ESTIMATING GENETIC PARAMETERS IN COTTON

(<u>GOSSYPIUM</u> <u>HIRSUTUM</u> L.) USING

COMSTOCK AND ROBINSON'S

DESIGN III

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CHAPTER I

INTRODUCTION

Since no variety has the ideal combination of characters and since some varieties are inherently better than others in one or more traits, the task of the plant breeder should be obvious, i.e., to incorporate more desirable combinations of characters into new commercial varieties.

With increasing demands being made by textile mills for a cotton (Gossypium hirsutum L.) fiber of higher quality, yield and lint percent can no longer be the only objectives of the breeder and of the individual producer. In Oklahoma where growing seasons may be extremely short because of cool temperatures and excessive rainfall in the spring or of cool temperatures and early frosts in the fall or both, earliness of maturity must also be given close consideration by the breeder. Therefore, a cotton variety to be bred for commercial production under such circumstances should combine high fiber quality with acceptable levels of yield, earliness, and lint percent.

A knowledge of the inheritance of the traits to be selected greatly benefits the breeder in formulating a program to most efficiently and effectively meet his objectives per unit of time. Although genotype is important in determining the performance of all traits of economic importance in cotton, environment also has a significant effect upon the degree to which genetic potentials are expressed. Genotype by environment interactions are also highly important for

traits in cotton.

The purpose of this experiment was to investigate the nature of inheritance of yield, earliness, lint percent, and fiber quality within an F_2 population derived from two parents whose desired qualities, if combined, should more nearly approximate the "ideal" variety for cotton production in Oklahoma. Genotypic, phenotypic, environmental, and genotype by environment interaction parameters; narrow-sense heritabilities and expected genetic advances; phenotypic correlations; and population means were estimated and used to make appropriate breeding implications within this material.

CHAPTER II

REVIEW OF LITERATURE

For convenience and to enhance the reader's comprehension, the
literature on each character studied in this experiment will be
reviewed separately. Within each character the topics that will be
discussed include the inheritance of the trait, correlated responses
with other traits, and genotype by environment interactions. Unless
otherwise stated, estimates described as being significant were so at
the 0.01 probability level.

Lint Yield

Miller and Marani (1963) indicated that the major portion of the
genetic variance for yield among eight inbred lines studied in a
diallel cross was additive genetic variance as suggested by very large
and highly significant general combining ability (GCA) variances in the
F_1 and F_2 generations. On the other hand, the presence of small but
significant, at the 0.05 probability level, estimates of specific
combining ability (SCA) variance in the F_2 suggested that at least
some of the genetic variance in the population was non-additive (due to
dominance or epistasis or both). Hayman (1958), in illustrating a
method of analysis for the detection of epistasis, found significant
epistasis of the complementary type for lint yield in a diallel cross
among seven Upland lines. White and Kohel (1964) in a five-parent

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diallel studying parents and F_1's concluded that yield had an overall de-
gree of dominance of 0.91, i.e., partial dominance, with the direction
of dominance being toward the higher parent. Significant additive and
and dominance genetic (0.05 probability level) variation was also detec-
ted in this material. White and Richmond (1963) had earlier found sig-
nificant GCA and SCA for lint yield. White (1966) in the same diallel,
but including F_2's, parents, and F_1's, detected significant dominance
and additive genetic variance at the 0.05 level for lint yield with an
average degree of dominance being calculated as 1.32, i.e., overdominance.
He detected no epistasis nor multiple allelism in this material. Miller
and Rawlings (1967) using recurrent selection for increased lint yield
in a cross involving two inbred lines, 'G-4' and 'H-1', derived from
'Coker 100' and 'Acala 1517', respectively, concluded that additive gene
effects predominated in this material although additive by additive ef-
fects could not be excluded. They obtained a linear selection response
over three cycles of selection. As selection increased lint yield,
simultaneous increases were observed for earliness, lint percentage, and
fiber coarseness while decreases were noted for fiber length and
strength. Al-Rawi and Kohel (1969), employing a nine-parent diallel
cross, found no epistasis for lint yield but did find multiple allelism
to be present. The additive genetic component was significant and
greater than the dominance component which was also significant. They
also pointed out that lint yield exhibited partial dominance (0.64) and
that it was polygenically inherited. They estimated a narrow-sense
heritability on a plot-mean basis of 0.41 for this character.

Fryxell (1956) studied heritabilities of yield and the components
of yield, in an F_2 population derived from a cross between strains of

the varieties 'Hartsville' and 'Acala'. Heritabilities progressively
increased at successive levels of subdivision of the trait, yield, into
its components. He interpreted these results to suggest compliance
with an additive genetic model. Murray and Verhalen (1969) calculated
a broad-sense heritability estimate in the Bc_2F_4 generation of a cross
between 'Acala 44' and 'OK-86' of 0.45 for lint yield on a plot-mean
basis with an expected genetic advance of 6.2% of the mean. They also
found lint yield to be negatively correlated with earliness (r = -0.38).
This genotypic correlation was significant.

Barnes and Staten (1961) secured estimates of GCA and SCA for
yield, in seven closely related Acala strains, which by their relative
magnitudes suggested that SCA was more important than GCA in six of
those parents. Lee et al. (1967) detected a significant GCA x location
interaction at the 0.05 level for lint yield. They did not obtain
significant estimates of GCA or SCA for this trait.

Manning (1955) calculated a selection response of 35% for yield
over six generations of selection in the Upland variety 'BP52' using a
selection index based on yield components. He estimated a narrow-sense
heritability of 0.10 to 0.15 on a single plant basis in this material.
Manning (1955) investigating the response to selection for yield in
several Upland crosses through the F_5 determined that the performance
of the F_1 and the F_2 did not correspond very closely to the performance
of future generations for yield and that selection on a single plant
basis for this character was highly ineffective.

Miller et al. (1958) in a study of the F_4 or F_5 of three popula-
tions derived from crosses of Upland varieties noticed that environmen-
tal variances for lint yield estimated by plot error were generally

large. In one of the populations, a significant second-order inter-
action of genotypes with years and locations was obtained. Within the
three populations they found phenotypic correlations of yield with lint
percent ranging from 0.59 to 0.64, with fiber length from -0.28 to
-0.35, fiber strength from -0.03 to -0.25, and with fiber fineness from
-0.10 to -0.49. They found genotypic correlations of yield with lint
percent ranging from 0.74 to 0.87, with fiber length from -0.33 to
-0.47, with fiber strength from -0.01 to -0.34, and with fiber fineness
from -0.25 to -0.71. Miller et al. (1959) evaluated fifteen cotton
varieties at nine locations in North Carolina over a three year period.
They ascertained that varieties yielded quite differently when grown
under different environments but that there were no consistent location
or year effects on differential varietal response over the test period.
Again, significant second-order but not first-order interactions were
obtained.

Abou-El-Fittouh et al. (1969) computed the genotype by environment
interactions among four varieties over 101 environments distributed
over three years. They observed that the genotype by location and geno-
type by year by location components for lint yield were very large with
the first order component being substantially larger than the second-
order one. Significance levels were not attached to these estimates.
Studying additional varieties within five subsets of the 101 environ-
ments, they found that the genetic component was generally the largest
in magnitude followed in order by the second-order component, the
genotype by location component, and the genotype by year component.
Bridge et al. (1969) obtained a substantial and significant variety
by year by location interaction for lint yield but nonsignificant

variety by location and variety by year interactions when eight varie-
ties were studied at three locations in Mississippi over three years.
Miller et al. (1962) investigated the genotype by environment inter-
actions among 16 varieties tested over three years at 11 locations from
North Carolina to Texas. When all locations were considered, a signifi-
cant variety by location and a large and significant second-order inter-
action were obtained for yield. When the three Texas locations were
omitted, the variety by location component was no longer significant.
Murray and Verhalen (1970) evaluated interactions of eleven varieties
over three years and three locations in Oklahoma. They obtained a
large and significant genotype by location interaction mean square, at
the 0.05 probability level, and a large and significant second-order
interaction mean square for lint yield.

<center>Earliness</center>

Al-Rawi and Kohel (1969) in the diallel described in the previous
section reported no epistasis for earliness. However, multiple
allelism for this trait was present. They found the additive genetic
component significant and greater than the dominance component which
was also significant. They concluded that earliness exhibited partial
dominance approaching complete dominance (0.95) and was polygenically
inherited. A narrow-sense heritability estimate on a plot mean basis
was calculated to be 0.41.

Murray and Verhalen (1969) obtained a broad-sense heritability
estimate of 0.73 on a plot mean basis in the Bc_2F_4 of the cross
described earlier. Their predicted genetic advance selecting the upper
10% of the population was 9.1% while actual progress was only 4.8%.

Genotypic correlations were calculated between earliness and fiber length, fiber coarseness, T_0 (a measure of fiber strength), and T_1 (another strength measurement) as -0.55, 0.37, 0.28, and -0.28, respectively. The correlations with fiber strength were significant at the 0.05 probability level. The others were also significant. The correlation between earliness and lint yield was described in the previous section.

White and Richmond (1963) detected significant GCA effects for earliness in their material but obtained nonsignificant estimates of SCA. White and Kohel (1964) in the same material obtained very large and significant estimates of additive genetic variance and very small and nonsignificant estimates of dominance variance. White (1966) also in the same material detected significant multiple allelism but no significant epistasis for this trait.

Barnes and Staten (1961) calculated estimates which showed SCA to be more important than GCA for earliness in six out of seven closely related Acala strains. Miller and Marani (1963) in the diallel described earlier obtained significant GCA in the F_1 and F_2 for earliness but did not find significant SCA in either generation. Al-Rawi (1970) in a 10-parent diallel cross obtained narrow-sense heritabilities on a plot mean basis for this trait in the F_1 and F_2 which ranged from 0.12 to 0.29. The degree of dominance appeared to be in the over-dominance range and to be in the direction of earlier maturity. In a heterozygous population derived from a cross between OK-86 and Acala 44, he obtained a realized heritability of 0.35 for earliness in the first cycle of mass selection. Results from the second cycle were contra-dictory.

Lint Percent

Al-Rawi and Kohel (1969) calculated no epistasis for lint percent in the diallel cross they studied. However, multiple allelism and possibly correlated gene distribution was present for this character. They detected significance for the additive genetic variance but not for the dominance variance. Stith (1955) found partial dominance for higher lint percent. Broad-sense heritability estimates in his material were 0.45 in the F_2 and 0.79 in the F_3 using variance components.

Lee et al. (1967) obtained a significant estimate of GCA and a nonsignificant estimate of SCA for lint percent. The interactions of GCA with environment were not significant for this character. White and Richmond (1963) in a five-parent diallel cross also observed significant GCA but nonsignificant SCA for this trait. White and Kohel (1964) in the same material obtained a significant estimate of additive genetic variance but a nonsignificant estimate of dominance variance. White (1966) again in the same material found no significant dominance for lint percent. No epistasis was evident for this trait, but multiple allelism was present.

Barnes and Staten (1961) secured estimates of SCA larger than GCA for six of seven closely related Acala strains. In the diallel described previously, Miller and Marani (1963) calculated significant estimates of GCA in the F_1 and F_2 but of SCA only in the F_2. Miller et al. (1958) found a single significant genotype by environment inter- action component for lint percent among three populations and that estimate was a confounded one based on two years at a different location each year. Within the three populations they found phenotypic correlations of lint percentage with fiber length ranging from -0.48 to

-0.57, with fiber strength from 0.07 to -0.24, and with fiber coarseness

from -0.09 to -0.43. Genotypic correlations of lint percentage with

fiber length, strength, and coarseness were estimated from -0.46 to

-0.50, from 0.07 to -0.17, and from -0.09 to -0.34, respectively.

Correlations of lint yield with these traits were described earlier.

Miller et al. (1962) in their evaluation of 16 cotton varieties

at 11 locations over three years traced significance at the 0.05 level

for the varieties by years interaction as well as significance for the

varieties by locations and varieties by locations by years interactions

for lint percent. All the interactions, however, were small in compar-

ison to the varietal component. Miller et al. (1959) in the North

Carolina study previously described obtained significant first- and

second-order interactions of environment with lint percent. Again,

these estimates, though significant, were extremely small in comparison

to the varietal component. Abou-El-Fittouh et al. (1969) in the study

described earlier computed first-order interactions one-sixth as large

as the varietal component and a second-order interaction two-thirds as

large. Significance levels were not attached to those estimates.

Bridge et al. (1969) in Mississippi secured a substantial and signifi-

cant second-order interaction for lint percent and nonsignificant

first-order interactions for eight varieties over three years and

three locations.

Fiber Length

Richmond (1949) evaluated 'Lintless', 'High-Smooth', 'Missdeland',

and 'Half and Half' and their six possible crosses to investigate the

genetics of factors responsible for lint quality in Upland cotton. He

reported two genetic systems controlling this character, i.e., one system is a single major gene for presence versus absence of lint which also controls the presence (fuzzy) versus absence (glabrous) of seed fuzz; the other system involves modifiers which function in the presence of the major gene and can be detected directly on a homozygous seedcoat background. Dark (1960) identified the gene, H_2, that controls pubescence in 'T 611' and concluded that it is independent of lint shortening effects when transferred into a G. barbadense background.

In a cross between 'Florida Green Seed' and 'Rowden', Ware et al. (1943) pointed out that long fiber was partially dominant over short fiber in the F_1 and that it showed monopodial distribution in segregating generations. Sloan (1955) indicated that the inheritance of fiber length in the F_2 and F_3 of a cross involving 'Wilds' and Half and Half was highly heritable and conditioned by at least three pairs of genes. Stith (1955) employing an Acala x 'Hopi' cross concluded that staple length is quantitatively inherited with no evidence of transgressive segregation. Partial dominance for longer fibers was exhibited, and estimates indicated that fiber length was controlled by a relatively large number of genes. He calculated a broad-sense heritability of 22.2 and 70.0 from F_2 plants and F_3 lines, respectively. Marani (1968) in tests of all possible crosses among three to four varieties over six years found that the inheritance of fiber length was mostly additive with some heterosis probably due to dominance effects. Degree of dominance was partial and toward the higher parent. Al-Rawi (1970) calculated realized heritabilities of 0.78 and 0.23 from the first and second cycles of mass selection, respectively, in a heterozygous

population derived from OK-86 and Acala 44. One cycle of mass selec-
tion after intermating gave a narrow-sense heritability of 0.37 on an
individual plant basis.

Ramey (1960) in a cross of Half and Half and 'Delfos 9252'
suggested the possibility of allelic and nonallelic interactions being
involved in the inheritance of this trait. Lee et al. (1967) concluded
that length is inherited entirely in an additive fashion and that
hybridization can only partially obscure the deficiencies of a poor
parent. They obtained a significant estimate of GCA and nonsignificant
estimates of the interaction between GCA and environments and of SCA
for this character. Miller and Marani (1963) also found significant
GCA and nonsignificant SCA in the material they studied. Verhalen
and Murray (1967, 1969) in a study including parents, F_1's, and F_2's
among 10 varieties using the diallel analysis concluded that the
average degree of dominance for fiber length was partial dominance
since the nine estimates calculated ranged from 0.36 to 0.79. The
direction of dominance was toward greater length of fiber. Narrow-
sense heritabilities on a plot-mean basis of 0.49 and 0.61 were esti-
mated in the F_1 in 1965 and 1966, respectively, and of 0.49 in the F_2
in 1966. A genotype by year analysis of the performance of the 10
parents over two years at one location did not reveal a significant
interaction mean square for this trait.

Murray and Verhalen (1969) obtained a broad-sense heritability
estimate of 0.85 on a plot mean basis and calculated an expected
genetic advance of 0.039 which agreed rather closely with the observed
response of 0.034. Barnes and Staten (1961) concluded that GCA was
more important than SCA for fiber length among five out of seven

closely related strains.

Al-Rawi and Kohel (1970) in a nine-parent diallel including F_1's and F_2's showed fiber length to be polygenically inherited and to show partial dominance (0.77) toward the longer fibered parents. Estimates of additive and dominance genetic variance were of the relative proportion 1.0:0.6 and both were significant. A narrow-sense heritability of 0.56 on a plot mean basis was calculated.

Miller et al. (1958) in one of two populations found significant genotype by location and genotype by location by year interactions at the 0.05 probability level for this trait. They also calculated phenotypic correlations in the three populations between fiber length and strength which ranged from -0.23 to +0.33 and between fiber length and fineness which ranged from 0.16 to 0.70. Genotypic correlations for those same two combinations ranged from -0.23 to 0.25 and from 0.12 to 0.57, respectively. Correlations of fiber length with yield and lint percent were described previously in this paper.

Green (1950) observed a phenotypic correlation of 0.71 between fiber length and fineness in five locally adapted Upland cotton varieties. Brown and Ware (1958) stated that within species coarseness is correlated in general with length but that it varies with variety and species. Velez-Fortuno (1954) in the F_1 and F_2 of a cross between 'Florida 1377' and 'Deltapine 45-867' found that long fibers would be very difficult to combine with fiber coarseness but that it would be relatively easy to retain parental combinations. Stith (1955) observed significant phenotypic correlations in the F_3 population between fiber length and strength and between length and fiber fineness. Soebiapradja (1963) in identifying genetically superior individuals for

lint length in two strains of cotton indicated that genetically super-
ior individuals could be identified and that gains could therefore be
made from selecting single plants within those populations. Eaton and
Engle (1952) concluded that significant increases in tensile strength
are accompanied by significant decreases in fiber length. However,
Miletello (1967) found most fiber properties were either independently
inherited or had desirable associations.

Miller et al. (1959) studied 15 varieties at nine locations in
North Carolina over three years. Their findings on fiber length
included significant estimates of the genotype by year and the second-
order interactions. Again, these were small in comparison to the geno-
typic component of variance. In an analysis of 16 varieties evaluated
at 11 locations from North Carolina to Texas over a three-year period,
Miller et al. (1962) obtained significant variety by year and variety
by year by location interactions for fiber length. However, all inter-
actions were small in comparison to the varietal component. Bridge
et al. (1969) conducted a test of eight varieties over three years at
three locations in the Delta of Mississippi and obtained no significant
genotype by environment interactions for this trait. Abou-El-Fittouh
(1969) investigating four varieties over 101 environments found the
interaction components to be relatively small compared to the genotypic
component though the three-factor interaction was the larger of the
three interactions. Significance levels were not attached to these
estimates. Murray and Verhalen (1970) in the experiment described
earlier found a variety by year interaction which was significant at
the 0.05 level for fiber length. It, as were the other interaction
components, was relatively small in comparison to the genetic component.

Fiber Length Uniformity

An extensive search of the literature failed to uncover any previous research on this fiber character. This was rather surprising considering the economic importance of this character to the fiber mills.

Fiber Strength

Ware and Harrell (1944) in a cross between Florida Green Seed and Rowden summarized the inheritance of strength as being intermediate with a slight tendency toward weaker fiber and stated that environment contributed considerably toward the expression of this trait. Self and Henderson (1954) in a cross of 'AHA' and Half and Half indicated that four to five pairs of genes are involved in the determination of fiber strength. El-Sharkawy (1962) estimated that the difference of 10.9 grams/tex differentiating the strengths of 'Cleveland Short Sympodia' and 'AHA 6-1-4' was controlled by as many as 12-13 pairs of genes. Soebiapradja (1965) found strength to be a partially dominant character in his four-parent diallel cross study. This, he maintains, was supported by an estimate of 0.09 for the average degree of dominance. However, it is rather doubtful that this estimate was significantly different from zero. He calculated narrow-sense heritabilities on a plot mean basis of 0.79 and 0.94 for the F_1 and F_2, respectively. Abdel-Nabi (1965) in determining the inheritance of fiber strength in the F_3 of a cross between Cleveland Short Sympodia and AHA 6-1-4 by partitioning variances among F_3 lines revealed that most of the geno-typic variance for fiber strength is attributable to additive effects of genes. Verhalen and Murray (1967, 1969) in a 10-parent diallel

obtained partial dominance estimates in the F_1 and F_2 ranging from 0.47

to 0.81 in the direction of the stronger parent. Narrow-sense herita-

bilities on a plot mean basis ranged from 0.52 to 0.68. In a genotype

by environment interaction analysis over two years at one location, a

nonsignificant interaction mean square was obtained.

Self and Henderson (1954) calculated a broad-sense heritability

estimate on an individual plant basis of 0.86 for fiber strength in the

F_2 of a cross between 'AHA 50' and Half and Half. They concluded that

selection on an individual plant basis in the F_2 and later segregating

generations should prove effective in obtaining lines with high fiber

strength. It should be noted, however, that this conclusion was based

on a broad-sense estimate rather than a narrow-sense one.

Barnes and Staten (1961) concluded that SCA was more important

than GCA for fiber strength among five of the seven strains tested.

Lee et al. (1967) in a 10-parent diallel obtained significant estimates

of GCA, nonsignificant estimates of SCA, and nonsignificant inter-

actions between GCA and environments. Miller and Marani (1963) also

calculated a significant estimate of GCA and a nonsignificant estimate

of SCA in their material. However, Al-Rawi and Kohel (1970) obtained

significant estimates of both GCA and SCA, significant estimates of

additive and dominance genetic variance, a partial dominance estimate

of 0.80 toward stronger fiber, and a narrow-sense heritability of 0.86

on a plot mean basis in their material. Murray and Verhalen (1969) in

the Bc_2F_4 generation of a cross between OK-86 and Acala 44 obtained

broad-sense heritability estimates on a plot mean basis of 0.39 or

0.56 depending upon the particular strength measurement studied.

Marani (1968) found in general that the F_1 performance for fiber

strength corresponded closely to that of the midparent. However, the performances of some crosses were closer to that of their stronger parents.

Miller et al. (1958) obtained no significant genotype by environment interactions for fiber strength in the two populations in which strength could be studied. They calculated phenotypic correlations of fiber strength with fineness in three populations ranging from -0.31 to 0.06 and genotypic correlations ranging from -0.23 to 0.04. Correlations of strength with lint yield, lint percent, and fiber length were listed in previous sections of this report. Miller et al. (1959) in North Carolina obtained a significant second-order genotype by environment interaction for this trait. Bridge et al. (1969) in Mississippi did not obtain any significant interactions for this trait. Abou-El-Fittouh et al. (1969) over 101 environments calculated estimates of interactions which were relatively small compared to the varietal component. Significance levels were not attached to those estimates. Murray and Verhalen (1970) calculated a significant variety by year interaction at the 0.05 level for one measure of fiber strength but not for the other strength measurement studied. All interaction components were very small in comparison to the varietal component.

Fiber Coarseness

Stith (1955) employing an Acala x Hopi cross inferred that fiber fineness is quantitatively inherited. Bilbro (1961) investigating the comparative effectiveness of three breeding methods in modifying the coarseness of fiber in the F_1, F_2, and backcross populations of 'CR-2' x '4-24' (breeding strains derived from 'Acala 5' and 'Stormmaster',

respectively) concluded that fiber coarseness is quantitatively inherited, that it has a relatively high narrow-sense heritability (30.4%, 73.6%, and 60.7% for the years 1955, 1956, and the combined data, respectively), and that recurrent selection, selection while inbreeding, and mass selection were effective in increasing the genes for fiber coarseness. From the standpoint of time and labor required, mass selection was the most efficient breeding method for this trait followed by selection-while-inbreeding and lastly by recurrent selection. Genotype by environment interactions were suggested as being present because of changes in rank among entries from environment to environment. Ware and Harrell (1963) employing four 'Kime's Fine' lines as fine-lint parents and Half and Half and Florida Green Seed as coarse-lint parents indicated that coarseness tended to show partial dominance over fineness but that the influence was not great enough to prevent shifting of the mean toward the finer parent when it was used as the recurrent parent in backcrossing. Marani (1968) found the performance of varieties for lint fineness to be inconsistent suggesting large interactions with environment. In one trial F_1 fibers were significantly coarser than the midparent. Overall, F_1 and F_2 performance were very similar to midparent values. Barnes and Staten (1961) recognized that fineness is an estimate of fiber weight per inch and that the measurement does not distinguish between inherent fineness and fineness due to immaturity of the fiber. They found SCA to be more important than GCA in six of the seven strains studied. Soebiapradja (1963) stated that gains in fiber coarseness within his populations could be made by selecting individual plants for coarseness. Verhalen and Murray (1967, 1969) in their 10-parent diallel stated that some

dominant genes appeared to increase fiber coarseness while others
appeared to decrease it. They concluded that fiber coarseness was in
the overdominance range and that pedigree, sib, and/or progeny tests
would be necessary to improve it. They calculated narrow-sense
heritabilities for the trait on a plot mean basis which ranged from
0.19 to 0.40. A genotype by environment analysis of the 10 parents
over two years at one location revealed a mean quare significant at
the 0.05 level.

Murray and Verhalen (1969) calculated a broad-sense heritability
estimate on a plot mean basis for the Bc_2F_4 of Acala 44 by OK-86 of
0.37. Correlations in this experiment between coarseness and yield,
earliness, fiber length, and fiber strength were reported earlier.
Lee et al. (1967) calculated a significant estimate of GCA and a non-
significant estimate of SCA for coarseness. No significant combining
ability by environment interactions were obtained for this trait.
Al-Rawi and Kohel (1970) estimated significant GCA and SCA for this
trait in their material. Significant estimates of additive and
dominance genetic variance were also calculated. Degree of dominance
was estimated as 1.08, i.e., overdominance, and heritability (narrow-
sense, plot mean basis) was calculated as 0.08.

Miller et al. (1958) found no significant genotype by environment
interactions for this character in two populations in North Carolina.
Correlations of fineness with yield, lint percent, fiber length, and
fiber strength in this experiment were described earlier. Miller et al.
(1959) obtained significant first-order but not second-order genotype
by environment interactions for fineness among 15 varieties at nine
locations over three years. Bridge et al. (1969) found a significant

second-order interaction at the 0.05 level for fiber fineness in Mississippi. Abou-El-Fittouh et al. (1969) showed the three-factor interaction to be the predominant one for fiber fineness over 101 environments. It was almost 50% larger than the genotypic component. Significance levels were not included in this analysis. Murray and Verhalen (1970) obtained a significant second-order interaction for coarseness in Oklahoma for 11 varieties over three years and three locations.

Moosberg (1956) in breeding for increased fiber coarseness found that variations in environmental conditions from year to year tended to nullify gains made toward desired coarseness especially as generations became more advanced. Fourteen different cross combinations were studied; a family was developed from each cross; and the desired end points in fiber coarseness and maturity were obtained to a satisfactory degree in all families.

CHAPTER III

MATERIALS AND METHODS

The experiment reported herein was conducted, under irrigation in 1968 and on dryland in 1969 on the Agronomy Research Station at Perkins, Oklahoma, on a Vanoss loam soil.

Backcross progeny of 48 (Acala 44 X OK-86) F_2 plants to both parents supplied the 96 entries tested in this study. The experimental design was a split-plot with two replications. Main plots were the backcross parents, i.e., Acala 44 and OK-86, hereafter designated as lines; the subplots consisted of the 48 backcross progenies within each line, the F_2 parents of those progeny are hereafter designated as males. The test was conducted in 1968 at one location under two dates, June 3 and June 17, of planting spaced two weeks apart. In 1969 the test was planted on May 26 and June 25; the second date was replanted because excessive rains shortly after this planting reduced stands considerably. The replanting of this second date resulted once again in very poor stands. By that time, the season was so far advanced that another replanting was adjudged useless.

Plots were single rows, 12 feet long with plants of 'De Ridder Red', a variety with the dominant marker gene, R_1, planted at the ends of each row. Rows were forty inches apart, while plants within rows were spaced one foot apart and thinned to one plant per hill. Blank hills were replanted to De Ridder Red to reduce border effects within

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plots as much as possible.

All cultural practices such as cultivation, weeding, and spraying for insects were applied as needed. Single plants on the end of each row on both dates were heavily selfed in 1968 to supply seed for the 1969 planting. The tests were hand harvested by rows each year. The first date of planting in 1968 was harvested on October 12 and December 17 while the second date of planting was harvested on October 29 and January 7. In 1969 the first date of planting was harvested on October 1 and November 21.

The total seedcotton yield of each row from each harvest, apart from the selfed plants, was weighed, then ginned on a saw gin, and lint weighed to determine lint yield per plot which was divided by the number of plants per plot to put yield on a plant mean basis, to determine lint percentage by dividing the weight of lint by the weight of seedcotton, and to obtain the lint required for measuremnt of fiber properties. Earliness was estimated on the basis of weight of lint of the first harvest expressed as a percentage of the total lint yield. Fiber length (2.5% span length expressed in inches), fiber length uniformity (50% span length/2.5% span length expressed as a percentage), strength (1/8-inch gauge stelometer and 0-inch gauge stelometer expressed in grams/grex), and coarseness (micronaire expressed in micronaire units) were obtained using the digital fibrograph, the stelometer, and the micronaire, respectively.

The preliminary analyses of the data followed Design III as described by Comstock and Robinson (1952) and Gardner (1963). To avoid needless repetition, the analysis and its interpretations and implications will be described with the results in the next chapter.

Narrow-sense heritabilities on a plot basis were constructed using the components derived from the analysis in individual environments and in various combinations of environments. Those heritabilities were then inserted in the formula for expected advance assuming the upper ten percent of the population were selected. Phenotypic correlation coefficients were calculated in individual environments and in combined environments to give a rough approximation of genotypic correlations and to thereby give some indication of how selection for one trait might inadvertently affect the performance of another trait. Relative heritabilities, genetic advances, phenotypic correlations, and population means were then used to make appropriate implications as to the correct breeding procedures to follow in order to maximize progress per unit of time in this population.

CHAPTER IV

RESULTS AND DISCUSSION

An individual phenotype is the total sum of that individual's
genes and of the interactions of those genes with the environment.
Some genes express themselves in a simple qualitative manner while
others are expressed quantitatively. The characters in this study are
of the latter type. The genetic component of an individual quantita-
tive trait may be made up of additive, dominance, and epistatic effects.
The additive effect for a given trait is the sum of the average effects
of the genes conditioning that trait, the sum being made for the alle-
lic pair at each locus and over all loci (Falconer, 1960). The
dominance effect results from the intra-allelic interactions of genes,
i.e., interactions between alleles at the same locus. The epistatic
effect of inter-allelic interaction results from interactions between
alleles at different loci. The inconsistent behavior of genotypes
relative to one another from environment to environment is termed
genotype by environment interaction.

Genetic parameters were estimated in this study using the Design
III analysis of variance described by Comstock and Robinson (1952) and
Gardner (1963). The form of the analysis and expected mean squares in
a single environment are presented in Table 1. The assumptions in-
volved in deriving mean square expectations and genetic interpretations
for this design are listed by Comstock and Robinson (1952). Those

TABLE I

FORM OF THE ANALYSIS AND EXPECTED
MEAN SQUARES FOR DESIGN III
IN A SINGLE ENVIRONMENT

Source	d.f.	Mean Square	Expected Mean Square*
Replications	$(r-1)$		
Lines	1	M_1	
Males	$(m-1)$	M_2	$\sigma_e^2 + 2r(\sigma_{ME}^2 + \sigma_M^2)$
Males X lines	$(m-1)$	M_3	$\sigma_e^2 + r(\sigma_{MLE}^2 + \sigma_{ML}^2)$
Error	$(2m-1)(r-1)$	M_4	σ_e^2

*σ_M^2 is the genetic variance among males, σ_{ME}^2 the male genotype by environment interaction variance, σ_{ML}^2 the male genotype by line genotype interaction variance, σ_{MLE}^2 the male genotype by line genotype by environment interaction variance, and σ_e^2 the variance among plots within replications.

assumptions are as follows:

1. Random choice of individuals mated for production of experi-
   mental progenies.

2. Random distribution of genotypes relative to variations in
   environments.

3. No non-genetic maternal effect.

4. Regular diploid behavior at meiosis.

5. No multiple alleles.

6. No correlation of genotypes at separate loci. This implies
   no linkage among genes affecting the character studied or
   that, if linkages exist, the distribution of genotypes is at
   equilibrium with respect to coupling and repulsion phases.

7. No epistasis, i.e., the effect on variation in genotype at
   any single locus is not modified by genes at other loci.

This design is particularly well suited for parameter estimation
in cross-fertilized plants. Since cotton, Gossypium hirsutum L., is
classified as an often cross-fertilized plant, this analysis should
yield useful information. However, Gardner (1963) cautions that the
genotypic component cannot be estimated by the analysis independently
of the genotype by environment interaction component when only a single
test is conducted. Estimates based on experiments conducted in two or
more environments are much more realistic, although these may be biased
upwards as well because they may be estimated from experiments at only
one location over years or in only one year over locations. Only by
testing over locations and years can unbiased estimates be obtained.
Even then, not all interactions with environment are usually separated
from genetic effects. The analysis in Table I can easily be extended

to include multiple experiments over environments to reduce or elimi-
nate the genotype by environment interactions confounded within geno-
typic estimates.

Estimates of Variances and Variance Components

Estimates of the additive, dominance, genotypic, environmental,
and phenotypic variances and variance components, as the case may be,
for lint yield, earliness, lint percent, and fiber length for 1968,
date one; 1968, date two; 1969, date one; 1968, over dates; date one,
over years; and over all three environments are presented in Table II.
The same information for fiber length uniformity, fiber strength (0"
and 1/8" gauge), and fiber coarseness is presented in Table III.
These estimates were obtained by setting observed mean squares from the
respective analyses of variance equal to expected mean squares and
solving for the components. The components were then manipulated as
follows in obtaining the estimates for the single environment analyses:

Additive variance = $4\sigma_M^2$,

Dominance variance = σ_{ML}^2,

Genotypic variance = $4\ \sigma_M^2 + \sigma_{ML}^2$,

Environmental variance = σ_e^2/r, and

Phenotypic variance = $4\ \sigma_M^2 + \sigma_{ML}^2 + \sigma_e^2/r$.

Symbols are defined in the footnote of Table I. From the analyses of
variance of combinations of two or more environments, estimates were
obtained as follows:

Additive variance = $4\ \sigma_M^2$,

Dominance variance = σ_{ML}^2,

Genotypic variance = $4\ \sigma_M^2 + \sigma_{ML}^2$,

TABLE II
ESTIMATES OF VARIANCES AND VARIANCE COMPONENTS
FOR LINT YIELD, EARLINESS, LINT PERCENT, AND
FIBER LENGTH. IN EACH SUBSET OF ENVIRONMENTS

Characters	Variances and Variance Components				
	Additive	Dominance	Genotypic	Environmental	Phenotypic
Lint Yield					
1968, Date One	1.38	0.00*	1.38	7.89	9.27
1968, Date Two	0.91	0.00*	0.91	14.60	15.51
1969, Date One	3.04	0.68	3.72	20.15	23.87
1968, Over Dates	5.86	0.78	6.64	5.73	12.37
Date One, Over Years	0.00*	1.08	1.08	8.17	9.25
Three Environments	0.00*	1.43	1.43	4.99	6.42
Earliness					
1968, Date One	95.27	0.00*	95.27	73.81	169.08
1968, Date Two	20.67	0.00*	20.67	133.46	154.13
1969, Date One	55.12	6.66	61.78	39.89	101.67
1968, Over Dates	54.88	1.07	55.95	65.31	121.26
Date One, Over Years	5.42	0.00*	5.42	44.00	49.42
Three Environments	5.11	0.00*	5.11	37.25	42.36
Lint Percent					
1968, Date One	2.87	0.52	3.39	0.62	4.01
1968, Date Two	2.67	0.49	3.16	0.51	3.67
1969, Date One	0.00*	1.71	1.71	1.21	2.92
1968, Over Dates	2.12	0.21	2.33	0.43	2.76
Date One, Over Years	0.00*	0.13	0.13	0.95	1.08
Three Environments	1.50	0.29	1.79	0.47	2.26
Fiber Length					
1968, Date One	0.001936	0.000235	0.002171	0.000212	0.002383
1968, Date Two	0.002000	0.000204	0.002204	0.000187	0.002391
1969, Date One	0.000232	0.000086	0.000318	0.000427	0.000745
1968, Over Dates	0.001480	0.000246	0.001726	0.000113	0.001839
Date One, Over Years	0.000040	0.000000	0.000040	0.000341	0.000381
Three Environments	0.000597	0.000075	0.000672	0.000165	0.000837

*Negative estimates for which the most reasonable value is zero.

TABLE III
ESTIMATES OF VARIANCES AND VARIANCE COMPONENTS
FOR FIBER LENGTH UNIFORMITY, FIBER STRENGTH
(0" AND 1/8" GAUGE), AND FIBER COARSENESS
IN EACH SUBSET OF ENVIRONMENTS

Characters	Variance and Variance Components				
	Additive	Dominance	Genotypic	Environmental	Phenotypic
Fiber Length Uniformity					
1968, Date One	0.00*	0.00*	0.00*	2.29	2.29
1968, Date Two	0.29	0.00*	0.29	0.59	0.88
1969, Date One	0.00*	0.00*	0.00*	0.70	0.70
1968, Over Dates	0.00*	0.19	0.19	0.87	1.06
Date One, Over Years	0.07	0.00*	0.07	0.80	0.87
Three Environments	0.00*	0.11	0.11	0.46	0.57
Fiber Strength (0" Gauge)					
1968, Date One	0.0212	0.0000*	0.0212	0.0184	0.0396
1968, Date Two	0.0228	0.0000*	0.0228	0.0131	0.0359
1969, Date One	0.0144	0.0000*	0.0144	0.0127	0.0271
1968, Over Dates	0.0281	0.0004	0.0285	0.0079	0.0364
Date One, Over Years	0.0124	0.0000	0.0124	0.0093	0.0217
Three Environments	0.0123	0.0007	0.0130	0.0059	0.0189
Fiber Strength (1/8" Gauge)					
1968, Date One	0.0152	0.0014	0.0166	0.0056	0.0222
1968, Date Two	0.0176	0.0022	0.0198	0.0077	0.0275
1969, Date One	0.0068	0.0037	0.0105	0.0057	0.0162
1968, Over Dates	0.0120	0.0010	0.0130	0.0038	0.0168
Date One, Over Years	0.0002	0.0000	0.0002	0.0057	0.0059
Three Environments	0.0010	0.0005	0.0015	0.0034	0.0049
Fiber Coarseness					
1968, Date One	0.14	0.03	0.17	0.02	0.19
1968, Date Two	0.06	0.00	0.06	0.03	0.09
1969, Date One	0.03	0.01	0.04	0.03	0.07
1968, Over Dates	0.04	0.02	0.06	0.02	0.08
Date One, Over Years	0.02	0.00*	0.02	0.03	0.05
Three Environments	0.02	0.01	0.03	0.01	0.04

*Negative estimates for which the most reasonable value is zero.

Environmental variance $= \sigma_{ME}^2/e + \sigma_{MLE}^2/e + \sigma_e^2/re$, and

Phenotypic variance $= 4 \sigma_M^2 + \sigma_{ML}^2 + \sigma_{ME}^2/e + \sigma_{MLE}^2/e + \sigma_e^2/re$.

The number of environments is designated by $\underline{e}$, and the other symbols are as previously defined. Negative estimates where they did occur were assumed to be estimates of zero quantities.

A knowledge of the relative magnitudes of the above parameters is of prime importance to the plant breeder. While selection is based on the phenotypic differences among plants or progenies, it is obvious that not all those differences are transmitted to the next generation. What is actually transmitted are the additive effects which may comprise only a portion of the genotypic differences among individuals or progenies. The other measurable portion of genotypic differences, namely dominance, if present, is not transmitted as such; but only part of it is passed on to the next generation. Epistasis, the third component which may comprise a part of the genotype, will not be discussed since it is assumed in the analysis that epistasis is not present (Comstock and Robinson, 1952). Therefore, a knowledge of the general magnitude of the additive and dominance genetic variances relative to the phenotypic variance for each character is required before accurate predictions can be made of heritabilities and genetic advances under selection. Their sum, the genotypic variance, is also shown in the tables. The relative magnitude of the environmental variance to the phenotypic variance is also of considerable interest to the plant breeder, although it varies, sometimes widely, from year to year and from location to location.

The estimates of additive and dominance variance are expected to be biased upwards, especially so in the single date analyses. The

estimates from analyses over increasingly greater numbers of environ-
ments are still expected to be inflated but progressively less so than
are the single environment estimates.

Lint Yield

The analyses of single environments for lint yield detected only a
very small proportion of the phenotypic variance as being due to
additive variance, the highest proportion being 15%. The majority of
the phenotypic variances in these analyses were overwhelmingly
environmental. The dominance variances were estimated as zero for
both environments in 1968. In 1969, however, the dominance variance
was about one fifth the genotypic variance, although its proportion to
phenotypic variance was still quite small.

The combined analysis over dates one and two in 1968 for lint
yield revealed an additive genetic variance of slightly less than one
half the phenotypic variance, and it constituted the majority of the
genotypic variance. However, the combined analysis of date one over
years and the combined analysis over three environments resulted in
zero estimates of additive genetic variance and suggested that the
majority of the phenotypic variance was environmental. These results
suggest that the relative behavior of the males for this trait was
inconsistent over environments and that in these two analyses what
differences there actually were for this trait among males tended to
cancel each other over environments.

Earliness

The additive genetic variance for earliness in the single and

combined dates analyses also varied over a rather wide range in
relation to the phenotypic variance. The highest estimate was 56% of
the phenotypic variance for 1968 date one, and the lowest was about one
ninth the phenotypic variance for date one over years. The estimates
for 1968 date two, date one over years, and the three combined environ-
ments were about the same in magnitude, i.e., about one ninth the
phenotypic variance. The dominance variance was very small in propor-
tion to the phenotypic variance in all cases. The environmental vari-
ance was over half of the phenotypic variance in most analyses and well
over half in some of them.

Lint Percent

The additive genetic variance for lint percent constituted over
half of the phenotypic variance estimates in the single environment
analyses in 1968. Estimates in the combined analyses over dates in
1968 and over the three environments were also quite large compared to
the phenotypic variance. However, the estimates from the 1969 environ-
ment and the analysis of date one over years were zero. The estimates
of dominance variance ranged from eight to 59% of the phenotypic
variance. Except for the date one-over years analysis, environmental
variance was 41% or less, often much less.

Fiber Length

Estimates of additive genetic variance for fiber length were very
large relative to the phenotypic variance in four out of six cases.
In the other two instances the estimate was approximately one tenth
of the phenotypic variance in the date one over years analysis and one

third in the single environment analysis in 1969. Estimates of

dominance variance varied from zero to 13% of the phenotypic variance

while estimates of environmental variance varied from six to 90% of the

phenotypic variance.

Fiber Length Uniformity

Negative values for additive variance, interpreted as zero, were

obtained in four of the six analyses. In the two cases where positive

estimates were obtained, their magnitudes relative to the phenotypic

variance were approximately one third and one twelfth for the analyses

of date two in 1968 and date one over years, respectively. Similar

findings were obtained for dominance variance. There were two

instances, over dates in 1968 and over all three environments, in

which positive dominance variances were detected; and they made up

about one fifth of the phenotypic variance estimates. As expected from

the foregoing results, environmental variance made up the majority of

the phenotypic variance for this trait in all analyses.

Fiber Strength

The magnitude of the additive variances for the fiber strength

measurements in proportion to the phenotypic variances was 42% or

above in all cases except for 1/8" gauge stelometer in the three

environment analysis which exhibited a ratio of about one fifth and

from the analysis of date one over years that was extremely low

compared to the phenotypic variance. The dominance variance estimates

were either zero or comparatively very small for both measurements.

The greatest ratio of dominance to phenotypic variance being on the

order of one fourth. In every instance when compared to their respec-
tive phenotypic variances, the 1/8" gauge measurement had larger
dominance variances than did 0" gauge. On the average for both
measurements, environmental variance accounted for 36% of the pheno-
typic variance.

Fiber Coarseness

The relative proportion of additive to phenotypic variance was
high for all the single and combined environment analyses for this
trait, and additive variance was at least twice as large as dominance
variance in every instance. The proportion of environmental variation
to phenotypic variation ranged from 11 to 60%.

Estimates of Heritability and Expected
Genetic Advance

The variance estimates obtained in the previous section were used
herein to calculate heritabilities and genetic advances for each trait
that would be expected if selection were practiced for that trait.

Heritability refers to the ratio of the genotypic variation to
the total phenotypic variation. Estimates of heritability are of
primary importance to the plant breeder because progress from selection
cannot be predicted without them. Two types of estimates are recog-
nized, i.e., broad- and narrow-sense. Broad-sense refers to the ratio
of the total genotypic variance to the phenotypic variance while narrow-
sense refers to the ratio of only the additive genetic variance to the
phenotypic variance. There are many techniques in estimating
heritability; however, Warner (1952) grouped them into three

categories: (a) parent-offspring regressions, (b) variance components from analyses of variance, and (c) approximations of non-heritable variance from genetically uniform populations to estimate total genetic variance.

In this study, narrow-sense heritabilities were derived using the variance component method. As such, the formulas used to obtain those estimates were ratios of additive variance to phenotypic variance. This ratio has been recommended by Falconer (1960) and Allard (1960).

Formulas were constructed following a pattern given by Gardner (1963). The formulas used for single and combined environments, respectively, are as follows:

$$h^2 = \frac{4 \, \sigma_M^2}{4 \, \sigma_M^2 + \sigma_{ML}^2 + \sigma_e^2/r}$$

$$h^2 = \frac{4 \, \sigma_M^2}{4 \, \sigma_M^2 + \sigma_{ML}^2 + \sigma_{ME}^2/e + \sigma_{MLE}^2/e + \sigma_e^2/re}$$

Heritabilities and expected genetic advances expressed in the actual units of measurement and as percents of the mean for lint yield, earliness, lint percent, and fiber length are presented in Table IV. The same information for fiber length uniformity, fiber strength (0" and 1/8" gauge), and fiber coarseness is presented in Table V. Expected genetic advances were calculated using the formula listed for that purpose by Allard (1960) and Falconer (1960), assuming that the upper 10% of the population was selected.

Lint Yield

Heritability estimates in the single date analyses for lint yield were low but were of the general magnitudes usually calculated for

TABLE IV
ESTIMATES OF HERITABILITY AND EXPECTED GENETIC
ADVANCE FOR LINT YIELD, EARLINESS, LINT PERCENT,
AND FIBER LENGTH IN EACH SUBSET OF ENVIRONMENTS

Characters	Heritabilities	Expected Genetic Advances	
		In Actual Units	As Percent of Mean
Lint Yield			
1968, Date One	0.15	0.8	5.1
1968, Date Two	0.06	0.4	3.1
1969, Date One	0.13	1.1	4.7
1968, Over Dates	0.47	2.9	20.5
Date One, Over Years	0.00*	----	----
Three Environments	0.00*	----	----
Earliness			
1968, Date One	0.56	12.9	23.5
1968, Date Two	0.13	2.9	5.3
1969, Date One	0.50	9.6	13.5
1968, Over Dates	0.45	8.8	15.9
Date One, Over Years	0.11	1.4	2.2
Three Environments	0.12	1.4	2.3
Lint Percent			
1968, Date One	0.72	2.5	7.6
1968, Date Two	0.73	2.5	7.5
1969, Date One	0.00*	----	----
1968, Over Dates	0.77	2.3	6.8
Date One, Over Years	0.00*	----	----
Three Environments	0.66	1.8	5.3
Fiber Length			
1968, Date One	0.81	0.070	6.9
1968, Date Two	0.84	0.074	7.4
1969, Date One	0.31	0.015	1.5
1968, Over Dates	0.80	0.061	6.1
Date One, Over Years	0.10	0.003	0.3
Three Environments	0.71	0.036	3.6

*Caused by negative estimates of additive variance, assumed to be zero, in the numerator of the heritability formula.

TABLE V

ESTIMATES OF HERITABILITY AND EXPECTED GENETIC
ADVANCE FOR FIBER LENGTH UNIFORMITY, FIBER
STRENGTH (0" AND 1/8" GAUGE), AND FIBER COARSENESS
IN EACH SUBSET OF ENVIRONMENTS

Characters	Heritabilities	Expected Genetic Advances	
		In Actual Units	As Percent of Mean
Fiber Length Uniformity			
1968, Date One	0.00*	----	----
1968, Date Two	0.33	0.5	1.1
1969, Date One	0.00*	----	----
1968, Over Dates	0.00*	----	----
Date One, Over Years	0.08	0.1	0.3
Three Environments	0.00*	----	----
Fiber Strength (0" Gauge)			
1968, Date One	0.54	0.19	4.3
1968, Date Two	0.63	0.21	4.8
1969, Date One	0.53	0.15	3.4
1968, Over Dates	0.77	0.26	5.9
Date One, Over Years	0.57	0.15	3.3
Three Environments	0.65	0.16	3.5
Fiber Strength (1/8" Gauge)			
1968, Date One	0.69	0.18	7.9
1968, Date Two	0.64	0.19	8.4
1969, Date One	0.42	0.09	4.0
1968, Over Dates	0.71	0.16	7.3
Date One, Over Years	0.03	0.01	0.2
Three Environments	0.20	0.02	1.1
Fiber Coarseness			
1968, Date One	0.72	0.6	11.7
1968, Date Two	0.66	0.4	8.1
1969, Date One	0.41	0.2	4.0
1968, Over Dates	0.50	0.2	5.3
Date One, Over Years	0.40	0.2	3.2
Three Environments	0.50	0.2	3.5

*Caused by negative estimates of additive variance, assumed to be zero, in the
numerator of the heritability formula.

yield. Values were about the same in magnitude for date one in 1968 and in 1969. However, the estimate for date two in 1968 was about half that of the ones mentioned above. Possibly, this lower estimate could have been due to the fact that the second date had a shorter season to express the genetic potential of the population than did the date one tests. The genetic advance estimates were also rather low as would be expected if one considers the low heritabilities which correspond to them. In the combined analysis for 1968 over dates the heritability estimate was quite high (0.47). The combined analyses of date one over years and of the three environments combined exhibited zero heritabilities and corresponding expected genetic advances. These results in general suggest that lint yield, as a low heritable character, would show little, if any, selection response based on the phenotype of the plants involved.

Earliness

Estimates of heritability for earliness from date one in 1968, date one in 1969, and the combined analysis of 1968 over dates were 0.56, 0.50, and 0.45, respectively. Their expected genetic advance estimates were also high, being 23.46, 13.52, and 15.94, respectively. Apparently, early rather than late planting allows one to differientiate more accurately among degrees of earliness. The estimates from the other three analyses were low; but even so, some progress could still be made in those instances.

Lint Percent

Lint percent heritability and expected genetic advance estimates

for dates one and two in 1968, 1968 over dates, and the three combined

dates were very high. On the other hand, the estimates were zero for

the other two analyses. In most cases this trait appeared to be highly

heritable and quite amenable to selection.

Fiber Length

Fiber length revealed very high heritabilities and expected

advances in four out of six analyses, a moderate estimate in the fifth

analysis, and a low estimate in the last case (date one over years).

Fiber length along with fiber strength and coarseness (as will be

seen shortly) appear to be the highest heritable characters in this

study. As such, selection for them should be highly effective in this

population.

Fiber Length Uniformity

Fiber length uniformity estimates of heritability were largely

zero. One estimate was low while another was moderate in size. It is

rather doubtful if selection for this trait would be effective to any

appreciable extent. Probably selection effort should be expended on

other characters where progress would more likely be obtained.

Fiber Strength

Fiber strength measured as either 0" or 1/8" gauge stelometer

provided relatively high heritability and genetic advance estimates in

all cases except for the date one over years and three environments

analyses for 1/8" gauge strength which were low and low to medium,

respectively. Either measurement should be easily modified by

selection.

Fiber Coarseness

All heritabilities for fiber coarseness were high to very high.
As a consequence, one would expect selection for this trait to be
highly effective in this population.

Estimates of Phenotypic Correlation Coefficients

Simple linear correlation coefficients for all possible
combinations among the eight characters in this study are presented
in Table VI. These coefficients were estimated using the 48 male
overall means in each subset of environments. The 46 degrees of
freedom required for testing the significance of those correlations
from zero were obtained by subtracting one, to account for the
covariable, from the 47 degrees of freedom among the male means.

Although phenotypic correlation coefficients are admittedly only
approximations of genotypic correlations (what the breeder is really
interested in), Miller et al. (1958) found them to be of comparable
magnitude with a general tendency for the genotypic correlation to be
slightly larger than its phenotypic counterpart. As a consequence,
phenotypic correlations give a fairly good indication about the
direction of change in a given trait indirectly brought about when
selection is actually being practiced on another trait. Where esti-
mates were largely consistent in sign and at least some of those
estimates were significantly different from zero, considerable
confidence could be placed on the implication that the correlation
described a real situation in the population rather than a temporary

TABLE VI

ESTIMATES OF PHENOTYPIC CORRELATION
COEFFICIENTS FOR ALL POSSIBLE COMBINATIONS
OF CHARACTERS IN EACH SUBSET OF ENVIRONMENTS

Combination of Characters	1968 Date 1	1968 Date 2	1969 Date 1	1968 Over Dates	Date One Over Years	Three Environments
Lint Yield with:						
Earliness	-0.01	0.08	-0.42**	0.15	-0.47**	-0.16
Lint Percent	0.09	0.21	0.52**	0.22	0.28	0.27
Fiber Length	-0.31*	-0.33*	-0.03	-0.43**	-0.22	-0.40**
Fiber Length Uniformity	-0.07	0.12	0.01	0.11	-0.21	0.12
Fiber Strength (0" Gauge)	-0.13	-0.01	-0.19	-0.16	-0.25	-0.29*
Fiber Strength (1/8" Gauge)	0.05	-0.10	-0.05	-0.09	0.01	-0.22
Fiber Coarseness	-0.14	0.04	0.23	0.07	0.18	0.21
Earliness with:						
Lint Percent	0.27	-0.04	-0.43**	0.13	0.03	0.14
Fiber Length	-0.22	-0.17	-0.31*	-0.34*	-0.08	-0.21
Fiber Length Uniformity	0.17	0.13	-0.24	0.25	0.13	0.16
Fiber Strength (0" Gauge)	0.06	0.02	0.32*	0.07	0.18	0.05
Fiber Strength (1/8" Gauge)	0.04	0.02	0.04	-0.12	0.11	-0.03
Fiber Coarseness	0.18	0.18	-0.09	0.22	0.03	0.02
Lint Percent with:						
Fiber Length	-0.41**	-0.43**	0.21	-0.46**	-0.19	-0.38**
Fiber Length Uniformity	0.17	-0.33*	-0.23	-0.09	0.02	-0.05
Fiber Strength (0" Gauge)	-0.39**	-0.39**	-0.22	-0.49**	-0.47**	-0.56**
Fiber Strength (1/8" Gauge)	-0.41**	-0.51**	-0.33*	-0.58**	-0.45**	-0.66**
Fiber Coarseness	0.22	0.14	0.30*	0.16	0.29*	0.27
Fiber Length with:						
Fiber Length Uniformity	-0.26	0.07	-0.46**	-0.28	-0.35*	-0.44**
Fiber Strength (0" Gauge)	0.19	0.18	0.02	0.26	0.13	0.28
Fiber Strength (1/8" Gauge)	0.36*	0.50**	-0.01	0.47**	0.18	0.44**
Fiber Coarseness	-0.58**	-0.38**	-0.26	-0.55**	-0.60**	-0.58**
Fiber Length Uniformity with:						
Fiber Strength (0" Gauge)	-0.15	0.07	-0.19	-0.03	-0.16	-0.04
Fiber Strength (1/8" Gauge)	0.13	0.21	0.02	0.22	-0.25	-0.05
Fiber Coarseness	0.26	0.20	0.34*	0.26	0.42**	0.38**
Fiber Strength (0" Gauge) with:						
Fiber Strength (1/8" Gauge)	0.42**	0.33*	0.21	0.51**	0.36*	0.58**
Fiber Coarseness	0.00	0.02	-0.14	-0.01	-0.11	-0.04
Fiber Strength (1/8" Gauge) with:						
Fiber Coarseness	-0.22	-0.22	-0.26	-0.32*	-0.31*	-0.42**

*,**Significant at the 0.05 and 0.01 levels of probability, respectively.

or accidental condition.

Lint Yield

Correlations involving lint yield were consistently positive or negative for only those combinations with lint percent, fiber length, and 0" gauge fiber strength, the first being positive with the last two being negative. Of the six correlations with lint percent, one was significant at the 0.01 probability level, two approached significance at the 0.05 level, and two others were above 0.2. Four of the six correlations with fiber length were significant while another was moderately high. Only one of the correlations with 0" gauge was significant although another did approach significance at the 0.05 level. Should selection be practiced for increased lint yield, one could reasonably expect lint percent to increase and fiber length and 0" gauge strength to decrease. All except one of the correlations with fiber coarseness were positive though none were significant. Perhaps, one would expect coarser fiber were he to select for increased lint yield in this population, but it would not be with the relative degree of certainty as in the cases of the three characters discussed above.

Earliness

All six earliness correlations with fiber length were consistent in sign, being negative in every case; and two of those correlations were significant. The correlations with 0" gauge fiber strength were uniformily positive, and one was significant; but most were extremely low, being less than 0.10. Five out of six correlations with fiber

length uniformity and fiber coarseness were positive; but none were significant, most were moderate to small in magnitude. Selecting for more earliness of maturity should decrease fiber length and, perhaps, increase 0" gauge strength, fiber length uniformity, and coarseness.

Lint Percent

Correlations of lint percent with lint yield were discussed in the section on lint yield. Correlations with 0" and 1/8" gauge strengths were highly negative, and eleven out of twelve estimates were significant. There can be no question that selections in this material for higher lint percent will probably result in large fiber strength losses. Correlations with fiber coarseness were all positive, and two were significant. Five out of the six correlations with fiber length were negative, and four of the five were highly significant. Selection for higher lint percent would probably decrease fiber strength and increase coarseness and would possibly decrease fiber length and increase lint yield.

Fiber Length

Correlations of fiber length with lint yield, earliness, and lint percent were described in the respective sections above. Correlations with fiber coarseness were uniformly negative, generally quite large in magnitude, and significant in five out of six cases. Correlations with 0" gauge strength were positive and nonsignificant though two did approach significance. Five out of six correlations with fiber length uniformity were negative, and five out of six with 1/8" gauge were positive. Three were significant and two approached significance in

the former case while four were significant in the latter. Selection for increased fiber length should cause decreases in lint yield, earliness, and fiber coarseness with possible decreases in lint percent and fiber length uniformity and possible increases in 0" and 1/8" gauge strength.

Fiber Length Uniformity

Correlations of fiber length uniformity with earliness and fiber length were presented above. Positive estimates were obtained in all six correlations with fiber coarseness with three of those being significant. Five out of six estimates with 0" gauge were negative though none were significant. Selections for higher fiber length uniformity should increase fiber coarseness and, perhaps, increase earliness and decrease fiber length and 0" gauge stelometer strength.

Fiber Strength

Correlations of fiber strength (0" or 1/8" gauge or both) with lint yield, earliness, lint percent, fiber length, and fiber length uniformity were analyzed above. Consistently positive estimates were obtained between 0" gauge and 1/8" gauge with five out of six being significant. Correlations between 1/8" gauge and fiber coarseness were consistently negative with three significant estimates and one approaching significance. Selections for higher 0" gauge strength should increase 1/8" gauge stelometer and decrease yield and lint percent and may increase earliness and fiber length but decrease fiber length uniformity. Selections for high 1/8" gauge strength should increase 0" gauge strength, should decrease lint percent and

fiber coarseness, and may increase fiber length.

Fiber Coarseness

Correlations involving fiber coarseness were discussed in the respective sections above. To summarize those conclusions, selecting for increased fiber coarseness would cause an increase in fiber length uniformity and decreases in fiber length and 0" gauge strength and may result in increases in lint yield, earliness, and lint percent.

CHAPTER V

SUMMARY AND CONCLUSIONS

In sections of the previous chapter variances and variance compon-
ents, heritabilities and expected genetic advances, and phenotypic
correlation coefficients were discussed. Relative magnitudes among
different variances and components of variance are of interest to the
geneticist in an academic way. Their practical significance, however,
is in the estimation of narrow-sense heritability, $\underline{i.e.}$, the proportion
of total variance that is transmittible from generation to generation.
An examination of the magnitudes of heritabilities will show whether
selection will be effective or not for a given trait, and an inspection
of genetic advances shows the approximate extent to which selection is
expected to be effective for that trait. Correlation coefficients show
the effect, if any, selecting for one character will have on other
traits. In this chapter the author has attempted to bring all of the
information in previous sections together with some additional data to
decide what breeding steps should be taken in this population.

Based on their variances and variance components, their narrow-
sense heritabilities, and ultimately on their expected genetic advances,
yield and fiber length uniformity indicate little, if any, progress
could be expected were selection to be practiced for them. Earliness
and lint percent will show some progress, but that progress will vary
widely from year to year. Fiber length, fiber strength (0" and 1/8"

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gauge), and fiber coarseness are expected to respond quite readily to selection.

One consideration in deciding what character or characters to select for is the current level of performance of the population for the characters which are candidates for selection. This information is presented in Table VII for each character in each subset of environments. Fiber strength in this population is already at a very high level. Converted into thousands of pounds per square inch, its strengths fall in the 94,000-97,000 pounds per square inch range. The fiber coarseness values are within the currently acceptable micronaire range (3.5 to 4.9). These levels of performance imply that selection is not necessary for those two characters.

Earliness, lint percent, and fiber length means indicate that these characters are medium early, medium to low, and average, respectively, and that they should be actively considered for selection. All three characters are of prime economic importance to the individual producer while lint length is important to the fiber mills as well. Based on heritability estimates, fiber length indicates the most probable response to selection in this population; and therefore, it should receive primary emphasis in selection. While selecting for fiber length, some pressure should be exerted in approximately equal proportions on earliness and on lint percent. In doing so, some of the undesirable trends in other characters likely to be obtained when selecting for fiber length alone, as indicated by the phenotypic correlations, would partially be nullified.

TABLE VII

MEANS FOR EACH CHARACTER IN EACH
SUBSET OF ENVIRONMENTS

Character	1968 Date 1	1968 Date 2	1969 Date 1	1968 Over Dates	Date One Over Years	Three Environments
Lint Yield	15.6	13.0	23.5	14.3	19.5	17.4
Earliness	55.0	55.1	68.2	55.0	61.6	59.4
Lint Percent	33.1	32.7	33.3	32.9	33.2	33.0
Fiber Length	1.005	1.003	1.012	1.004	1.009	1.007
Fiber Length Uniformity	54.2	51.6	51.1	52.9	52.6	52.3
Fiber Strength (0" Gauge)	4.39	4.36	4.51	4.37	4.45	4.42
Fiber Strength (1/8" Gauge)	2.29	2.24	2.36	2.27	2.32	2.30
Fiber Coarseness	4.7	4.5	4.8	4.6	4.8	4.7

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