cross. Thomas (46) obtained a lower estimate of 36 percent for heritability of fiber elongation.

Association Among Traits

One of the major concerns of plant breeders is to study the association among economic traits. It is an advantage to find desirable characters associated together. A favorable association would benefit a breeding program designed to combine the desirable expression of several characters. On the other hand, an association between desirable and undesirable characters may represent a
problem to the breeder who wants to select for one character without the other. The correlation coefficient is used as a measure of the degree of association between characters.

In a study of association between 2 traits, it is often desirable to distinguish between the 2 possible causes of association, genetic and environmental. Environment is a cause of correlation when 2 characters are influenced in a positive or a negative manner by the same differences of environmental conditions. The genetic causes of correlation are due to either linkage or pleiotropy. Linkage causes an association between characters when all or some of the genes affecting the respective characters are located on the same chromosomes. Correlations arising from pleiotropy occur when 2 characters are influenced by the same gene or genes. The genetic and environmental causes of correlation combine together to give the phenotypic correlation. Falconer (15) stated that if both characters have low heritabilities the phenotypic correlation is determined chiefly by association due to environmental causes, and where they have high heritabilities the phenotypic correlation is determined chiefly by association due to genetic causes.

Since the parents used in this study were inbred for several years and were considered relatively homozygous, the phenotypic correlations among the parent plants were used as estimates of environmental correlations. Genetic
correlations were calculated by the method used by Falconer (15). The following associations were studied:

(1). Association of fiber strength with fiber elongation.

The degree of association between fiber strength and fiber elongation is shown in Figure 3. It can be seen that F₃ lines low in fiber strength tended to be high in fiber elongation, and F₃ lines high in fiber strength tended to be low in fiber elongation. A simple phenotypic correlation coefficient of -0.60 was obtained where the calculation was based on the 69 F₃ line means. A somewhat higher correlation coefficient of -0.69 was obtained where the calculation was based on the total individual plants in F₃. These values agree fairly close with the correlation coefficient of -0.57 obtained from the F₂ population of this cross (14). Thus, it is apparent that a strong negative association occurred between fiber strength and fiber elongation in the early segregating generations of this cross.

In order to obtain an estimate of the environmental correlation between these 2 characters, correlation coefficients were determined between fiber strength and fiber elongation for the 72 plants of each parent. A low and non-significant correlation coefficient of -0.21 was obtained for the Cleveland Short Sympodia parent and a slightly higher but statistically significant value of
Figure 3. A scatter diagram showing the association between fiber strength and fiber elongation in 69 F3 lines.
- .33 was obtained for the AHA 6-1-4 parent. This suggests that a part of the phenotypic correlation may have been due to environmental causes.

Using the method proposed by Falconer (15) the genetic correlation between fiber strength and fiber elongation was found to be -.84. This indicates that most of the association between fiber strength and fiber elongation was due to genetic causes. This was expected since both characters had high heritability estimates and since the estimate of environmental correlation between the 2 characters was moderately low. This high correlation coefficient suggests that it would be extremely difficult, if at all possible, to combine high expressions for both of these characters in a single line.

It is not clear whether the genetic correlation was due to linkage or pleiotropic effect. If the character combination of high strength and low elongation was due primarily to pleiotropic effect, it would of course be impossible to obtain the desired combinations of both characters from this population. On the other hand, if linkage was the major problem in the present material, breeding procedures which would maximize the opportunity of breaking up this linkage could be employed. Further studies are needed to determine the cause of the genetic correlation between these 2 characters.
Very few studies have been reported on the association between fiber strength and fiber elongation. Al-Jibouri (1) reported a strong negative association between fiber strength and fiber elongation in an interspecific cross. Thomas (46), in his F2 study of a cross between Stardel and Cleveland Short Symodia, obtained a correlation coefficient of -0.39 between fiber strength and fiber elongation. Based on the results from this study and those reviewed above, it can be concluded that selection for high fiber strength would probably result in a substantial decrease in fiber elongation.

(2). The association of fiber strength with other characters.

The correlation coefficients involving fiber strength with each of lint percentage, 50 percent span length and 2.5 percent span length, are given in Table 3. The phenotypic correlations are based on the 69 F3 line means.

A highly significant negative correlation coefficient of -0.43 was obtained between fiber strength and lint percentage. The environmental correlations estimated from Cleveland Short Symodia and AHA 6-1-4 were non-significant values of -0.01 and -0.02 respectively. The genetic correlation between these 2 characters was high and significant (r = -0.40). This would indicate that the association of these 2 characters in the present F3 population was due to genetic causes. The direction and magnitude of the correlation
Table 3. The association of fiber strength and fiber elongation with some important economic traits

<table>
<thead>
<tr>
<th>Fiber Elongation</th>
<th>Lint Percentage</th>
<th>2.5% span length</th>
<th>50% span length</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fiber Strength</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-.60**</td>
<td>-.43**</td>
<td>+.60**</td>
</tr>
<tr>
<td>G</td>
<td>-.84**</td>
<td>-.40**</td>
<td>-</td>
</tr>
<tr>
<td>Fiber Elongation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P</td>
<td>-.002</td>
<td>-.095</td>
<td>-.18</td>
</tr>
<tr>
<td>G</td>
<td>+.12</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*P = phenotypic correlation coefficient based on the 69 F3 line means.*

*G = genotypic correlation coefficient.*

**Significant at the .01 level of probability.
would indicate difficulty in combining high expressions of both characters.

Several studies have been reported on the correlations of fiber strength with lint percentage. In an interspecific cross, Worley (51) found the 2 characters to be non-associated in F2 but obtained a low and significant correlation \( r = -0.21 \) between the 2 characters in F3. Al-Jibouri (2) reported a high degree of association between fiber strength and lint percentage in an interspecific cross. A phenotypic correlation coefficient of \(-0.58\) was obtained while the genotypic correlation was \(-0.53\). In intervarietal crosses in Upland cotton Miller et al (29) reported low associations between fiber strength and lint percentage. In the 3 populations studied, the correlation coefficients ranged from \(-0.07\) to \(-0.24\).

The degree of association between fiber strength and the 50 percent span length is indicated by a simple phenotypic correlation coefficient of \(+0.44\). The 2 parents gave different estimates of environmental correlation. The environmental correlations obtained from the Cleveland Short Sympodia and AHA 6-1-4 were \(+0.39\) and \(+0.10\) respectively. This indicates that a portion of the association between fiber strength and 50 percent span length in F3 could be attributed to environmental causes. The positive association between fiber strength and 50 percent span length
suggests that it would be easy to combine the desirable expressions of both characters.

The phenotypic correlation coefficient between fiber strength and 2.5 percent span length (which is comparable to the U.H.M. on the Servo Fibrograph) was +.60. The 2 parents also gave different estimates of environmental correlation. The environmental correlations estimated from the Cleveland Short Sympodia and the AHA 6-1-4 were +.25 and +.06 respectively. Although the environmental correlation in Cleveland Short Sympodia was significant, its value was fairly low. The low estimate of environmental correlations would indicate that the association probably was largely due to genetic causes. The direction and magnitude of this correlation should benefit a breeding program designed to combine the desirable expressions of both fiber strength and 2.5 percent span length.

Several studies have been reported on the degree of association between fiber strength and U.H.M. A very low degree of association between these 2 characters have been reported by many workers. Miller et al (29) reported phenotypic correlations ranging from -.23 to +.33 and genotypic correlations ranging from -.23 to +.25.

It would be emphasized that these correlations will differ with different gene association existing in the parental lines of the segregating populations.
(3). Association of fiber elongation with other characters.

The correlation coefficients involving fiber elongation with each of lint percentage, 50 percent span length and 2.5 percent span length are given in Table 3.

A very low non-significant phenotypic correlation coefficient of -.002 was obtained between fiber elongation and lint percentage. Environmental correlation coefficients were +.06 and +.005 for Cleveland Short Sympodia and AHA 6-1-4 respectively. Also, a very low non-significant genotypic correlation of +.12 was obtained. This indicates that no association occurred between these 2 characters in the present population.

The phenotypic correlation coefficient between fiber elongation and 50 percent span length was very low and non-significant (r = -.18), indicating no association between the 2 characters. The environmental correlations were +.06 and +.15 for Cleveland Short Sympodia and AHA 6-1-4 respectively.

The phenotypic correlation coefficient between fiber elongation and 2.5 percent span length was -.095. This is a very low and non-significant correlation indicating no association between these 2 characters. The environmental correlations were +.04 and +.14 for Cleveland Short Sympodia and AHA 6-1-4 respectively.

The values of these correlations suggested that high elongation probably could be combined fairly easily with high levels of fiber length and lint percentage.
SUMMARY AND CONCLUSIONS

The inheritance of fiber strength and fiber elongation was studied in the parents and 69 F3 lines of a cross between Cleveland Short Sympodia and AHA 6-1-4, both varieties of Upland cotton, *Gossypium hirsutum*. The Cleveland Short Sympodia had low fiber strength of 12.8 grams/tex and high fiber elongation of 11.3 percent. On the other hand, AHA 6-1-4 had high fiber strength of 18.8 grams/tex and low fiber elongation of 5.4 percent.

The F3 lines along with progenies of each parent were grown in small plots replicated 5 times. The minimum number of plants evaluated for any one line was 20; the maximum number was 14. The number of plants evaluated for each parent was 72. Each plant was evaluated separately for fiber strength, fiber elongation, lint percentage and fiber length.

Fiber strength and fiber elongation were determined by the Stelometer at 1/8 gauge. Lint percentage was determined in the conventional manner. Fiber lengths at the 50 percent and 2.5 percent span length were determined on the Digital Fibrograph. Lint percentage and fiber length at the 1-spin lengths were determined in order to measure their association with fiber strength and fiber elongation.
The following results and conclusions were derived:

(1). The distribution of the 69 F_3 line means for strength was continuous, indicating that fiber strength was inherited as a quantitative character.

(2). Analysis of variance of fiber strength data indicated that none of the F_3 lines could be considered as a probable parental recovery. The 10.0 grams/tex by which the parents differed appeared to have been controlled by a large number of pairs of genes. Estimates of the minimum number of effective factor pairs controlling the difference between the parents were 11 and 17 pairs of genes as obtained by the formulae proposed by Panse and Mather respectively.

(3). The partitioning of variance data indicated that the major portion of the variation in fiber strength was due to additive gene action. The additive portion of the genotypic variance was about 3 times larger than the non-additive portion and about 4 1/2 times as large as the environmental variance.

(4). Estimates of heritability of fiber strength were high. An estimate of 59 percent was obtained based on the regression of F_3 means on their F_2 corresponding plant values. A slightly lower estimate of 52 percent was obtained when heritability was computed on the basis of the additive genetic variance. These high estimates of heritability suggest that selection on an individual plant
basis during early segregating generations would have been highly effective in this population.

(5). A continuous distribution was also obtained for the 69 F3 line means for fiber elongation suggesting that fiber elongation was inherited as a quantitative character.

(6). Analysis of variance of fiber elongation data indicated that none of the F3 lines could be considered as a probable parental recovery. The large difference between the parents of 6.9 units appeared to have been controlled by fewer factor pairs than was the case for fiber strength. The formulae proposed by Panse and Mather suggested that the difference between the parents for fiber elongation was controlled by 5 and 7 pairs of genes respectively.

(7). All the genotypic variance in fiber elongation was found to be due to additive effect of gene action.

(8). A very high estimate of heritability (80 percent) was obtained. This very high estimate suggests that selection for fiber elongation on individual plant basis would be highly effective.

(9). A highly significant negative phenotypic correlation coefficient of $-0.60^{*}$ was obtained between fiber strength and fiber elongation. A higher value for the genotypic correlation coefficient ($r = -0.84^{**}$) between these 2 characters was obtained. The magnitude and nature of these correlations suggest that it would be very difficult to obtain lines with high levels of both fiber strength and fiber elongation.
(10). Fiber strength was negatively correlated with lint percentage \((r = -0.43^{**})\) and positively correlated with fiber length at both the 50 percent span length \((r = +0.44^{**})\) and the 2.5 percent span length \((r = +0.60^{**})\). The direction and magnitude of these correlations indicate that it would be difficult to combine high expression of fiber strength and lint percentage, while it would be easy to combine desirable expressions of both fiber strength and fiber length.

(11). Fiber elongation was not correlated with neither lint percentage nor fiber length at either span length.
LITERATURE CITED


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EXAMINATION AND THESIS REPORT

Candidate: Hound A. Abec-half

Major Field: Array

Title of Thesis: Inheritance of Filter-feeding and filter-feeding in
Crass between the varieties of the series

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

May 20, 20??