

A QUANTITATIVE GENETIC STUDY OF SEVERAL
AGRONOMIC AND FIBER PROPERTIES AMONG
SELECTED LINES OF UPLAND COTTON,
GOSSYPIUM HIRSUTUM L.

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Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
DOCTOR OF PHILOSOPHY
May, 1972

AUG 10 1973

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ACKNOWLEDGMENTS

I wish to express sincere appreciation to my major adviser, Dr. D. E. Weibel, for his guidance and assistance in the course of my graduate work. To another member of my advisory committee, Dr. L. M. Verhalen, I am especially thankful for his constant encouragement and many constructive criticisms during the course of this research and in the preparation of this manuscript. Grateful acknowledgment is also extended to the remaining members of my graduate committee: Dr. L. A. Brinkerhoff and Dr. R. M. Reed, who provided valuable assistance and advice in planning my studies and in the writing of this report.

My deep appreciation also goes to Mr. J. W. Simmons for his assistance in the collection of the data. Sincere gratitude is likewise expressed to Mrs. Margaret Simmons and Mrs. Alva Clingenpeel for their contributions in the fiber testing laboratory. Special appreciation is also extended to Mr. Don Holbert for programming many of the computation procedures for data analysis and to Dr. R. W. McNew for aid in interpreting parts of the analysis.

I am indebted to the Department of Agronomy of Oklahoma State University for the use of its facilities in the conduction of this research and to the United States Department of Health, Education, and Welfare for the NDEA Fellowship which enabled me to continue my education.

I especially want to thank my wife, Jan, for typing the preliminary

copy of this thesis and for her extreme dedication, patience, and encouragement throughout the course of my studies.

I am also thankful to Mrs. Frank Roberts for typing the final copy of this thesis.

To all of the people mentioned above and to those whose names may have been omitted, the author offers his most sincere thanks.

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CHAPTER I

INTRODUCTION

The choice of breeding method for the genetic improvement of a quantitative trait is largely dependent upon the types and relative amounts of genetic variability for that trait in the population of interest. To realize maximum progress (per unit of time), the breeding procedures used must be adapted to the type of gene action involved.

The diallel cross technique allows the breeder to detect the kinds and relative magnitudes for each of the possible sources of genetic variability among any given group of genotypes. In this regard, the breeder as usual must be satisfied with average measures of gene action for quantitative characters. These are generally of two types. One is the comparison of means between different generations, e.g., parental means with the means of their crosses; and the other is a comparison of genetic variances and covariances between relatives which are functions of squares of gene effects (13). The diallel utilizes both types of measures.

In addition, the diallel procedure permits a methodical approach for identifying parents and hybrids which are superior for the characters being considered. Heretofore, heterosis has been variously defined as the increase in hybrid performance above the midparent, the better parent, or a standard commercial check variety. Hybrid vigor, if exhibited, results from dominance, epistasis, or their combined effects.

Possibly these non-additive effects, even when quite small in comparison to the additive effects, are still sufficient to account for rather substantial amounts of heterosis (as well as inbreeding depression).

The practical utilization of heterosis on a commercial scale is not yet economically feasible in cotton. This is because of the lack of a fully usable male-sterility and fertility-restoration mechanism and because of the frequently small amounts of natural crossing which take place in cotton's major production areas. For hybrid cotton to be commercially successful, the F_1 must not only exhibit high yields, but it must also have an acceptable combination of other agronomic traits and fiber quality. A substantial degree of heterosis would be required to offset increased production costs. Regardless of the seed production methods utilized, it appears at present that the greatest ultimate advance would depend on breeding procedures which utilize both additive and non-additive types of genetic variance. However, as long as commercial hybrid seed production remains prohibitive, crosses exhibiting substantial amounts of additive genetic variance should be preferred over those with the more heterotic responses.

Cotton producers in Oklahoma are faced with an increasingly serious problem regarding the relatively low price they receive for their product. Oklahoma produces cotton which generally has lower fiber quality than that of the remaining states in the Cotton Belt, with the possible exception of Texas. Textile mills in the recent past increased their demands for and paid a premium for high quality cotton. Though the trend is not so obvious at present, over the long term, quality cotton would appear to be desirable. Therefore, yield and other agronomic traits cannot be the only objective of the breeder and the

producer. In order for the cotton industry in Oklahoma to compete with synthetic fibers, other cotton producing areas in the United States and the world, and other income-producing crops, it must produce a fiber for which there is a substantial demand. Earliness of maturity must also be given consideration because growing seasons in Oklahoma are frequently rather short. The growing season may be limited by low temperatures and excessive rainfall in the spring or because of cool temperatures and early killing frosts in the fall. The maturity of a crop may also be affected by a shortage of moisture in the mid-to-late growing season as well as by extensive insect and disease damage. It is evident that a cotton variety bred for Oklahoma conditions should combine high fiber quality with acceptable levels of yield, earliness, and other desirable agronomic traits (including lint percent).

The purpose of the research reported herein was to determine the frequency and magnitude of heterosis and inbreeding depression and to study the nature of gene action for yield, earliness, lint percent, and the several fiber quality traits of major economic importance among 10 selected lines of upland cotton (Gossypium hirsutum L.). The Jinks-Hayman diallel cross technique was chosen to partition the genetic variance of each trait into its components. These components were then used to obtain various genetic estimators. From these estimators, suggestions could be reached regarding the most efficient breeding system required to maximize breeding progress (per unit of time) in this material.

CHAPTER II

REVIEW OF LITERATURE

Lint yield, earliness, and lint percent are three of the most important agronomic properties of cotton while fiber length, length uniformity, fineness, and strength are four of the primary components of fiber quality. Each of these economically important properties is quantitatively inherited and is governed by several to many genes whose individual effects are at least partially masked by the environment. To reduce confusion, the available information for each of the above traits will be presented separately herein. Under each character heading, the subjects discussed for that trait will include heterosis, inheritance, and genotype by environment interaction. Unless otherwise noted, the terms "significant" and "highly significant" will refer to the 0.05 and 0.01 probability levels for statistical significance, respectively. It should be understood that some bias may well exist in the comparison of results obtained by various researchers because of differences in the scales of measurement used. Also, literature cited is concerned only with that research conducted within the G. hirsutum L. species, unless otherwise stated.

Yield

Heterosis for yield has been studied in cotton by numerous researchers over the years. Generally, some degree of heterosis has been

found in most studies, both in intra- and interspecific crosses. The magnitudes of midparent heterosis for yield (including lint and seed cotton) in intraspecific crosses has been reported as 19% by Kime and Tilley (31), 35% by Jones and Loden (29), 27% by Miller and Marani (45), 18% by Miller and Lee (44), 15.5 to 24.5% by Galal, Miller, and Lee (19), 26% by Lee, Miller and Rawlings (33), and 33% by El-Adl and Miller (15) and Turner (69). Al-Rawi and Kohel (7), employing a nine-parent diallel cross, found both midparent heterosis of 5.5% and inbreeding depression of 5.8%. These effects were small but significant. Kime and Tilley (31), Turner (69), Miller and Marani (45), and others have also witnessed reductions in heterotic effect in the F_2 and later generations. Muramoto (53) analyzed the performance of seven top-cross progenies and showed that heterosis was manifested in seed cotton yields of certain F_1 's. Small degrees of high-parent heterosis were reported by White and Richmond (80) in a five-parent diallel cross. They concluded that number of bolls per plant and boll size were the primary components of yield contributing to the heterosis observed.

Hawkins, Peacock, and Ballard (21) reported an average high-parent heterosis of 19% and that four out of six hybrids gave significantly higher yields than their better parent and their corresponding F_2 . Barnes and Staten (9) found that 23 out of the 43 crosses they studied produced higher yields than their higher parent. In a comparison between three doubled haploids and their parental varieties in regard to their ability to produce F_1 and F_2 hybrids, Meredith, Bridge, and Chism (43) found both midparent heterosis and inbreeding depression for lint yield.

In several trials, Marani (36, 37, 39, 40) has reported that midparent heterosis for lint yield averaged from 20 to 25% in intraspecific crosses of G. hirsutum, 22 to 26% in intraspecific crosses of G. barbadense L., and 52 to 82% in interspecific crosses between those two species. Marani (39) obtained relatively small F_2 deviations for this trait in intraspecific crosses while she (40) found highly significant F_2 and backcross deviations in interspecific crosses. Young and Murray (82) showed that the expression of midparent heterosis and inbreeding depression was less pronounced and less consistent in G. hirsutum (an amphidiploid) crosses than in G. arboreum L. (a diploid) crosses. Stroman (66) investigated two interspecific crosses and 20 intraspecific crosses and revealed that only the two interspecific crosses were significantly better (35-38%) than the control. Fryxell, Staten, and Porter (18) found that 17 of the 36 G. hirsutum X G. barbadense crosses they evaluated yielded more than the most productive parent, while two were lower than either parent.

From an experiment comprised of diallel crosses among seven inbred lines, Turner (69) reported specific combining ability (SCA) to be more important than general combining ability (GCA) for seed cotton yield. Hayman (24) reanalyzed the data reported by Turner (69) and found significant "epistasis" of the complementary type for this character. Fryxell (17) investigated an F_2 population derived from a cross between strains of the varieties 'Hartsville' and 'Acala'; and in general, the heritabilities of the several subtraits of yield progressively increased at successive levels of subdivision. This he considered was indicative of an additive genetic model.

Barnes and Staten (9) acquired estimates for GCA and SCA from diallel crosses among seven closely related Acala strains and found SCA to be of greater magnitude than GCA for lint yield. However, when 11 other varieties were testcrossed on two strains of Acala, GCA was significantly greater than SCA. White and Richmond (80) studied a diallel cross among five primitive and foreign strains and disclosed that GCA variance was predominant. White and Kohel (79) in the same five-parent diallel and analyzing the parents and F_1 's showed that this trait had an overall measure of dominance of 0.91, *i.e.*, partial dominance. Their analysis also indicated that most of the dominant genes had positive (toward higher yield) effects. Highly significant additive and significant dominance genetic variation were also detected in this material. White (78) in the same diallel, but including F_2 's as well as parents and F_1 's, obtained an average degree of dominance of 1.32, which indicated overdominance for lint yield. Significant amounts of additive and dominance genetic variance were estimated, but neither epistasis nor multiple allelism was detected for this trait.

Miller and Marani (45) in a diallel cross among eight inbred lines also found an appreciable amount of variance due to GCA in the F_1 and F_2 generation for lint yield. There were indications in the F_2 of the presence of some type of nonadditive gene effects. In a diallel cross of three varieties of *G. hirsutum* and three of *G. barbadense*, Marani (36) determined in the case of interspecific crosses, the effects of GCA were more important for this trait while SCA effects were significant only in a few cases and were not consistent from year to year. It was suggested that the main component of genetic variance was of the additive type; however, the presence of some non-additive genetic

variance was also suggested. In later research Marani (37) found GCA effects for lint yield in interspecific crosses were not consistent from year to year. Marani (39) also obtained evidence indicating that although some epistatic effects may be operative for this trait, additive and dominance genetic effects were more important in the intraspecific crosses; whereas, in interspecific crosses (40) heterosis was caused by dominance in the presence of epistasis. Fryxell et al. (18) concluded that the parental varieties involved in their study differed in GCA for lint yield but not in SCA.

Ramey and Miller (59) in an evaluation of the first backcross generation of an F_2 population derived from a cross between 'Empire 10' and the line 'TH 131-5' (which in turn was derived from the sixth backcross to upland cotton of the trispecies hybrid of G. hirsutum, G. thurberi Tod., and G. arboreum) obtained positive but small estimates of additive variance and small negative estimates of dominance variance for lint yield. Earlier, Al-Jibouri, Miller, and Robinson (5) had reported that substantial amounts (59%) of genotypic variance were observed for lint yield in a population study of 92 randomly chosen F_3 progenies from the same cross.

Young and Murray (82) disclosed that SCA for lint yield was more important than GCA in their material. In a 10-parent diallel study, nonsignificant estimates of GCA and SCA were observed by Lee et al. (33); however, they did secure a significant GCA by location interaction for this trait. Miller and Rawlings (46) used three cycles of 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, and concluded that additive effects predominated in this

material although additive by additive effects could not be excluded. Dominance effects could not be detected and were reasoned to be lacking or of minor relative importance. El-Adl and Miller (15), in a diallel study among six inbred lines derived after three cycles of recurrent selection in the cross cited above, found GCA to be more important than SCA for this property. They also showed that each of the six inbred lines was higher in yield than the higher parent of the original cross indicating that transgressive segregation had occurred.

Al-Rawi and Kohel (7) found additive variance to be significant and larger than dominance variance which was also significant. Lint yield exhibited 0.64 partial dominance and a narrow-sense heritability estimate on a plot-mean basis of 0.41. Epistasis was not detected; however, multiple allelism was shown to be present. Kohel (32) in a study of the same material reported that parents were significantly less variable than F_1 's for lint yield. Verhalen *et al.* (72) in a study including parents, F_1 's, and F_2 's among 10 varieties using the diallel cross analysis determined the degree of dominance for lint yield to be in the overdominance range. There appeared to be an equal distribution of positive and negative alleles in the parents. Narrow-sense heritabilities on a plot-mean basis of 0.14 and 0.25 were calculated in the F_1 in the first and second year, respectively, and of 0.31 in the F_2 .

In the Bc_2F_4 generation of a cross between 'Acala 44' and 'OK-86,' Murray and Verhalen (55) calculated a broad-sense heritability estimate on a plot-mean basis of 0.45 for lint yield with an expected genetic advance of 6.2% of the mean. Tabrah (67) investigated both backcross populations from the cross cited above and disclosed that lint yield was influenced slightly more by additive effects than by dominance

effects. He also found environmental variance components to be substantially larger than the genotypic variance components. Narrow-sense heritabilities based on variance components ranged from 0.00 to 0.47 over six subsets of environments. Meredith et al. (43) identified one case of significant epistasis out of six crosses studied. They were able to show considerable dominance effects for lint yield. Manning (34) investigated the selection response for lint yield in several upland crosses through the F_5 generation and determined that the performance of F_1 or bulk F_2 generations did not consistently predict the yield potential of a hybrid in subsequent generations. He concluded that the heritability of lint yield was too erratic to justify single plant selection. Manning (35) estimated a narrow-sense (realized) heritability for lint yield per plant of 0.10 to 0.15 over six generations of selection in 'BP52.' He used a selection index based on the primary yield components, namely, bolls per plant, seeds per boll, and lint per seed to obtain a genetic advance of 35%.

In an evaluation of two populations of breeding lines grown at two locations over two years and of another population grown at one location in each of two years, Miller et al. (49) observed that environmental variances for lint yield were generally large. In one population a highly significant genotype by location by year interaction was obtained and was of sufficient magnitude to be important from a breeding standpoint. Sufficient genetic variability appeared to be present in all populations to provide for rather substantial genetic advancements through selection. Murray and Verhalen (55) studied 62 lines at two locations over a two-year period and found the genetic component of variance for lint yield to be larger than any of its corresponding

interaction components. Miller, Williams, and Robinson (48) tested 15 cotton varieties at nine locations in North Carolina over three years and observed a highly significant and substantial variety by location by year interaction for lint yield. The first-order interactions were relatively small and nonsignificant. They suggested that a differential varietal response existed under different environments but that those conditions were not consistent over locations or over years. After eight varieties were grown at three Mississippi Delta locations for three years, Bridge, Meredith, and Chism (11) reported results which approached those found in North Carolina. A highly significant second-order interaction was larger than the corresponding varietal component of variance or any of the first-order interactions.

Miller, Robinson, and Pope (47) analyzed the performance of 16 cotton varieties over three years at 11 locations from North Carolina to Texas. When all locations were studied, a large (and highly significant) second-order interaction and a smaller (but still highly significant) variety by location interaction were obtained for this character. A re-examination of the data indicated that the major portion of the first-order interaction was due to three Texas locations. Abou-El-Fittouh, Rawlings, and Miller (2) evaluated four cotton varieties over 101 environments distributed over three years at some 39 locations across the Cotton Belt. Genotype by location and second-order interaction components were large compared to their respective genotypic components. Investigating additional varieties within each region of the Cotton Belt, they found that the genotypic 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. Five varieties were studied by Walton (73) at 20 different sites in the Northern and Eastern Provinces of Uganda during a three-year period. He found significant (0.10 probability level) variety by year and variety by year by location interaction components for lint yield. However, both interaction components were small in comparison to the varietal component.

Eleven varieties were evaluated by Murray and Verhalen (56) at three locations in Oklahoma over a three-year period. A large and significant variety by location interaction and a large and highly significant three-factor interaction was evident for lint yield. These interaction components were more than three times as large as the varietal component. Verhalen et al. (72), in a genotype by environment analysis of 10 parents over two years at one location, did not observe significance for this trait. More recently in Oklahoma, Morrison (51) studied 10 varieties grown at five locations over two years and acquired a relatively large and highly significant variety by year and variety by location by year interaction for lint yield. All interaction components were greater than the varietal component in his experiments.

Earliness

Various morphological, physiological, and product-quantity measures for determining earliness have been proposed and discussed by Brown (12), Richmond and Radwan (61), Ray and Richmond (60), Richmond and Ray (62), Murray (54), Munro (52), and various other researchers. However, only those papers describing methods of measuring earliness which also

include an investigation of the genetic systems therein will be discussed in this section.

Kime and Tilley (31) in crosses among inbred lines selected from Coker 100, 'Stoneville,' and 'Deltapine 11A' reported an average midparent heterosis of 35% for earliness of boll opening. However, this heterotic effect was reduced to 15% in the F_2 generation. In a study involving 'DeRidder Red Leaf' crossed with each of nine commercial varieties, Jones and Loden (29) found F_1 's to be significantly earlier than their midparents. The hybrids had an average of 71% of their total yield harvested at the first picking as compared to an average of 61% for their corresponding midparents. Stroman (66) revealed that in first pick yields (also an indicator of earliness) both interspecific crosses doubled the yield of the check strain, while nine of the 20 intraspecific crosses were significantly better than the control. In two different studies, Barnes and Staten (9) showed F_1 performance for earliness to be equal to or better than the midparent. They also observed 13 of the 43 crosses evaluated were earlier than their higher parent. However, White and Richmond (80) detected no case of heterosis for this trait in a five-parent diallel.

Miller and Marani (45), in the diallel described earlier, showed a highly significant midparent heterosis of 11.9% for this character. Inbreeding depression of 3.0% was observed in the F_2 although it was not statistically significant. Marani (40) detected an intermediate F_1 performance (i.e., no high-parent heterosis) for maturity in the interspecific crosses but did not find significant F_2 and backcross deviations. Fryxell et al. (18) also found F_1 's of interspecific crosses to be consistently intermediate in maturity to their parents. Al-Rawi and

Kohel (7) in a nine-parent diallel witnessed highly significant and midparent heterosis of 5.3% and inbreeding depression effects of 5.1% for earliness. In the same material, Kohel (32) found that F_1 's were slightly less variable than their parents.

Hintz and Green (25) obtained results from a study involving 'Lankart 57,' 'Oklahoma Special,' and 'Stormproof #1,' their F_1 's, F_2 's, and backcrosses suggesting that boll period as a measure of earliness was influenced largely by genes with additive effects. A narrow-sense heritability estimate for boll period in the Lankart 57 X Stormproof #1 cross was 50.6 percent.

Barnes and Staten (9) showed that SCA for earliness was more important than GCA among six out of seven closely related Acala lines. However, in another study involving the performance of 22 hybrids they found only GCA to be important. The latter results are in agreement with those reported by White and Richmond (80) and Miller and Marani (45). In interspecific crosses, Marani (37) also showed GCA to be predominant. In another study of interspecific crosses, Fryxell et al. (18) demonstrated that both GCA and SCA were important for earliness.

White and Kohel's (79) diallel analysis of the five genotypes studied previously by White and Richmond (80) demonstrated large and highly significant estimates of additive variance and very small and nonsignificant estimates of dominance variance. White (78) also in the same material concluded that multiple allelism was operative in the genetic control of earliness. In interspecific crosses Marani (40) detected epistatic gene action.

Richmond and Ray (62) using three stocks of upland cotton designated as 'C.B. 3051,' 'Z-106,' and 'Contextum' (early, late, and late,

respectively) obtained broad-sense heritabilities for three product-quantity measures of earliness: amount of crop harvested (ACH); percentage of crop harvested (PCH); and mean maturity date (MMD). Estimates based on ACH in the C.B. 3051 X Z-106 and C.B. 3051 X Contextum crosses were not greater than zero until after the fourth harvest or when approximately 30% of the crop was open. Estimates of 0.14 and 0.03, respectively, were obtained for PCH in the C.B. 3051 X Z-106 and Z-106 X Contextum crosses at the sixth harvest. Estimates exceeded 0.20 at the sixth, seventh, and eighth harvest dates from the C.B. 3051 X Contextum hybrid. A heritability of 0.41 for MMD based on boll number rather than seed cotton yield was also acquired in the same hybrid. The authors concluded that MMD was the most reliable measure for use in genetic studies.

Ray and Richmond (60) studied morphological measurements of earliness in the same three stocks and calculated a broad-sense heritability estimate for node of first fruiting branch (NFB) in the C.B. 3051 X Z-106 hybrid of 0.60 and in C.B. 3051 X Contextum of 0.43. They also investigated the first backcross population of 21 randomly chosen F_2 's from C.B. 3051 X Z-106 and obtained estimates of average degree of dominance for NFB of 0.54 and 0.42 and for MMD of 1.18 and 0.89. This suggested that genes with partial dominance control NFB, but those associated with MMD have complete or near complete dominance.

Murray and Verhalen (55) obtained a broad-sense heritability estimate of 0.73 on a plot-mean basis for earliness in the Bc_2F_4 of the cross described earlier. Their predicted genetic advance on the assumption that the upper 10% of the population would be selected was 9.1% while actual progress was only 4.8%. Al-Rawi and Kohel (7)

reported epistasis for earliness in their material. They found the additive genetic variance component highly significant and larger than the dominance component which was also highly significant. A narrow-sense heritability on a plot-mean basis was estimated to be 0.41. They concluded that earliness exhibited a partial dominance of 0.95.

Verhalen et al. (72) in a 10-parent diallel cross obtained narrow-sense heritabilities on a plot-mean basis for earliness in the F_1 and F_2 which ranged from 0.12 to 0.29. The trait was apparently governed by overdominance, and the dominance was in the direction of earlier maturity. In a highly heterozygous population derived from a cross between OK-86 and Acala 44, Al-Rawi (6) secured a realized heritability of 0.35 for this character in the first cycle of mass selection. However, results from the second-cycle were rather inconclusive. Tabrah (67) determined that the inheritance of earliness in his material was controlled by additive effects. Narrow-sense heritability estimates were calculated which ranged from 0.11 to 0.56 over six subsets of environments.

Murray and Verhalen (55) tested 62 families for two years at two locations in Oklahoma and detected a relatively large three-factor interaction compared to each of the two-factor components. However, all interactions were overshadowed by the magnitude of the genotypic component. Verhalen et al. (72) showed some evidence for an interaction occurring between years and dominance effects for this character at a single location in Oklahoma.

Lint Percent

Highly variable results for heterosis have been reported for many

traits in crosses among upland cottons and between upland and American-Egyptian types. However, heterosis for lint percent almost invariably appears to be of relatively minor importance. Numerous past (9, 21, 29, 31, 36, 44, 45, 53, 80) and more recent (7, 15, 19, 33, 37, 39, 43) investigations have shown that lint percent occasionally exhibits small heterotic effects but that F_1 performance is generally intermediate between the performance of the parents of that cross. In a few of the cases where small but significant amounts of midparent heterosis were present, small inbreeding depression effects have also been found (7, 39, 43, 45). In interspecific crosses Marani (36, 40) obtained highly significant negative midparent heterosis. Highly significant F_2 and backcross deviations were also present (40) which suggested epistatic gene action. Fryxell *et al.* (18) found that 18 of 36 interspecific F_1 's were within the range of their respective parents for lint percent while 14 were lower than either of their parents.

In a cross between Acala and 'Hopi,' Stith (65) demonstrated partial dominance for higher lint percent. Broad-sense heritabilities in his material were 45.3 and 79.0% in the F_2 and F_3 , respectively. In an evaluation of several crosses, Manning (34) concluded that entire crosses could be eliminated in either the F_1 or F_2 on the basis of lint percent. Narrow-sense heritability estimates were obtained which ranged from 62 to 76% thereby suggesting that selection for this character would be effective on an individual plant basis. Muramoto (53) estimated broad-sense heritabilities for lint percent ranging from 30.5 to 75.9% among seven top-cross progenies.

Barnes and Staten (9) found estimates of SCA to be greater than GCA for six out of seven closely related Acala lines. However, in the

top-cross performance of 22 progenies, they reported GCA to be more important than SCA. White and Richmond (80) also obtained a highly significant estimate of GCA and a nonsignificant estimate of SCA for lint percent in their five-parent diallel cross study. In a reanalysis of the same parental and F_1 material, White and Kohel (79) acquired a highly significant additive genetic variance but a nonsignificant dominance component. In the same material, but also including F_2 's, White (78) observed the same results. He detected multiple allelism but not epistasis. Miller and Marani (45) and Lee et al. (33) have also determined that GCA is highly significant and predominant in the F_1 generation. In addition, Miller and Marani (45) calculated significant estimates of SCA in F_2 material. Data compiled by Marani (36, 40) and Fryxell et al. (18) indicate that in interspecific crosses GCA is substantially larger than SCA.

Ramey and Miller (59) in a population derived from Empire 10 and TH 131-5 reported a substantial amount of additive genetic variation for lint percent and an estimate of dominance variation which was small but positive. An average degree of dominance of 0.25 was calculated. Marani (40) concluded that the negative heterosis found in interspecific crosses was determined by additive by additive epistatic variation being larger than dominance effects.

Al-Rawi and Kohel (7) did not detect significant epistasis for lint percent in their nine-parent diallel cross. However, multiple allelism (and possibly correlated gene distribution) appeared to be present. They found a highly significant estimate for additive genetic variance but a nonsignificant one for dominance. Earlier in the same material, Kohel (32) showed that F_1 's were significantly less variable for lint

percent than were their parents.

Tabrah (67) obtained narrow-sense heritabilities ranging from 0.00 to 0.77 over six subsets of environments. In general, the additive effects he estimated were greater than the dominance effects. Verhalen et al. (72) recorded narrow-sense heritability estimates on a plot mean basis in the F_1 and F_2 which ranged from 0.26 to 0.40. Degree of dominance was in the overdominance range except in the 1966 F_1 data where partial dominance was calculated. Results by Meredith et al. (43) also indicated considerable dominance effects. El-Adl and Miller (15) found that all six inbred lines derived from three cycles of recurrent selection exceeded the higher parent of the original cross in lint percent which indicated transgressive segregation. In addition, a diallel cross of the six inbred lines revealed nonsignificant estimates of GCA and significant estimates of SCA.

In a North Carolina study of three different populations composed of 95, 92, and 81 lines, respectively, Miller et al. (49) detected a single highly significant genotype by environment interaction for lint percent, and it was a confounded estimate based on two years data at a different location each year. Al-Jibouri et al. (5) found progeny by environment interaction components accountable for only 2% of the total phenotypic variance for this property among 92 F_3 progenies tested over two North Carolina locations in one year. Ninety percent of the total variance was attributed to the genotypic component.

Again in North Carolina, Miller et al. (47, 48) reported highly significant first- and second-order interactions although they were overshadowed substantially in magnitude by the varietal component. When variety tests from across the Cotton Belt were analyzed, Abou-El-Fittouh

et al. (2) also observed small and generally unimportant interactions for lint percent when compared to the genotypic component. The three-factor interaction was the predominant interaction component while the one for genotype by location was the least important. In the Mississippi Delta, Bridge et al. (11) obtained evidence of a large and highly significant three-factor interaction with the two-factor interactions being of no practical significance for this trait. In another study in Mississippi, Meredith et al. (43) revealed that both F_1 and F_2 hybrids tended to give more consistent performances over locations than did their parents. Verhalen et al. (72) showed evidence of an interaction for this trait between years and additive effects at a single location in Oklahoma.

Fiber Length

In general, heterosis for fiber length varies with the parental combination involved, and greater heterosis more frequently results from interspecific than from intraspecific crosses. Kime and Tilley (31), Jones and Loden (29), Muramoto (53), Barnes and Staten (9), and Miller and Lee (44) have reported intraspecific hybrid performance very similar to midparent values for fiber length. Others (7, 33, 38, 43, 45) have disclosed a small, but significant and/or highly significant midparent heterosis in the F_1 ; whereas, mean F_2 performance was generally intermediate between that of parents and F_1 's. In a cross between 'Florida Green Seed' and 'Rowden,' Ware, Jenkins, and Harrell (77) showed that long fiber was partially dominant over short fiber in the F_1 . White and Richmond (80) discovered five F_1 's which possessed significantly longer fiber than their longer parent by amounts ranging

from three to six percent.

In three sets of crosses among lines of G. hirsutum and G. barbadense, Ware (74) showed that dominance of long fiber was practically complete over short fiber. In interspecific crosses between varieties of G. hirsutum and G. barbadense, Marani (41) found F_1 performance for two measures of fiber length exceeded that of either parent by 10 to 16% and 6 to 13%, respectively. The F_2 performance for length was slightly above the parental mean; however, a small but highly significant F_2 deviation was detected. Backcross deviations were small and, in some cases, not significant. Fryxell et al. (18) determined that the expression of fiber length in 36 interspecific hybrids was generally equivalent to that of the G. barbadense (longer-fibered) parent. Young and Murray (82) noted that G. arboreum hybrid combinations exhibited more heterosis for fiber length than G. hirsutum and were more sensitive to inbreeding. Their data also showed that the exhibition of heterosis was inconsistent from year to year.

Green (20) evaluated variation within the varieties 'Bobshaw,' 'Coker 100 (Str. 9),' 'Delfos 9169,' 'Deltapine 15,' and 'Stoneville 2B.' He observed sufficient phenotypic variability in fiber length for selection to be effective. Stith (65) analyzed an Acala by Hopi cross but found no evidence of transgressive segregation. Length was partially dominant over shortness, and broad-sense heritabilities based on F_2 plants and on F_3 lines were 0.22 and 0.70, respectively. Muramoto (53) secured broad-sense heritability estimates ranging from 0.0% for some crosses to 6.5% for others.

Ramey (58) suggested that allelic and nonallelic gene interactions were involved in the inheritance of fiber length in a cross between

'Half and Half' and 'Delfos 9252.' Barnes and Staten (9) found GCA to be more important than SCA for length among five out of seven closely related Acala lines. They also showed GCA to be of greater magnitude than SCA in 22 top-cross progenies. Miller and Marani (45) and Lee et al. (33) obtained highly significant GCA and nonsignificant SCA in the material they evaluated. Lee et al. (33) concluded that this property is inherited largely in an additive fashion and that hybridization can only partially obscure the deficiencies of a poor parent.

Ramey and Miller (59) observed substantial amounts of additive genetic variation and small positive estimates of dominance variation for fiber length in a cross between Empire 10 and TH 131-5. An estimate of average degree of dominance of 0.63 was obtained for this trait in this particular hybrid. Marani (38) determined that inheritance of lint length in intraspecific crosses was primarily additive with some relatively small dominance effects. In a study of interspecific crosses, Marani (41) showed that additive, dominance, and additive by additive epistatic effects were operative in the inheritance of this character.

Murray and Verhalen (55) reported a broad-sense heritability estimate of 0.85 and an estimated genetic advance of 0.039 which compared very favorably with the observed response of 0.034. Verhalen and Murray (70, 71) also noted that long fibers were partially dominant over short fibers since nine estimates for degree of dominance ranged from 0.36 to 0.79. Narrow-sense heritabilities of 0.49 and 0.61 were calculated in the F_1 in years one and two, respectively, and of 0.49 in the F_2 in the second year. From the first and second cycles of mass selection in a highly heterozygous population derived from Acala 44 and OK-86, Al-Rawi (6) obtained realized heritabilities of 0.78 and 0.23, respectively. A

narrow-sense heritability estimate on an individual plant basis of 0.37 was obtained from one cycle of mass selection after intermating.

Al-Rawi and Kohel (8) in a nine-parent diallel showed fiber length to exhibit partial dominance in the direction of the longer-fibered parents. Estimates of GCA and SCA effects were highly significant. They calculated narrow-sense heritabilities for two measures of fiber length of 0.23 and 0.56, respectively. In the study previously described, Meredith et al. (43) indicated that one measure of fiber length showed considerable dominance effects while another tended to be inherited in an additive fashion. Tabrah (67) acquired substantial estimates of additive variance and small, but positive, amounts of dominance variance for lint length. He estimated narrow-sense heritabilities on a plot-mean basis which ranged from 0.10 to 0.81 over six subsets of environments.

In genotype by environment analyses of breeding lines for fiber length, a few investigators (5, 49, 55) have clearly demonstrated that genotypic variance components are of much greater magnitude than are the interaction components. This would indicate that sufficient genetic variability is present among populations to provide for rather substantial amounts of improvement and that relative performances can be adequately determined over a small number of environments. Miller et al. (48) in North Carolina, Bridge et al. (11) in Mississippi, and Murray and Verhalen (56) and Morrison (51) in Oklahoma have reported results of variety tests which indicate that the conclusions drawn from breeding lines are also applicable to varieties. In each instance, the second-order interaction component was larger than the first-order interactions, but even it was greatly overshadowed by the varietal component.

In an analysis of varietal performance over an area extending from North Carolina to Texas, Miller et al. (47) acquired results very similar to those cited above, indicating relative varietal stability over environments for this character. Abou-El-Fittouh et al. (2) investigated four varieties over 101 environments from 39 locations from North Carolina to California and over three years. They also found the interaction components to be relatively small compared to the varietal component and the three-factor interaction to be the largest in magnitude of the interaction components.

In Oklahoma, Verhalen and Murray (71) found no evidence of year by additive effects or by dominance effects interactions in a test involving 10 varieties, two years, and one location. In Mississippi, Meredith et al. (43) reported that F_1 's and F_2 's gave more consistent performance over four locations than did their parents.

Fiber Length Uniformity

An extensive search of the literature revealed very little previous research on this fiber property. However, two recent studies in Oklahoma have provided some information on the subject.

A study by Tabrah (67) of the first backcross populations derived from a cross between Acala 44 and OK-86 showed that environmental variance for length uniformity was substantially larger than genotypic variance components. He obtained narrow-sense heritability estimates of zero in four out of six subsets of environments while estimates of 0.08 and 0.33 were found for the remaining subsets. He, therefore, concluded that in his material this trait would show little response to selection.

Morrison (51) evaluated 10 varieties for this trait at four Oklahoma locations over a two-year period and found the first-order interactions to be small and nonsignificant while the second-order interaction, though slightly larger and significant, did not approach the magnitude of the varietal component. Indications in his material were that genotype by environment interactions for this trait were not important.

Fiber Fineness

Muramoto (53) suggested that environmental effects were largely responsible for the inconsistent results he obtained for fiber fineness. Some hybrids approached the coarseness of the coarser parent; whereas, others possessed fiber fineness essentially halfway between the two parents. Barnes and Staten (9) found the fiber of 22 top-cross progenies to be somewhat coarser than their midparent performance; and in a diallel test involving seven closely related Acala lines, they found fiber fineness of the F_1 's to be intermediate between the parents. Miller and Lee (44), Lee *et al.* (33), and Al-Rawi and Kohel (8) also reported that hybrid performance for this character was very similar to the midparent.

Ware and Harrell (76) disclosed that F_1 's (from two crosses in which four 'Kime's Fine' lines were used as fine-lint parents and Half and Half and Florida Green Seed were used as coarse-lint parents) were generally intermediate in inheritance, but that there was some tendency for coarseness to be dominant over fineness. They found F_2 means to be very similar to F_1 means. White and Richmond (80) detected no heterosis for this trait among the 10 crosses evaluated. Marani (38) noted that

fineness of lint in intraspecific crosses within G. hirsutum and within G. barbadense was intermediate between parental performances with a slight tendency of the F_1 fibers to be somewhat coarser. Young and Murray (82) also found this to be true in their G. hirsutum material. However, in intraspecific crosses with G. arboreum, they found a slight tendency for F_1 's to be finer than their midparents. Meredith et al. (43) discovered similar results in their G. hirsutum material and also noted that hybrids performed more consistently over four locations than did their parents. In interspecific F_1 's, Marani (41) obtained a negative heterosis of 12 to 19% for this trait. However, F_2 performance was near the mean of the F_1 and parental means and displayed no significant inbreeding depression. Fryxell et al. (18) also showed that interspecific hybrids were generally about as fine as or finer than the fine-fibered parent (G. barbadense).

Employing an Acala by Hopi cross, Stith (65) found no evidence that transgressive segregation had occurred for fiber fineness. His material exhibited a lack of dominance for this trait. He observed broad-sense heritabilities of 74.6% for F_2 plants and 69.9% among F_3 lines. Muramoto (53) also obtained broad-sense heritability estimates for this trait which ranged from 50.9 to 79.3%. Bilbro (10) studied the inheritance of fiber fineness in a cross between 'CR-2' and '4-24' (breeding lines derived from 'Acala 5' and 'Stormmaster,' respectively) and estimated narrow-sense heritabilities for this trait on the basis of F_2 and backcross variances as 30 and 74%, respectively.

Barnes and Staten (9) reported important SCA effects for fiber fineness among F_1 's of various Acala strains. However, in an analysis of fineness in 22 top-cross progenies, they found GCA effects to

predominate. Lee et al. (33) also noted a preponderance of GCA for this character. Ramey and Miller (59) witnessed large amounts of additive genetic variance and small positive amounts of dominance variance in a population of interspecific origin. Partial dominance of 0.31 was observed. In intraspecific crosses among varieties of G. hirsutum and G. barbadense, Marani (38) obtained results which supported the conclusions of Ware and Harrell (76) that inheritance was mostly additive but that there was slight dominance toward coarseness. However, in interspecific crosses between the two species, Marani (41) found only dominance effects operating significantly in the inheritance of fiber fineness.

In the Bc_2F_4 generation of a cross between Acala 44 and OK-86, Murray and Verhalen (55) acquired a broad-sense heritability estimate on a plot-mean basis of 0.37. Verhalen and Murray (70, 71) noted that overdominant gene action governed fiber fineness in their 10-parent diallel. Some dominant genes appeared to increase fiber coarseness while others decreased it. Narrow-sense heritabilities were estimated in the F_1 and F_2 which ranged from 0.19 to 0.40. Al-Rawi and Kohel (8) also showed fiber fineness to be controlled by overdominant gene action and to possess a narrow-sense heritability of 0.08. Meredith et al. (43) pointed out that additive and dominance effects were more important than epistasis for this trait in their material. Tabrah's (67) investigation revealed that fiber fineness was influenced more by additive effects than by dominance effects. He obtained narrow-sense heritability estimates ranging from 0.40 to 0.72 over six subsets of environments.

In breeding for fiber coarseness (and maturity) in Arkansas, Moosberg (50) concluded that environmental variations from year to year tended to nullify gains made toward the desired goal, especially in advanced generation breeding lines. Bilbro (10) suggested that genotype by environment interactions were present in his material because of changes in rank in fiber fineness among entries from environment to environment in Oklahoma. Marani (38) also found the performance of varieties for fiber fineness were inconsistent and suggested the presence of large interactions with environment. However, Al-Jibouri et al. (5) observed that progeny by environment interactions made up a rather small proportion (about 12%) of the total variance for this fiber property among 92 F_3 progeny means analyzed over two North Carolina locations in one year. Also in North Carolina, Miller et al. (49) indicated that genotype by environment interactions over two years and two locations were not present for fiber fineness in two different populations composed of 95 and 92 lines, respectively. Murray and Verhalen (55) evaluated 62 Bc_2F_4 lines at two Oklahoma locations over a two-year period and recorded a second-order interaction component greater than the genetic component.

In North Carolina variety tests, Miller et al. (48) considered the highly significant first-order interaction components for fiber fineness as relatively unimportant since they were very small relative to the variety component. However, in the Mississippi Delta, Bridge et al. (11) obtained evidence of a large and significant second-order interaction with first-order interactions being small and nonsignificant. Abou-El-Fittouh et al. (2) disclosed the variety by location by year component of variance to be the dominant interaction for fiber fineness

over 101 environments.

Verhalen and Murray (71) revealed the occurrence of an interaction between years and additive effects as well as between years and dominance effects over two years at a single Oklahoma location. In a later study, Murray and Verhalen (56) obtained a highly significant variety by location by year interaction component for fiber fineness in 11 varieties when tested over three years and three locations. More recent research by Morrison (51) revealed highly similar results. He found the varietal component of variance to be four times the size of the second-order interaction which in turn was larger than either of the first-order interactions.

Fiber Strength

Heterosis for fiber strength appears to be of minor importance in crosses among upland cottons. Miller and Marani (45) and Al-Rawi and Kohel (8) have identified small but highly significant amounts of midparent heterosis. They did not find significant inbreeding depression between the F_1 and the F_2 . However, other workers (9, 31, 33, 38, 43, 44, 53, 80) have shown hybrid performance for fiber strength to correspond closely to the midparent. In intervarietal crosses of G. barbadense, Marani (38) determined that F_1 's were much closer to the parent having stronger lint and that F_2 performance was only slightly lower. Young and Murray (82) obtained data which indicated that heterosis for fiber strength was more pronounced in G. arboreum hybrids than in G. hirsutum hybrids and that the G. hirsutum hybrids were less sensitive to inbreeding. In interspecific crosses between varieties of G. hirsutum and G. barbadense, Marani (41) observed the fiber strength

of the F_1 's to be almost as high as that of the stronger G. barbadense parents. The magnitude of midparent heterosis was from 9 to 15% for this trait with no apparent F_2 or backcross deviations. Fryxell et al. (18) found that 33 of 36 interspecific hybrids were within the range of their respective parents for this character.

In advanced generations of a Florida Green Seed by Rowden cross, Ware and Harrell (75) concluded that the inheritance of fiber strength was intermediate with a slight tendency toward weakness. Self and Henderson (63) studied a cross between 'AHA 50' and Half and Half and came to the same conclusion. They obtained a broad-sense heritability estimate, based on the variance of individual F_2 plants, of 86% and a narrow-sense estimate of 53% based on the regression of F_3 means on the F_2 plants. Tipton et al. (68) evaluated crosses between 'Cleveland Short Sympodia' and 'AHA 6-1-4' and between Cleveland Short Sympodia and 'Stardel 6-6' and also detected partial dominance of low fiber strength. On the basis of F_2 data, broad-sense heritabilities for strength were 84 and 59% for the respective crosses. Stith (65) detected no dominance for strength in a cross between Acala and Hopi. Broad-sense heritability estimates of 54.1 and 87.3% were derived from F_2 plants and among F_3 lines, respectively. Neither Stith (65) nor Tipton et al. (68) found any indication of transgressive segregation for this character.

In the F_1 , F_2 , and F_3 generations of an interspecific cross between Deltapine 15 (G. hirsutum) and 'Sea Island' (G. barbadense), Worley (81) obtained values indicating that F_3 results were more reliable in the estimation of heritability than were F_2 's and that 50-60% of the high strength F_2 plants produced high strength F_3 lines. Muramoto (53)

obtained broad-sense heritabilities which ranged from 0.0% in some crosses to 57.9% in others.

Barnes and Staten (9) concluded that SCA for this trait was larger than GCA among five of the seven Acala strains analyzed. However, in another study involving 22 top-crosses, they acquired highly significant estimates of GCA and nonsignificant estimates of SCA. Similar results were obtained by Miller and Marani (45) and Lee et al. (33) in their material.

Soebiapradja (64) in a four-parent diallel cross showed fiber strength to be partially dominant in the direction of weakness with narrow-sense heritabilities of 79 and 94% based on the variance of the parents and on the mean variance of arrays, respectively. In an evaluation of 69 F_3 lines from a cross between Cleveland Short Sympodia and AHA 6-1-4, Abdel-Nabi (1) estimated narrow-sense heritabilities of 59% using the regression of F_3 lines on F_2 plants and of 52% by partitioning variance among F_3 lines. Ramey and Miller (59) secured large estimates of additive genetic variance and small positive estimates of dominance variance in the cross previously described. They estimated an average degree of dominance of 0.31, i.e., partial dominance. Marani (38) observed the inheritance of fiber strength in G. barbadense to be largely additive with some dominance effects. However, no evidence of epistatic gene action was detected within G. hirsutum or G. barbadense. In the analysis of interspecific hybrids, Marani (41) also obtained results suggesting that only additive and dominance effects were operating in the inheritance of this character.

In a 10-parent diallel study, Verhalen and Murray (70, 71) noted that additive gene action predominantly governed fiber strength. They

did report partial dominance estimates in the F_1 and F_2 ranging from 0.47 to 0.81 in the direction of the stronger parent, and narrow-sense heritabilities ranging from 0.52 to 0.68. In backcross generations of a cross between Acala 44 and OK-86, Murray and Verhalen (55) revealed broad-sense heritability estimates of 0.39 and 0.56 for two measures of fiber strength. Al-Rawi and Kohel (8) obtained results which were in close agreement to those of Verhalen and Murray (70, 71). They secured highly significant estimates of GCA and SCA effects as well as highly significant amounts of additive and dominance variance. A partial dominance estimate of 0.80 toward stronger lint and narrow-sense heritability of 0.86 were also obtained in their study. Meredith et al. (43) also determined that this trait tended to be inherited in an additive fashion. Tabrah (67) observed substantial amounts of additive genetic variance and very small but positive amounts of dominance variance for two measures of fiber strength. Narrow-sense heritability estimates ranged from 0.53 to 0.77 for one measure and from 0.03 to 0.71 for the other over six subsets of environments.

Al-Jibouri et al. (5) disclosed that for fiber strength the progeny by environment interaction made up a very small portion (1%), whereas, the genotypic variance among progenies made up a large portion (90%) of the total phenotypic variance among 92 F_3 lines of interspecific origin when evaluated in one year at two locations. Miller et al. (49) found no significant genotype by environment interaction for strength in two populations of 95 and 92 breeding lines, tested over two years at two locations in North Carolina. Murray and Verhalen (55) in Oklahoma observed no important family by environment interactions when one measure of lint strength was evaluated. However, for another measurement a

rather large family by location interaction was expressed.

In variety tests conducted at nine North Carolina locations over three years, Miller et al. (48) found a small but highly significant second-order interaction for fiber strength. Bridge et al. (11) revealed similar results from the Mississippi Delta except that the second-order interaction was not significant. Abou-El-Fittouh et al. (2) over 101 environments reported results which were in general agreement with those cited above. For this trait, the three-factor interaction was the predominant interaction component. However, all interaction components were small when compared to the varietal component.

Verhalen and Murray (71) in a test for genotype by environment interaction which involved 10 cotton varieties, two years, and one Oklahoma location did not detect a significant variety by year interaction mean square for either of two measures of fiber strength. In later research Murray and Verhalen (56) calculated a significant variety by year interaction for one measure of fiber strength but not for another. All interaction components were very small in comparison to the varietal component. More recently in Oklahoma, Morrison (51) has shown in a four-location, two-year analysis that the variances among varieties were highly significant and greatly overshadowed the variances due to genotype-environment interaction (even when some of the interactions were significant). Meredith et al. (43) in Mississippi found F_1 's and F_2 's to be more stable than their parents for this trait when tested over four locations.

CHAPTER III

MATERIALS AND METHODS

Experimental Materials

The 10 varieties and lines of upland cotton (Gossypium hirsutum L.) which follow were selected for use as parents in the experiment described herein:

- | | |
|--------------------|--------------------|
| 1. 'Deltapine 16' | 6. 'Lockett 4789A' |
| 2. 'Mo-Del' | 7. 'Quapaw' |
| 3. 'Stoneville 7A' | 8. 'Dunn 56C' |
| 4. 'Tancot 788' | 9. 'S65-391' and |
| 5. 'Westburn' | 10. 'S65-396' |

Hereafter, parents and crosses among parents will be identified by the numbers and/or names given above and by the appropriate number combinations, respectively. Except for S65-391 and S65-396, each of the parents is a commercial variety of upland cotton. The S65-391 and S65-396 strains were bulked after this experiment was initiated in a 1:1 mixture and released as the variety 'Delcot 277' by the Missouri Agricultural Experiment Station in 1970. The parents were specifically chosen and do not represent a random sample of all upland cotton varieties. Therefore, inferences derived from the data apply in the strict sense only to the parents, crosses, and generations studied. The extent to which they apply to upland cotton as a whole is unknown.

Experimental Methods

Experimental Design

Diallel crosses among the parents, ignoring reciprocals, were made at Iguala, Mexico, in the winter of 1968-69 and 1969-70. The 10 parents and their 45 F_1 's were grown on the Agronomy Research Farm at Perkins, Oklahoma, on a Vanoss loam in 1969 and 1970. The 45 F_2 progenies were included in 1970. Plantings were made on May 27 in both years. The experiment was conducted in a randomized complete-block design with four replications. Plots were single rows 7.6 m long, and rows were 1.0 m apart. Plants within plots were spaced approximately 0.5 m apart with one plant per hill. To partially compensate for differential spacing between plants caused by missing hills, 'De Ridder Red' (a variety with the dominant marker gene, R_1) was planted as soon as such hills were detected. All cultural practices such as cultivation, irrigation, and weed and insect control were conducted as required.

Laboratory Procedures

Two harvests were made on the material each year. Harvest dates were September 26 and November 20, 1969, and October 15 and December 5, 1970. Seven plants from each plot were chosen at random for laboratory analyses. The following characters were measured:

1. Yield - The total weight of lint in grams per plant.
2. Earliness - The ratio of lint yield from the first harvest to total lint yield expressed as a percentage.
3. Lint Percent - The ratio of lint to seed cotton expressed as a percentage.

4. Fiber Length (2.5% Span) - The length in inches at which 2.5% of the fibers are of that length or longer as measured on the digital fibrograph.
5. Fiber Length (50% Span) - The length in inches at which 50% of the fibers are of that length or longer as measured on the digital fibrograph.
6. Fiber Length Uniformity Ratio - The ratio of 50% to 2.5% span length expressed as a percentage.
7. Fiber Fineness (Micronaire) - The fineness as measured on the micronaire (an air-flow instrument) and expressed in standard micronaire units.
8. Fiber Strength (T_1) - The strength of a bundle of fibers as measured on the stelometer with two jaws (separated by a 1/8 inch spacer) holding the fiber bundle and expressed in grams per grex.

Fiber samples from each harvest from each plant were analyzed separately; and then weighted averages for each fiber measurement and lint percent over the two harvests were calculated for each plant based on the percentage of total lint yield per harvest. All subsequent calculations were based on those weighted averages.

Statistical and Analytical Procedures

Two approaches were taken to determine relative magnitudes of the various genetic components of variation in the population and to resolve more clearly the genetic mechanisms controlling the inheritance of each trait. Heterosis, inbreeding depression, and F_2 deviations were first evaluated; and then the data were analyzed using the diallel

analysis proposed by Jinks and Hayman (22, 23, 24, 27, 28).

Heterosis, inbreeding depression, and F_2 deviations were measured as follows:

$$\text{Heterosis} = (F_1 - \text{Midparent})/\text{Midparent},$$

$$\text{Inbreeding depression} = (F_1 - F_2)/F_1, \text{ and}$$

$$F_2 \text{ deviations} = \{F_2 - [(F_1 + \text{Midparent}/2)]\} / [(F_1 + \text{Midparent})/2].$$

Heterosis is expressed as percent increase of the F_1 above the mean of its parents, i.e., the midparent. Inbreeding depression is the percent reduction of the F_2 performance below that of the F_1 , and F_2 deviation is calculated as the percentage decrease or increase of mean F_2 performance from the mean of the F_1 and midparent performance. A significant F_2 deviation is interpreted as being an indicator of epistatic gene action.

Analyses of variance were conducted on a plot-mean basis for each trait in each year over all entries. A combined analysis of variance over the two years at Perkins was also computed for the 10 parents and 45 F_1 's. Standard errors of the difference for each individual and over-all heterosis, inbreeding depression, and F_2 deviations were calculated; and t-tests were used to determine significant differences from zero. For example, since the numerator for

$$\text{Heterosis} = F_1 - \text{Midparent} = F_1 - [(P_j + P_j')/2],$$

its variance (V) then becomes

$$\begin{aligned} V(\text{Heterosis}) &= V(F_1) + 1/4[V(P_j) + V(P_j')] \\ &= \sigma_e^2 + 1/4(\sigma_e^2 + \sigma_e^2) \\ &= 3/2\sigma_e^2; \end{aligned}$$

and the appropriate t-test is $t = (F_1 - \text{Midparent}) / (3/2\sigma_e^2)^{1/2}$.

In the single analysis of variance, the residual or replication by genotype mean square was used as the appropriate estimate of error variance (σ_e^2). For the combined two-year analyses involving only F_1 's and parents, the year by genotype interaction mean square was used as the error term when it was statistically significant. When it was not significant, the residual mean square was used. It is realized that the variance component for genotypes is confounded with the genotype by location interaction since the experiment was conducted only at a single location.

Estimates of genetic constants for line effects and heterosis effects were obtained for each trait. Hooks, Williams, and Gardner (26) defined line effects as the average effects of the j and j' lines and heterosis effect in the cross of line j with line j' as the F_1 deviation from the midparent. These terms are believed to be meaningful since they are defined in genetic and plant breeding terms rather than in statistical terms (26).

Considering the length and complexity of the Jinks-Hayman analysis, the procedures therein will be described in the next chapter as the individual analyses are presented. In following this procedure, extensive and needless duplication will be avoided.

CHAPTER IV

RESULTS AND DISCUSSION

Heterosis and Inbreeding Depression

Means and Analyses of Variance

Overall means for the parents and their mean performance in crosses and the overall means for the F_1 generation over 1969 and 1970 are shown for each trait in Appendix Tables XXVII and XXVIII, respectively. The same types of means are shown for each year in Appendix Tables XXIX, XXX, and XXXI. In addition, the mean performance in crosses and means for the F_2 's in 1970 are shown in Appendix Tables XXX and XXXII, respectively. The data in Tables XXVII, XXIX, and XXX suggest that a relatively high correlation exists for most traits between parental performance and the means of their F_1 and F_2 arrays.

There were significant differences among the parental and F_1 genotypes for all characters in the analyses of variance over years as shown in Table I. In 1969 and in 1970, the individual year analyses (Tables II and III, respectively) also revealed highly significant differences among genotypes. This implies that there were significant genetic differences among entries for these traits and that detailed analyses of gene action could be conducted.

TABLE I
ANALYSES OF VARIANCE OF PARENTAL AND F₁ MEANS OVER 1969 AND 1970

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
Years	1	27761.90**	33936.9852**	965.4787**	.000081	.037918**	339.5560**	4.6546**	1.9281**
Reps within years	6	23.10	521.7985**	6.1164**	.001476**	.002523**	10.0357**	.5150**	.0703**
Genotypes	54	43.21**	687.6718**	6.9686**	.006425**	.001342**	4.4075**	.5635**	.1301**
Years by genotypes	54	23.89**	223.5638**	1.2963**	.000655*	.000199	.9774**	.0970**	.0108
Error	324	12.03	103.7200	.7793	.000460	.000163	.5792	.0477	.0110

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

TABLE II
ANALYSES OF VARIANCE OF PARENTAL AND F₁ MEANS IN 1969

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
Replications	3	159.68	2439.2463**	15.8646**	.015178**	.022562**	81.0488**	.0277	.3553**
Genotypes	54	217.88**	4441.6521**	26.1726**	.019123**	.004900**	17.2831**	1.5965**	.4343**
Error	162	106.03	462.7195	3.4035	.001827	.000668	3.1230	.2068	.0830

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

TABLE III
ANALYSES OF VARIANCE OF PARENTAL, F₁, AND F₂ MEANS IN 1970

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
Replications	3	125.89	8472.5083**	55.3393**	.009594	.020792**	93.0193**	13.0067**	1.1058**
Genotypes	99	198.41**	1746.9688**	26.5719**	.030481**	.005961**	19.8190**	2.5600**	.5296**
Error	297	71.63	959.4194	9.6479	.004639	.001494	5.1909	.4567	.0751

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

Overall Heterosis and Inbreeding Depression

Heterosis over both years is summarized in Table IV. The F_1 means were higher than the midparent (MP) for all traits except length uniformity. The range of variability for each trait among the parents was expressed as the ratio of the highest parent (HP) to the lowest parent (LP). The amount of variability ranged between 1.08 for length uniformity to 1.91 for earliness. Overall mean heterosis was nonsignificant for all characters measured. The magnitudes estimated were greatest for earliness (15.7%) and yield (14.0%) and relatively small (-0.4 to 1.9%) for the remaining traits. The results suggest that those traits which had the greatest range of variability among the parents also exhibited the greatest degree of heterosis.

Individual heterotic effects were calculated for each hybrid; and the number of hybrids showing significant effects at the 0.05 and 0.10 levels, respectively, are also presented in Table IV. Yield and 2.5% span length exhibited the most individual cases of heterosis at both levels of significance. Fiber length uniformity, fineness, and strength exhibited very few cases of either negative or positive effects.

Results for heterosis in 1969 and for heterosis, inbreeding depression, and F_2 deviations in 1970 are summarized in Tables V and VI, respectively. The combined analyses of variance in Table I revealed significant year by genotype interaction for all traits except 50% span length and fiber strength. This suggests the possibility (which is verified in Tables V and VI) that mean heterosis also varied from year to year for these traits. The expression of heterosis varied more from year to year for yield, earliness, and fiber fineness than for the other

TABLE IV

MEAN PERFORMANCE OF PARENTAL AND F₁ GENERATIONS AND MEAN HETEROSIS OVER 1969 AND 1970

Trait	Generation Mean		HP/LP	Mean Heterosis	Number of Crosses Showing Significant Differences From Their Midparent*	
	MP	F ₁			0.05 Prob. Level	0.10 Prob. Level
Yield	24.9	28.4	1.35	14.0	12	20
Earliness	63.6	73.6	1.91	15.7	6	17
Lint Percent	35.7	36.2	1.12	1.6	7	14
2.5% Span Length	1.036	1.056	1.12	1.9	12	21
50% Span Length	.479	.487	1.12	1.5	8	10
Length Uniformity	46.3	46.1	1.08	-0.4	0 (2)	1 (3)
Fiber Fineness	4.07	4.08	1.26	0.2	0	2 (2)
Fiber Strength	2.18	2.19	1.29	0.5	2 (1)	5 (2)

*Numbers in parentheses denote cases of heterosis in the negative direction.

TABLE V

AVERAGE PERFORMANCE OF PARENTAL AND F₁ GENERATIONS AND MEAN HETEROSIS IN 1969

Trait	Generation Mean		HP/LP	Mean Heterosis	Number of Crosses Showing Significant Differences From Their Midparent*	
	MP	F ₁			0.05 Prob. Level	0.10 Prob. Level
Yield	33.1	36.3	1.47	10.1	0	3
Earliness	54.7	64.8	2.59	19.5	1	9
Lint Percent	36.9	37.7	1.12	2.3	3	8
2.5% Span Length	1.041	1.054	1.10	1.3	0	3
50% Span Length	.490	.496	1.13	1.3	1	3
Length Uniformity	47.0	47.0	1.08	-0.1	0	0 (1)
Fiber Fineness	4.09	4.20	1.27	2.7	0	1
Fiber Strength	2.25	2.25	1.21	0.2	0	0

*Number in parentheses denotes a case of heterosis in the negative direction.

TABLE VI

AVERAGE PERFORMANCE OF PARENTAL, F₁, AND F₂ GENERATIONS AND MEAN HETEROSIS,
INBREEDING DEPRESSION, AND F₂ DEVIATIONS IN 1970

Trait	Generation Mean			HP/LP	Mean Heterosis	Inbreeding Depression
	MP	F ₁	F ₂			
Yield	16.7	20.5	19.3	1.86	24.1	7.7
Earliness	72.5	82.3	76.9	1.65	14.8	6.2
Lint Percent	34.4	34.7	34.4	1.13	0.8	0.8
2.5% Span Length	1.032	1.057	1.045	1.15	2.5	1.2
50% Span Length	.469	.478	.473	1.15	1.8	1.0
Length Uniformity	45.5	45.2	45.3	1.09	-0.7	-0.2
Fiber Fineness	4.04	3.96	4.03	1.29	-2.0	-2.0
Fiber Strength	2.10	2.12	2.11	1.32	1.1	0.4

TABLE VI (Continued)

Trait	Number of Crosses Showing Significance (0.05)*		Number of Crosses Showing Significance (0.10)*		F ₂ Deviations
	Heterosis	Inbreeding Depression	Heterosis	Inbreeding Depression	
Yield	3	0	6	0	3.7
Earliness	0	0	2	0	-0.6
Lint Percent	0	0	0	1	-0.4
2.5% Span Length	0	0	5	1	0.0
50% Span Length	0	0	0	1	0.1
Length Uniformity	0	0	0	1	-0.1
Fiber Fineness	0	0	1	0	0.7
Fiber Strength	0	1	0	0	0.0

*No cases of heterosis in the negative direction were detected.

characters. The level of heterosis was quite different from year to year for all characters except 2.5% span length. The most drastic differences are related to yield, earliness, and fiber fineness. This suggests that these traits are influenced to a greater extent by environmental conditions than are the other traits studied. The range of variability among the parents was fairly consistent from year to year for all characters except yield and earliness.

Overall inbreeding depression and F_2 deviations were not significant for any of the traits measured. Estimates of inbreeding depression ranged from -2.0% for fiber fineness to 7.7% for yield. The data show only two cases where the amount of inbreeding depression was equal to the amount of heterosis (lint percent and fiber fineness). The results suggest that those characters which displayed the greatest variation among the parents exhibited the greatest degree of heterosis and inbreeding depression. The deviations of F_2 performance from the mean of midparent and F_1 performance were quite small and nonsignificant in all cases. This suggests that additive and dominance effects are probably more important than epistatic effects in this material.

Individual heterosis and inbreeding depression effects were calculated for each cross, and the number of crosses possessing significant heterotic and inbreeding depression effects at the 0.10 and 0.05 levels are also shown in Tables V and VI. Few cases of significance were detected among hybrids for any of the traits. This was perhaps an indicator of the weakness of the tests, *i.e.*, the relatively large error variance associated with the randomized complete-block design when tested in one year. The tests become more powerful when tested over years as shown by the number of individual cases of heterosis in

Table IV. Because of this inability to detect significant differences within years at the 0.05 probability level, the author also chose to test at the 0.10 probability level. It was the author's opinion that several crosses for each trait exhibited sufficient heterosis and inbreeding depression effects to be of practical importance even though they could not be declared significant at the 0.05 level.

Individual Line and Heterotic Effects

Estimates of genetic constants for line effects for each parent and for heterotic effects for each cross over the two years are shown in Tables VII and IX, respectively. The same type of estimates in each year plus inbreeding depression effects in 1970 are summarized in Tables VIII, X, and XI, respectively.

Yield. Entries varied significantly in yield (Table I) and differed in relative response between the two years. The average yield of the hybrids could not be grouped according to the estimates for line effects. Crosses between parents having positive line estimates averaged 28.0 grams per plant while crosses between parents with negative estimates averaged 27.9. The average yield of crosses between one parent with negative and one with positive estimates was 28.7.

The rank of the parents for line effects and their rank on the basis of mean performance of their crosses (Table XXVII) suggests that parents three and six have good GCA for yield. In the absence of heterosis, the estimates of line effects would indicate little contribution for high yield in the hybrids from parents two, four, five, and eight. However, the data shows that parent five had very good GCA.

TABLE VII

ESTIMATES OF GENETIC CONSTANTS FOR LINE EFFECTS OVER 1969 AND 1970

Line	Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
1 Deltapine 16	0.6	-10.9	0.7	.011	.002	-0.3	0.20	-0.03
2 Mo-Del	-1.2	- 0.1	-0.4	.013	.002	-0.4	0.15	0.05
3 Stoneville 7A	1.4	-11.1	1.3	.011	-.001	-0.7	0.15	-0.15
4 Tamcot 788	-0.8	5.2	-0.1	-.008	-.007	-0.3	-0.15	0.00
5 Westburn	-0.5	1.2	-0.9	-.034	-.017	-0.1	-0.25	-0.09
6 Lockett 4789A	1.5	5.8	-0.3	-.007	-.002	0.1	-0.10	-0.08
7 Quapaw	0.3	7.8	-0.3	-.023	.001	1.1	0.25	0.00
8 Dunn 56C	-2.1	- 0.5	-0.5	-.003	.005	0.6	-0.15	0.07
9 S65-391	0.1	2.9	-0.1	.025	.009	-0.2	-0.25	0.07
10 S65-396	0.9	- 0.2	0.5	.016	.011	0.3	-0.10	0.13

TABLE VIII

ESTIMATES OF GENETIC CONSTANTS FOR LINE EFFECTS IN 1969 AND IN 1970

Line	Yield		Earliness		Lint Percent		2.5% Span Length	
	1969	1970	1969	1970	1969	1970	1969	1970
1 Deltapine 16	0.5	0.6	-12.6	-9.3	0.9	0.4	.007	.013
2 Mo-Del	-3.1	0.7	-2.6	2.4	-0.2	-0.6	-.001	.027
3 Stoneville 7A	3.2	-0.4	-12.4	-9.8	1.4	1.2	.011	.012
4 Tamcot 788	0.5	-2.1	6.5	3.9	0.3	-0.4	-.001	-.015
5 Westburn	-0.1	-0.9	5.2	-2.8	-0.7	-0.9	-.031	-.037
6 Lockett 4789A	1.0	1.9	6.2	5.5	-0.2	-0.5	-.005	-.010
7 Quapaw	-0.3	1.0	10.9	4.7	-0.2	-0.3	-.017	-.028
8 Dunn 56C	-1.4	-2.9	-1.1	0.0	-0.8	-0.1	-.003	-.004
9 S65-391	-1.0	1.0	-1.8	7.5	-0.3	0.2	.015	.033
10 S65-396	0.6	1.1	1.7	-2.1	-0.1	1.1	.023	.009

Line	50% Span Length		Length Uniformity		Fiber Fineness		Fiber Strength	
	1969	1970	1969	1970	1969	1970	1969	1970
1 Deltapine 16	.001	.001	-0.2	-0.4	0.23	0.27	-.02	-.03
2 Mo-Del	-.001	.005	0.0	-0.8	0.08	0.29	.06	.06
3 Stoneville 7A	-.003	-.001	-0.8	-0.6	0.13	0.22	-.14	-.14
4 Tamcot 788	-.004	-.009	-0.3	-0.2	-0.05	-0.23	.00	.00
5 Westburn	-.016	-.019	-0.1	-0.2	-0.21	-0.23	-.06	-.11
6 Lockett 4789A	-.001	-.005	0.2	0.0	-0.02	-0.10	-.06	-.09
7 Quapaw	.001	-.001	1.0	1.2	0.27	0.23	.01	-.01
8 Dunn 56C	.003	.007	0.3	0.8	-0.12	-0.15	.05	.09
9 S65-391	.005	.013	-0.2	-0.2	-0.23	-0.21	.05	.09
10 S65-396	.013	.007	0.2	0.3	-0.07	-0.05	.11	.15

TABLE IX
ESTIMATES OF GENETIC CONSTANTS FOR HETEROTIC
EFFECTS OVER 1969 AND 1970

Yield: Upper right-hand corner Earliness: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		5.0**	2.6	4.9*	4.4*	2.0	4.2*	4.8*	0.4	-0.5
2	9.9		1.1	5.9**	5.0**	3.7	7.0**	6.1**	3.6	2.3
3	11.3**	8.1		3.1	6.4**	0.7	2.4	1.7	0.3	1.2
4	16.6**	11.0*	11.0**		5.5**	4.4*	2.8	2.3**	2.6**	4.8**
5	21.5**	12.6	22.3**	2.8		3.1	4.7*	7.1**	7.1**	6.3**
6	18.3**	5.7*	12.0*	2.3	8.5		2.1	5.3**	1.0	3.1
7	14.0*	12.8*	14.6**	8.9	8.7	2.9		5.3**	2.5	2.6*
8	11.2	13.7*	19.5**	4.1	13.9*	7.8	4.6		2.8	4.2*
9	8.7	4.9**	9.8*	9.6*	11.2	5.0	0.8	11.8*		-1.9
10	8.9	19.8**	13.9*	12.8*	8.5	6.5	3.3	12.7*	-9.8	

*, ** Significant at the 0.10 and 0.05 levels of probability, respectively.

Lint Percent: Upper right-hand corner 2.5% Span Length: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		1.1*	0.2	1.3**	2.4**	-0.1	0.1	1.6**	1.0*	-0.7
2	.003		0.3	1.5**	1.6**	0.5	1.0*	0.5	0.9*	-0.6
3	.012*	.034**		0.5	1.0*	0.3	0.3	-0.4*	0.2	-0.1
4	.021*	.009	.023*		0.9*	0.8	-0.4**	1.1	0.4*	-0.1**
5	.009*	.012	.016	.021*		1.0	1.6**	0.5	1.1	2.1**
6	.023*	.013	.014	.022*	.027**		0.2	0.4	0.5	-0.6
7	.024**	.001	.009**	.007**	.016	.011*		0.2	0.6	-0.3
8	.046**	.000	.039**	.036**	.049**	.023*	.021*		0.7	-0.2
9	.008	.011	.010**	.012**	.017**	.017**	.007**	.021**		0.2
10	.015	.007	.032**	.032**	.031**	.033**	.027**	.051**	.015	

TABLE IX (Continued)

50% Span Length: Upper right-hand corner Length Uniformity: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		.005	.003**	.009	.002**	.008	.015**	.020**	.005	.004
2	0.4		.022**	.006*	.015**	.007	.003	.003**	.008	-.002
3	-0.3	0.5		.011*	.003	.005	.004	.016**	.004*	.007
4	-0.1	0.2*	0.0		.001	.006	.005	.018**	.011	.010
5	-0.3	0.9*	-0.4	-0.9*		.009	-.003	.016**	.003	.007
6	-0.2	0.0	-0.1	-0.4	-0.4**		.007	.009	.004	.009
7	-0.3	0.2	-0.1	-0.1	-1.1**	0.1		.006	-.001	.001**
8	-0.1	0.3	-0.2	0.1	-0.6	-0.1	-0.4		.002	.018**
9	0.1	0.3	0.1	0.5	-0.5	-0.3	-0.5**	-0.7		.010
10	-0.3	-0.5	-0.8	-0.5	-0.6	-0.6	-1.3	-0.5	0.3	

Fiber Fineness: Upper right-hand corner Fiber Strength: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		-0.15	-0.02	-0.07	0.15	-0.11	0.11	0.24*	-0.01	-0.18*
2	0.04		0.11	-0.15	-0.07	0.09	-0.21	0.04	0.10	-0.30*
3	0.03**	0.09*		-0.06	-0.01	0.21	-0.03	0.01	0.18	-0.02
4	0.11**	0.06	0.07		0.09	0.01	-0.06	-0.08*	0.08	0.04
5	-0.04**	0.08	-0.07	0.00		0.07	-0.10	0.28*	-0.08	0.15
6	0.11**	0.01	0.04	0.01	-0.01		0.08	0.10	0.10	-0.11*
7	0.02	-0.07	-0.02	0.01*	0.00	-0.03		0.21	-0.10	-0.30*
8	-0.02	0.00*	0.06	0.09*	0.02	0.05	-0.03		0.11	0.04
9	0.02	0.10*	0.03	-0.03	-0.05**	0.02	-0.06**	-0.03		0.11
10	-0.03	0.07	0.03	0.04	-0.10**	-0.04	-0.15**	0.02	0.05	

TABLE X
ESTIMATES OF GENETIC CONSTANTS FOR HETEROTIC
EFFECTS IN 1969 AND IN 1970

<u>Yield</u>										
1969: Upper right-hand corner 1970: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		9.4*	4.0	4.2	2.1	1.2	3.5	4.5*	1.7	-2.0
2	0.6		0.2	6.8	7.3	5.7	6.7	9.2*	5.7	1.5
3	1.2	2.0		0.9	3.1	-0.2	-0.2	0.2	1.8	-0.1
4	5.5*	5.0	5.4**		4.2	1.8	-0.1	-0.5	1.2*	4.4
5	6.8*	2.7	9.7**	6.9*		0.6	3.1	1.5	8.9*	3.2
6	2.8	1.7*	1.7	7.0*	5.6		4.0	5.2	4.0	4.2
7	4.9	7.3*	5.1	5.8	6.3**	0.2		6.3	6.3	4.3
8	5.0	3.1	3.2	5.1	12.7**	5.5	4.3		2.9	2.6
9	-0.9	1.5	-1.1	4.0	5.3**	-2.0	-0.4	2.7		-1.0
10	1.1	3.2	2.5	5.2	9.3**	2.1	0.9	5.7	-2.8	

*, ** Significant at the 0.10 and 0.05 levels of probability, respectively.

<u>Earliness</u>										
1969: Upper right-hand corner 1970: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		12.8	5.9	14.6*	29.9**	20.8*	17.2*	11.8	8.5	-0.7
2	7.0		2.3	18.0*	13.5	7.3*	12.4	18.5*	13.2	18.7*
3	16.7	13.9		10.4	16.9	18.8*	16.2	17.4*	9.6	2.3
4	18.6	4.0	11.8*		4.1	8.2	3.3	4.7	16.2	7.4
5	13.1	11.6	27.7*	1.5		11.8	13.0	7.6	10.0	2.9
6	15.9	4.2	5.4	-3.6	5.3		9.6	6.1	8.1	1.9
7	10.8	13.2	12.9	14.5	4.5	-3.7		9.4	2.5*	-0.5
8	10.6	8.9	21.7	3.5	20.3	9.5	-0.2		17.4*	7.9
9	8.9	-3.4	9.9*	3.0	12.4	1.8	-1.0	6.3		-13.4
10	18.6	21.0	25.6*	18.1	14.1	11.0	7.0	17.4	-6.2	

TABLE X (Continued)

<u>Lint Percent</u>										
1969: Upper right-hand corner 1970: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		0.7	0.5	1.1	2.4**	0.2	0.4	1.5*	0.8	0.0
2	1.4		0.3	1.0	1.8*	0.6	1.1	1.7*	0.8	0.5
3	-0.1	0.3		0.3	1.1	0.1	0.4	0.2*	0.5	-0.1
4	1.5	2.1	0.7		0.9	0.6	-0.7*	1.6	0.6**	1.0**
5	2.3	1.5	0.9	0.9		0.8	1.7*	1.3	2.1	2.9
6	-0.3	0.3	0.6	1.1	1.3		-0.1	1.2	0.8	0.4
7	-0.1	0.9	0.3	-0.2	1.6	0.5		0.6	0.5	0.5
8	1.7	-0.7	-1.0	0.6	-0.2	-0.5	-0.2		1.4	1.3
9	1.1	1.0	0.0	0.3	0.0	0.2	0.6	0.0		0.7
10	-1.5	-1.7	-0.1	-1.2	1.4	-1.5	-1.1	-1.8	-0.3	

<u>2.5% Span Length</u>										
1969: Upper right-hand corner 1970: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		.007	.003	.009	-.005	.009	.009	.037*	.016	.011
2	-.001		.026	.011	.022	.018	.001	.004	.012	-.003
3	.021	.042		.018	.007	.011	-.007	.025	.013	.017
4	.034	.008	.028		-.001	.013	-.003	.026*	.027	.023
5	.023	.002	.026	.043		.021	.013	.039*	.017	.000
6	.036	.009	.017	.032	.034		.006	.019	.020	.008
7	.039*	.000	.025	.018	.020*	.017		.014	.009	.010*
8	.054*	-.003	.052	.047	.059*	.026	.028		.027	.037*
9	.001	.011	.006	-.003	.016*	.014*	.006	.015*		.017
10	.019	.017	.046	.041	.061*	.058*	.045	.065*	.012	

TABLE X (Continued)

50% Span Length

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		-.001	-.001	.003	-.007	.003	.013	.017	.012	.004
2	.013		.013	.004	.019	.002	.005	.000	.010	-.001*
3	.008	.031		.011	.002	.007	.002	.016*	.007*	.023*
4	.015	.008	.010		-.007	.000	.002	.023*	.026*	.005
5	.010	.011	.004	.008		.010	-.006	.015	.013	-.007
6	.014	.011	.004	.012	.007		.003	.012	.004	-.001
7	.017	.002	.005	.007	.000	.010		.009	.003	-.006
8	.024	.007	.015	.014	.018	.006	.003		-.003	.020
9	-.003	.007	.002	-.005	-.007	.004	-.005	.007		.012
10	.004	-.003	.007	.014	.022	.018	.005	.016	.007	

Length Uniformity

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		-0.5	-0.3	-0.1	-0.4	-0.2	0.7	-0.6	0.4	-0.1
2	1.2		0.1	0.0	0.9	-0.6	0.4	-0.2	0.4	0.0
3	-0.3	1.1		0.3	-0.1	0.1	0.5	0.5	0.1	-0.1
4	-0.1	0.4	-0.3		-0.6	-0.5	0.4	1.1	1.2	-0.5
5	-0.1	1.0	-0.7	-1.1		0.1	-1.2	-0.3	0.5	-0.7
6	-0.3	0.6	-0.4	-0.3	-0.8		0.0	0.3	-0.5	-0.5
7	-0.2	0.1	-0.7	-0.2	-0.9	0.1		0.3	-0.1*	-1.1
8	-0.1	0.9	-0.8	-0.8	-0.8	-0.6	-1.0		-1.4*	0.2
9	-0.2	0.2	0.0	-0.3	-1.4	-0.2	-0.9	0.0		0.4
10	-0.4	-1.0	-1.4	-0.5	-0.5	-0.8	-1.6	-1.3	0.2	

TABLE X (Continued)

Fiber Fineness

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		-0.06	0.04	-0.03	0.25	0.09	0.23	0.16	0.02	-0.05
2	-0.23		0.16	0.01	0.25	0.04	-0.01	0.21	0.31	0.04
3	-0.08	0.06		-0.07	0.21	0.15	0.27	0.11	0.18	0.03
4	-0.10	-0.31	-0.07		0.23	-0.05	0.01	0.11*	0.18	0.15
5	0.06	-0.38	-0.24	-0.05		0.26	0.01	0.39*	0.19	0.11
6	-0.30	0.14	0.28	0.09	-0.11		0.02	0.12	0.18	-0.04
7	-0.03	-0.43	-0.34	-0.12	-0.21	0.13		0.32	-0.02	-0.17
8	0.31	-0.13	-0.09	-0.27	0.17	0.09	0.10		0.16	0.05
9	-0.05	-0.12*	0.17	-0.02	-0.33	0.03	-0.20	0.05		0.13
10	-0.31	-0.64*	-0.07	-0.07	0.17	-0.17	-0.42	0.05	0.07	

Fiber Strength

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		0.01	0.01	0.11	-0.11	0.07	0.02	-0.05	0.01	0.00
2	0.07		0.04	0.03	0.01	-0.05	-0.05	0.00	0.10	0.15
3	0.04	0.15		0.05	-0.12	0.07	-0.02	0.05	0.04	0.01
4	0.11	0.09	0.09		-0.06	0.02	0.01	0.13	0.06	-0.03
5	0.03	0.15	-0.02	0.06		-0.03	-0.04	0.07	-0.02	-0.10
6	0.15	0.07	0.01	0.01	0.02		-0.08	0.06	0.00	-0.09
7	0.02	-0.08	-0.03	0.01	0.03	0.01		-0.02	-0.13	-0.19
8	0.01	-0.01	0.07	0.05	-0.03	0.05	-0.04		-0.09	0.06
9	0.02	0.10	0.01	0.13	-0.07	0.04	0.01	0.03		0.07
10	-0.05	-0.01	0.04	0.10	-0.09	0.02	-0.12	-0.02	0.03	

TABLE XI
ESTIMATES OF GENETIC CONSTANTS FOR INBREEDING
DEPRESSION EFFECTS IN 1970

Yield: Upper right-hand corner Earliness: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		1.8	-0.8	2.2	-0.6	3.5	2.1	1.5	0.9	-1.4
2	7.7		3.4	4.3	-2.1	2.9	3.3	-0.5	2.5	1.8
3	-2.9	6.3		1.0	5.7	1.1	2.8	1.1	1.7	1.8
4	16.1	11.1	1.1		2.6	3.6	3.0	-0.2	-0.7	4.4
5	-3.8	7.1	14.1	3.7		0.4	2.3	6.7	2.8	5.1
6	13.0	7.9	1.7	-11.5	-1.1		-2.6	3.5	-1.3	2.8
7	-3.7	27.0	10.0	10.0	-1.5	-6.5		0.1	0.2	-3.4
8	-4.0	-1.1	10.0	12.0	6.5	1.5	-3.5		-0.7	3.4
9	7.8	5.6	-3.6	-1.3	7.9	-1.9	20.7	-1.1		-0.5
10	10.5	26.5	10.6	21.3	0.5	8.0	3.8	10.8	-6.4	

*, ** Significant at the 0.10 and 0.05 levels of probability, respectively.

Lint Percent: Upper right-hand corner 2.5% Span Length: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		0.5	0.1	0.5	1.3	-0.9	-0.1	2.8*	1.9	0.5
2	.024		0.8	0.8	-0.1	0.6	-0.4	-1.2	0.5	-1.7
3	.021	.011		-0.2	-1.0	1.8	-0.1	-0.1	1.4	1.2
4	.050	-.002	.004		-0.8	0.3	0.4	0.1	2.2	-0.2
5	.004	-.004	.015	.009		-0.3	1.3	-1.2	-0.7	1.3
6	.051	.022	-.003	.025	.015		0.8	0.0	0.6	-1.8
7	.031	.039	.000	-.002	.003	.007		-0.7	1.3	0.6
8	.035	.010	.017	.029	.032	.013	.027		0.2	0.5
9	-.016	-.021	.002	-.026	-.003	.030*	.007	.026		0.8
10	-.027	-.005	.016	.018	.019	.068*	-.010	.019	-.017	

TABLE XI (Continued)

50% Span Length: Upper right-hand corner
Length Uniformity: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		.016	.007	.021	-.007	.021	.022	.021	-.003	-.018
2	0.5		-.001	-.006	-.006	.021	.006	.007	-.013	-.023
3	-0.3	-0.5		-.004	.000	-.004	-.003	.000	.011	.003
4	-0.2	-0.5	-0.5		-.003	.007	.002	.015	-.008	.007
5	-0.9	-0.4	-0.7	-0.7		.006	-.004	.014	-.012	.019
6	-0.2	1.0	-0.3	-0.5	-0.1		.014	.014	.021	.021
7	0.7	-1.2	-0.3	0.2	-0.5	1.0		-.001	.003*	-.013
8	0.4	0.2	-0.7	0.1	-0.1	0.8	-1.3		.040*	.009
9	0.4	-0.3	0.9	0.3	-1.0	0.7	-0.1	2.6*		.005
10	-0.6	-1.9	-0.5	-0.1	0.5	-1.0	-0.8	0.2	1.1	

Fiber Fineness: Upper right-hand corner
Fiber Strength: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		-0.07	-0.06	-0.10	-0.15	-0.14	0.43	0.31	0.31	-0.21
2	0.08		0.12	-0.12	-0.37	0.48	-0.44	-0.13	-0.06	-0.59
3	-0.05	-0.01		-0.16	-0.26	0.06	-0.29	-0.13	0.36	-0.17
4	0.10	-0.19	-0.04		-0.54	0.01	-0.15	-0.22	0.03	-0.02
5	-0.08	0.07	-0.06	0.09		-0.26	-0.28	-0.17	-0.41	-0.04
6	0.08	0.04	-0.02	-0.02	0.09		0.22	0.05	0.19	-0.23
7	0.04	-0.05	-0.13	-0.03	0.06	0.03		-0.09	0.02	-0.30
8	0.11	0.05	-0.03	0.04	0.00	0.13	-0.09		0.19	0.02
9	-0.03	-0.03	0.11	-0.16	-0.09	0.07	0.03	0.35**		0.24
10	-0.05	-0.07	0.11	0.12	-0.04	-0.02	-0.09	0.05	-0.04	

Estimates of heterosis were positive for 43 of the 45 hybrids (Table IX). The means of 32 of the hybrids ranged from 100 to 116% of the highest yielding parent. Six of the 10 individual cases of significant heterosis in Table X were observed for hybrids involving parent five. The results indicate that both additive and non-additive (dominance) effects are involved in the expression of lint yield in this material.

Earliness. The line estimates indicate that hybrids with parents four, five, six, seven, and nine should mature earlier than the mean of the parents while hybrids involving other parents would mature later. However, the heterosis estimates (Table IX) for 44 out of the 45 crosses ranged from 0.8 to 22.3%, indicating a general positive heterosis for earliness. The crosses could be arranged together on the basis of the estimates of line effects for earliness. Hybrids developed from parents having positive line estimates averaged 78.8%; hybrids from parents with negative estimates averaged 67.4%; and the mean maturity of hybrids from one parent with negative and one with positive estimates was 74.0%. The rank of the parents for line effects and the rank based on mean performance of their crosses was very similar. Parents four, six, and seven had greater line estimates and mean cross performances.

Nine hybrids matured earlier than the earliest parent; none were later than the latest parent; and 39 matured earlier than the overall average of the parents. Five of the six late maturing hybrids were derived from parents with large negative line estimates. Seventeen hybrids (Table IX) were significantly earlier over both years than their midparent at the 0.10 level of probability. The variation among entries was highly significant for earliness; however, relative response among

entries was not consistent between years (Table I). The heterotic response also varied widely among crosses in the two years as shown in Table X. The results suggest that both additive and dominance effects are also involved in the expression of earliness in this population.

Lint percent. Lint percent varied significantly among entries (from 34.0 to 38.2%), and the entry by year interaction was highly significant (Table I). Higher lint percents were evident for several hybrids involving parents one and three. These two parents had the greatest line estimates and consequently ranked highest in mean cross performance. In the absence of heterosis, the large negative estimates of line effects (Table VII) would indicate little contribution for higher lint percent in the crosses involving parent five. Conversely, parent 10 had a large positive estimate but contributed essentially nothing to increased lint percent in its hybrids (Table XXVII).

Crosses between parents with positive line effects averaged 37.1%, and crosses between parents with negative line estimates averaged 35.7%. The average lint percent of crosses between one parent with negative and one with positive estimates was 36.6%. The rank of the parents for line effects and their rank on the basis of mean cross performance were fairly similar. Some degree of positive heterosis was expressed in 35 hybrids (Table IX). Thirty-three had higher lint percent than the midparent value; however, only 16 of the 33 were significantly greater than their midparent at the 0.10 level of probability. No hybrid had a higher lint percent than the highest parent or a lower value than the lowest parent. Indications point to the conclusion that additive effects are more important but that dominance effects are also involved in the expression of lint percent in this material.

2.5% span length. Lengths ranged from 0.968 to 1.100 inches among the parents and F_1 's (Tables XXVII and XXVIII), and the variation was highly significant (Table I). The entries also differed significantly in relative response between years. Heterosis for longer fiber was expressed in all hybrids (Table IX). However, only 24 crosses were equal to or longer than the average of the parents. Parent five did not produce a hybrid that was as long-fibered as the midparent value. Parents nine and 10 were involved in four of the six hybrids that exceeded the fiber length of the longer parent. No hybrid had fiber shorter than the shortest parent. Significant heterosis at the 0.10 level was expressed in 21 hybrids.

The average lengths of the hybrids could easily be grouped based on the estimates for line effects. Hybrids developed from parents with positive line estimates averaged 1.081 inches; hybrids from parents with negative estimates averaged 1.030; and the mean length of all hybrids from one parent with negative and one with positive estimates was 1.056. Parents four, five, six, and seven possessed the largest negative line estimates and also ranked lowest in mean cross performance. The results would seem to indicate that a major portion of the expression for 2.5% span length is due to additive effects; however, dominance effects do account for some of the expression of this trait in this population.

50% span length. 50% span length varied significantly among entries (0.445 to 0.513 inches), and the year by entry interaction was small and not significant (Table I) indicating that this trait was relatively consistent over years.

In the absence of heterosis, the line estimates indicate that hybrids from parents one, two, seven, eight, nine, and 10 should be longer

than the mean of the parents and that hybrids involving other parents would be relatively shorter. However, the heterosis estimates (Table IX) for 42 crosses ranged from .001 to .022 inches. Four hybrids produced longer fiber than the longest parent; parent eight was involved as a parent in two of those crosses. Parent seven was involved in two of the three hybrids exhibiting heterosis in the negative direction which would suggest that it contributes little to increased length in hybrids.

Grouping of the hybrids was again possible according to the estimates for line effects. Crosses between parents with positive line estimates averaged 0.495 inches; those between parents with negative estimates averaged 0.471; and the average length of hybrids with one parent having a negative and the other having a positive estimate was 0.485. Heterosis was evident for length as 37 hybrids had equal to or longer fiber than the midparent average. However, only 10 of those hybrids were significant at the 0.10 probability level above the average of their parents. Parent five was a parent in five of the eight hybrids which fell below the midparent average. Parents eight, nine, and 10 had the highest line effects estimates and mean cross performances (Table XXVII). The data suggests that both additive and dominance effects are involved in the expression of this trait.

Length uniformity. Thirty hybrids had a lower length uniformity than the average of their parents (Table IX); six had uniformity equal to or lower than the lowest parent; and no hybrid exceeded the highest parent. Three hybrids had significant negative estimates, and one had a significant positive estimate at the 0.10 level of probability.

Crosses among parents with positive line estimates averaged 46.8%; those among parents with negative estimates averaged 45.7%; and the mean length uniformity for hybrids from one parent with negative and the other with positive estimates was 46.2%. The rank of the parents for line effects and their rank based on mean cross performance (Table XXVII) were almost identical. For instance, parents seven and eight had the greatest positive line estimates and mean cross performance. Those two parents were involved in 13 of the 17 hybrids which exceeded the midparent value; whereas, parent three had the largest negative estimates and the lowest mean cross performance. It was the parent of eight of the 28 hybrids which fell below the midparent mean.

Significant variation occurred among entries for this trait, and a significant year by entry interaction suggests a differential response to environments (Table I). The results suggest that additive effects are of major importance in the expression of this character but that some dominance effects also influence its expression.

Fiber fineness. The entries varied significantly for fiber fineness and differed in relative response over the two years (Table I). Estimates of heterosis were positive for 24 of the 45 hybrids (Table IX); one hybrid was coarser than the coarsest parent; and no cross was as fine as the finest parent. Two positive and two negative heterosis estimates were significant at the 0.10 level of probability. Parent eight was involved in both hybrids with positive estimates, and parent 10 was a parent of both hybrids with negative estimates. Twenty-two hybrids were equal to or coarser than the average of the parents. All of the 22 involved parents one, three, and/or seven.

The average fiber fineness of the hybrids could be grouped together relative to the estimates of line effects. Hybrids from parents having positive line effects averaged 4.5 micronaire units; hybrids from parents having negative estimates averaged 3.8; and the mean of all hybrids between one parent with negative and one with positive estimates was 4.1. The rank of the parents for line effects and their rank based on mean cross performance (Table XXVII) were very much the same. The results would suggest that additive gene effects are probably of major importance in the expression of fiber fineness in this population.

Fiber strength. Fiber strength varied significantly among entries (1.88 to 2.44 grams per grex) and appears to be relatively consistent over years since the years by entry interaction was small and not significant (Table I). Twenty-seven crosses exhibited heterosis (Table IX) above the average of their parents. No hybrid was as strong as the strongest parent, and only one was weaker than the weakest parent. Heterosis above the average of the parents was expressed in 24 hybrids. Though each was stronger than the midparent value, only 17 of those 24 hybrids had positive heterotic effects. Seven hybrids had significant estimates at the 0.10 level, and four of the seven were also significant at the 0.05 level. Five of the seven estimates were positive, and two were negative. Parents one and two were involved in four out of five crosses with positive estimates, and parent 10 was a common parent in both hybrids with negative estimates.

Average hybrid performance groupings were definitely in accordance with the line effects estimates. Those crosses among parents possessing positive line estimates averaged 2.29 grams per grex; those from parents having negative estimates averaged 2.03; and the mean of all hybrids

developed from one parent with positive and one with negative line estimates was 2.17. The rank of the parents for line effects and their rank on the basis of mean cross performance (Table XXVII) were very much the same. Parent 10 ranked first in both line effects estimates and mean cross performance; whereas, parents six, five, and three, respectively, ranked lowest in descending order. The data seem to indicate that both additive and dominance effects are involved in the expression of this trait in this material but that additive effects are probably much more important.

Expression of Heterosis and Inbreeding Depression

There is general agreement among researchers that the expression of heterosis is dependent on genetic diversity among the parents and on directional dominance. Therefore, failure to observe heterotic response is not sufficient evidence for concluding that individual loci show no dominance.

In general, the differences among hybrids for all eight traits were related to the differences among their parents. The relatively low level of heterosis, inbreeding depression, and F_2 deviations in this material would suggest that a major portion of the genetic variance in the population is additive in nature. Additional evidence for the importance of additive gene effects would come from the very close agreement for most traits between the ranking of the lines for line effects and the ranking based on the mean cross performance of the parents. However, the magnitude of heterosis for yield and earliness and the slight differences in ranking of the parents for line effects from their ranking on the basis of mean cross performance in some instances suggest

that non-additive variance accounts for a portion of the total genetic variance. Therefore, the low level of heterosis, inbreeding depression, and F_2 deviations might be related to the presence of some degree of dominance rather than to sampling errors. Again, it may be that dominance effects, although quite small relative to the additive effects, are still sufficient to account for rather sizable amounts of heterosis and inbreeding depression observed in the case of yield and earliness.

A more detailed description of the causes of this heterosis will be discussed later.

Jinks-Hayman Diallel Analysis

The diallel analysis, as outlined by Jinks and Hayman (22, 23, 24, 27, 28) attempts to partition phenotypic variation into genotypic and environmental variation and to further divide the genotypic variation into additive and dominance components. In addition to a detailed description of the various genetic properties and parameters operating among a given set of lines, the analysis can also be used to detect epistasis. Such estimates are of theoretical interest since they provide information on the genetic mechanisms by which traits are inherited. They are of practical interest since they in large measure influence breeding procedures. The diallel crossing scheme also provides a systematic method for screening the large number of crosses among a given set of potential parents for possible use in the breeder's program.

Assumptions of the Diallel Analysis

The Jinks-Hayman method is based on the following assumptions (14):

1. Diploid segregation,
2. Homozygous parents,
3. No reciprocal differences,
4. No genotype-environment interactions within locations and years,
5. No epistasis,
6. No multiple alleles, and
7. Uncorrelated gene distributions.

General Tests of the Assumptions

The failure of an assumption or any combination among them influences and, perhaps, invalidates to some extent the inferences derived using the analysis. To determine whether the traits fulfilled the assumptions of the analysis as a whole, the following broad, general tests were employed:

1. Analysis of variance of the quantity $(W_r - V_r)$,
2. Analysis of variance of deviations,
3. Analysis of the (W_r, W_r^2) regression, and
4. Analysis of the (V_r, W_r) regression.

The statistics necessary for the analyses were derived from variances and covariances in the L_1 (F_1) and L_2 (F_2) diallel tables and from covariances between various values in the two tables. If we let p_s refer to the s^{th} parent, f_{rs} refer to the F_1 of the r^{th} and s^{th} parents, and g_{rs} to the F_2 of the same parents, these statistics are

identified and described as follows using Hayman's (24) notations:

<u>Statistic</u>	<u>Abbreviation</u>	<u>Meaning</u>
$W_{01}(r)_{L01}$	W_{r1}	$\text{cov}(p_s, f_{rs})$
$V_1(r)_{L1}$	V_{r1}	$\text{var } f_{rs}$
$W_{01}(r)_{L1}$	W_{r1}'	$\text{cov}(\bar{f}_s, f_{rs})$
$W_1(r)_{L12}$	W_{r12}	$\text{cov}(f_{rs}, g_{rs})$
$W_{10}(r)_{L12}$	W_{r12}'	$\text{cov}(f_{rs}, \bar{g}_s)$
$W_{01}(r)_{L12}$	W_{r21}'	$\text{cov}(\bar{f}_s, g_{rs})$
$W_{01}(r)_{L02}$	W_{r2}	$\text{cov}(p_s, g_{rs})$
$V_1(r)_{L2}$	V_{r2}	$\text{var } g_{rs}$
$W_{01}(r)_{L2}$	W_{r2}'	$\text{cov}(\bar{g}_s, g_{rs})$

The r (array) values for each of the nine statistics are averaged and the means provide an additional set of statistics, *i.e.*, W_{0L01} , V_{1L1} , V_{0L1} , W_{1L12} , $W_{0L12} = W_{0L21}$, W_{0L02} , V_{1L2} , and V_{0L2} . These mean statistics will be discussed in greater detail later.

Analysis of variance of the quantity $(W_r - V_r)$. The analysis of variance of the quantities $(W_{r1} - V_{r1})$ and $(W_{r2} - V_{r2})$ is conducted to test their constancy over arrays. Significant differences among arrays (*i.e.*, heterogeneity) indicate failure of one or more of the assumptions for that particular trait (28).

The quantity $(W_r - V_r)$ was calculated for each of the 10 arrays in each of the four replications, and an analysis of variance was conducted on the 40 values which resulted. The results of this analysis for the F_1 's in 1969 and 1970 and for the F_2 's in 1970 are summarized in Table XII. The significant array values suggest at least partial failures of the assumptions for lint percent, length uniformity, fiber fineness,

TABLE XII
ANALYSES OF VARIANCE OF ($W_r - V_r$) VALUES

Source	d.f.	Mean Squares					
		Yield			Earliness		
		$F_1(1969)$	$F_1(1970)$	$F_2(1970)$	$F_1(1969)$	$F_1(1970)$	$F_2(1970)$
Replications	3	18.9	119.2*	40.0	4835.02*	10692.46	10807.49
Arrays	9	72.0	56.0	42.8	2510.32	3778.95	11662.62
Error	27	79.7	29.7	52.5	1273.72	5389.34	9338.15

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

Source	d.f.	Mean Squares					
		Lint Percent			2.5% Span Length ($\times 10^{-4}$)		
		$F_1(1969)$	$F_1(1970)$	$F_2(1970)$	$F_1(1969)$	$F_1(1970)$	$F_2(1970)$
Replications	3	0.44*	0.03	4.55**	.000224	.011385**	.004491*
Arrays	9	0.38**	1.03**	1.41	.000309	.002273	.000805
Error	27	0.11	0.26	0.94	.000297	.001379	.001276

TABLE XII (Continued)

Source	d.f.	Mean Squares					
		50% Span Length ($\times 10^{-4}$)			Length Uniformity		
		F ₁ (1969)	F ₁ (1970)	F ₂ (1970)	F ₁ (1969)	F ₁ (1970)	F ₂ (1970)
Replications	3	.000278 ^{**}	.000598 [*]	.000311 [*]	0.12	0.37	0.82 [*]
Arrays	9	.000069	.000174	.000188	0.16 ^{**}	0.13	0.31
Error	27	.000040	.000164	.000098	0.05	0.15	0.25

Source	d.f.	Mean Squares					
		Fiber Fineness ($\times 10^{-2}$)			Fiber Strength ($\times 10^{-4}$)		
		F ₁ (1969)	F ₁ (1970)	F ₂ (1970)	F ₁ (1969)	F ₁ (1970)	F ₂ (1970)
Replications	3	.3574 ^{**}	1.2866 ^{**}	.3187	.4242	.8998 [*]	1.5886
Arrays	9	.0142	.6155 ^{**}	.1899	.3542	.9300 ^{**}	.6677
Error	27	.0204	.1281	.2105	.2670	.2164	.5636

and fiber strength. In each case the significant arrays mean squares were observed in the F_1 in 1969 and/or 1970.

Analysis of variance of deviations. All of the 9r observed statistics were corrected for E_0 , E_1 , and E_2 . (E_0 , E_1 , and E_2 are estimates of the parental, F_1 , and F_2 environmental variances, respectively.) These corrected statistics were then employed to furnish the least-squares solution for the genetic components: D , F_r , H_1 , H_{r1} , and H_{r2} , as described by Hayman (24).

The genetic components were calculated from the corrected statistics by using D , H_1 , F_r , and H_{r2} : first by fitting them to the block totals and then by fitting block values of these statistics to each block. The sum of squares of deviations (Residual SS = R_1) of observed from expected statistics using block totals was based on $7n - 2$ degrees of freedom where n equals the number of arrays. The $7n - 2$ d.f. is derived from the algebraic solution of the following formula: [$9n$ statistics - $(2n + 2)$ constants]. In this particular test, $7n - 2$ equals 68. The sum of squares resulting from individual blocks (R_2) was based on $4(7n - 2)$ d.f. which equals 272 in this specific case. Subtracting the former from the latter ($R_2 - R_1$) leaves a sum of squares based on $(b - 1)(7n - 2)$ d.f. (i.e., 204, herein) which serves as an experimental error for testing R_1 . A nonsignificant mean square for deviations shows that various differences among statistics varying with r were independent of r and that the assumptions were considered fulfilled for the trait under study. If the deviations mean square is significant for a trait, additional steps are taken in the analysis of variance in an attempt to determine the cause of that failure, i.e., which assumptions had been violated. This will be further discussed under the

topics, multiple allelism and gene correlation.

The analysis of variance of deviations of observed second-degree statistics from their expectations is given in Table XIII. Significant differences were observed for all characters except for fiber fineness. Thus, this test suggests that all traits (other than fiber fineness) failed one or more of the assumptions of the analysis.

Analysis of the (W_r, W_r') regression. In this test the regression coefficient should be significantly different from zero but not from 0.5 if the assumptions are fulfilled (3). The estimates of W_{r1} and W_{r1}' in 1969 and 1970 and W_{r2} and W_{r2}' in 1970 were averaged over blocks. The regression coefficients were then calculated using those means. The coefficients from each population along with their 95% confidence limits may be found in Table XIV.

The coefficients were not significantly different from zero for yield in any population, for earliness in the F_2 , and for length uniformity in the 1970 F_1 . Yield and lint percent failed one or both criteria of this test in each set of data examined while 2.5% and 50% span length conformed to both requirements in every instance. Earliness and fiber fineness were similar in that their 1969 F_1 regressions corresponded to expectations whereas their 1970 F_1 and F_2 regressions did not. The coefficients in the 1969 F_1 and 1970 F_2 populations for length uniformity and fiber strength conformed; however, in the 1970 F_1 they did not. The data would indicate that this test was not consistent in the F_1 from year to year nor from the F_1 to the F_2 for most of the traits.

Analysis of the (V_r, W_r) regression. Mean estimates of V_r were obtained by the same procedure as were the W_r and W_r' means in the

TABLE XIII

ANALYSES OF VARIANCE OF DEVIATIONS OF THE SECOND-DEGREE STATISTICS

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length (X 10 ⁻⁶)	50% Span Length (X 10 ⁻⁶)	Length Uniformity	Fiber Fineness (X 10 ⁻³)	Fiber Strength (X 10 ⁻⁴)
Total	272	16.45	2640.14	.3209	.1091	.0095	.1099	.9164	.3716
Deviations	68	23.32**	4502.10**	.5324**	.1788**	.0165**	.1911**	.9819	.5705**
Error	204	14.16	2019.49	.2504	.0858	.0072	.0828	.8945	.3053

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

TABLE XIV
(W_r, W_r') REGRESSION COEFFICIENTS

Trait	Generation and Year	Coefficient	95% Confidence Limits
Yield	F ₁ (1969)	.103	(-.163) - .367
	F ₁ ¹ (1970)	.007	(-.395) - .409
	F ₂ ¹ (1970)	-.345	(-.872) - .181
Earliness	F ₁ (1969)	.456	.323 - .589
	F ₁ ¹ (1970)	.257	.066 - .448
	F ₂ ¹ (1970)	-.006	(-.070) - .058
Lint Percent	F ₁ (1969)	.174	.089 - .259
	F ₁ ¹ (1970)	.160	.000 - .319
	F ₂ ¹ (1970)	.237	.048 - .427
2.5% Span Length	F ₁ (1969)	.478	.280 - .677
	F ₁ ¹ (1970)	.358	.193 - .523
	F ₂ ¹ (1970)	.494	.277 - .711
50% Span Length	F ₁ (1969)	.608	.393 - .824
	F ₁ ¹ (1970)	.365	.105 - .624
	F ₂ ¹ (1970)	.263	.014 - .511
Length Uniformity	F ₁ (1969)	.324	.100 - .547
	F ₁ ¹ (1970)	.213	(-.016) - .442
	F ₂ ¹ (1970)	.415	.194 - .636
Fiber Fineness	F ₁ (1969)	.451	.403 - .500
	F ₁ ¹ (1970)	.378	.262 - .493
	F ₂ ¹ (1970)	.210	.019 - .402
Fiber Strength	F ₁ (1969)	.499	.368 - .630
	F ₁ ¹ (1970)	.350	.217 - .483
	F ₂ ¹ (1970)	.409	.225 - .594

previous test. Utilizing those means, regression coefficients between V_r and W_r were obtained for each trait in each population. In this test, regressions for each trait are expected to be significantly different from zero but not from 1.0 if all the assumptions are met (28). These regressions and their 95% confidence limits are presented in Table XV.

Yield and lint percent again failed the assumptions in all three populations. Earliness, 50% span length, and fiber strength corresponded to expectations in only the 1969 F_1 . 2.5% span length again conformed to both requirements in all three populations. Length uniformity and fiber fineness met all requirements in the 1970 F_1 and F_2 and in the 1970 F_1 , respectively. As in the previous test, the results of this test were not consistent in comparison of F_1 's from year to year nor in comparisons of the F_1 and F_2 in the same year.

In summary, four general tests were conducted on three populations (the F_1 in 1969 and 1970 and the F_2 in 1970) to determine compliance of each trait with the assumptions of the analysis as a whole. The results show that none of these traits strictly fulfilled the assumptions though some more nearly complied with them than did others. The two fiber length traits were the most satisfactory; yield and lint percent the least so; and the remaining traits were intermediate in compliance.

Specific Tests of the Assumptions

The tests conducted above are broad, general tests and are not capable of detecting specific assumptions which have not been fulfilled. However, some assumptions (based on prior experience) may be deemed valid with some degree of confidence. More can be learned about the

TABLE XV
 (V_r, W_r) REGRESSION COEFFICIENTS

Trait	Generation and Year	Coefficient	95% Confidence Limits
Yield	F ₁ (1969)	.077	(-.472) - .625
	F ₁ (1970)	.482	(-.571) - 1.534
	F ₂ (1970)	-.021	(-.334) - .291
Earliness	F ₁ (1969)	.834	.591 - 1.077
	F ₁ (1970)	.516	(-.113) - 1.145
	F ₂ (1970)	-.256	(-1.258) - .746
Lint Percent	F ₁ (1969)	.477	(-.064) - 1.018
	F ₁ (1970)	.455	(-.116) - 1.027
	F ₂ (1970)	.178	(-.382) - .738
2.5% Span Length	F ₁ (1969)	.656	.219 - 1.092
	F ₁ (1970)	1.101	.149 - 2.054
	F ₂ (1970)	.708	.393 - 1.024
50% Span Length	F ₁ (1969)	.604	.168 - 1.040
	F ₁ (1970)	.383	(-.372) - 1.138
	F ₂ (1970)	.138	(-.460) - .736
Length Uniformity	F ₁ (1969)	.446	(-.732) - 1.624
	F ₁ (1970)	.961	.039 - 1.883
	F ₂ (1970)	.625	.121 - 1.129
Fiber Fineness	F ₁ (1969)	.798	.614 - .982
	F ₁ (1970)	.788	.253 - 1.322
	F ₂ (1970)	.506	(-.372) - 1.384
Fiber Strength	F ₁ (1969)	.727	.305 - 1.149
	F ₁ (1970)	.720	(-.024) - 1.463
	F ₂ (1970)	.530	(-.153) - 1.212

remaining assumptions by conducting specific tests for them.

Assumptions not tested. The assumption of diploid segregation was not tested because, as Endrizzi (16) and Kimber (30) have pointed out, Gossypium hirsutum L. is an amphidiploid and segregates in a diploid manner.

The parental lines used in this experiment are varieties and strains of upland cotton which were not selfed prior to crossing and evaluation. Since upland cotton is a predominantly self-pollinated plant, it was assumed that the parents were relatively homozygous. However, some degree of heterozygosity may exist even after many generations of selfing.

In an often cross-pollinated crop such as upland cotton, the method of selfing employed would also have some bearing on the degree of heterozygosity or heterogeneity existing in the population after several generations. For example, if plants within a heterozygous population are selfed and bulk harvested in each of several subsequent generations, then the population rapidly approaches the homozygous condition regardless of the number of heterozygous gene pairs present in the beginning. However, the final result is a homozygous but not a homogeneous population, because such a population would include many different homozygous combinations. Thus, one would be bulking many genetically distinct families or groups, each uniform within itself. In contrast, by starting with an individual plant selection from the population and then selfing and randomly selecting a single plant each subsequent generation, one can develop a uniform, homozygous, homogeneous line. However, by separating the original population or parental line into a genetically distinct group by selection within each generation, one has

reduced the genetic variability in the final population to a point where that population may be completely distinct from the original line or population.

Therefore, the assumption of homozygous parents may not be completely true and may account for some of the partial non-compliance previously found in this study for these traits.

As a general rule, reciprocal crosses in G. hirsutum L. have not been significantly different. In a study among primitive, foreign, and cultivated American upland cottons, White and Richmond (80) observed no significant differences between reciprocals for yield, earliness, lint percent, fiber length, fiber fineness, and fiber strength. In more recent studies, Al-Rawi and Kohel (7, 8) detected a significant reciprocal difference for lint percent in a diallel cross among nine upland cultivars. However, nonsignificance was observed between reciprocal crosses for yield, earliness, and several fiber properties.

Assumptions tested. The assumption of no epistasis was tested for each trait using the chi-square test devised by Hayman (23). To conduct this test, both F_1 and F_2 data are necessary. Therefore, only the 1970 data could be used for this purpose. Hayman's formula for chi-square with $n(n-1)/2$ degrees of freedom is as follows:

$$X^2 = k_2 [(n-1)(V_{1LX} - V_{OLX}) + n(\bar{p} - \bar{x})^2 / (1+k) + (n-1) \\ (V_{OLO} - 4W_{OLOX} + 4V_{OLX}) / (2+k)]$$

where $k = nE_0 / (8E_2 + 2E_1 - E_0)$,

$$k_2 = n / (8E_2 + 2E_1),$$

E_0 = Mean environmental variance of the parents,

E_1 = Mean environmental variance of the F_1 's,

E_2 = Mean environmental variance of the F_2 's,

n = The number of parents,

\bar{p} = The mean of the parents, and

\bar{x} = The overall mean of the entries in the experiment.

A $2L_2 - L_1$ table is constructed by subtracting each term of the L_1 table from twice the term in the same position of the L_2 table. From this table, V_{OLO} , V_{OLX} , V_{1LX} , and W_{OLOX} may be calculated. Letting

p_r = The mean of the r^{th} parent and

\bar{x}_r = The mean of the r^{th} array,

these statistics may be described as follows:

$$V_{OLO} = \text{var}(p_r),$$

$$W_{OLOX} = \text{cov}(p_r, \bar{x}_r),$$

$$V_{OLX} = \text{var}(\bar{x}_r), \text{ and}$$

$$nV_{1LX} = \sum_r \text{var}(x_{rs}).$$

The chi-square tests for epistasis were calculated for each trait and are presented in Table XVI. None of the values were significant at the 0.05 level of probability. This suggests that epistasis was either absent in or made a negligible contribution to the expression of these traits in 1970.

The assumption of no genotype-environment interactions within locations and years was tested for each trait using the procedure outlined by Allard (4) for the additive and dominance components of variation. Since this study was conducted at one location over two years, a location effect is confounded in the results making them somewhat less

sensitive than they would have been had an additional location been included.

TABLE XVI
CHI-SQUARE ANALYSES FOR EPISTASIS

Trait	Chi-Square Values (d.f. = 45)
Yield	28.03
Earliness	39.14
Lint Percent	26.95
2.5% Span Length	41.56
50% Span Length	56.12
Length Uniformity	33.53
Fiber Fineness	26.14
Fiber Strength	50.43

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

The test for the additive components is founded on the assumption that heritable differences between homozygous parents, in the absence of non-allelic interactions (epistasis), result from the additive effects of genes controlling that trait. Hence, parental lines differing significantly from each other must carry genes with different additive effects. Estimates of plot means for each trait were obtained for each

parent in each replication in 1969 and 1970, and analyses of variance were then conducted on those 80 values. The results of the analyses are summarized for each character in Table XVII. The significance of the years item has no specific genetical interpretation, as any of a host of environmental factors could have caused the observed differences between the two seasons. The significance of the parents mean square, however, is direct evidence that for each of the traits except yield, at least some of the parents carry alleles with different additive effects. Nonsignificance of the years by parents mean squares suggest that these additive effects were constant over years for earliness, 50% span length, length uniformity, fiber fineness, and fiber strength. The significant interaction term for yield, lint percent, and 2.5% span length indicates that those effects were not consistent from year to year.

The test of the dominance components of variation was based on an analysis of variance of the $80 V_{r1}$ and $80 W_{r1}$ values for each trait from the 10 arrays, four replications, and two years the study was conducted. Each V_{r1} and W_{r1} estimate within each replication was divided before analysis by the variance of the parents (V_{0L0}) occurring in that replication to minimize the additive component of variation and to thereby improve the prospects for detecting dominance interaction terms. Rescaling in this manner alleviates the fluctuation of basic variability between different environments which tends to obscure between-environment comparisons of genetic systems. The results of this analysis for each trait are given in Table XVIII. The interpretations again follow Allard's (4) reasoning where epistasis is not a complication.

TABLE XVII

GENOTYPE BY YEAR ANALYSES OF THE ADDITIVE COMPONENTS OF VARIATION

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
Years	1	5362.8 ^{**}	6310.13 ^{**}	124.25 ^{**}	.001647	.008467 ^{**}	45.30 ^{**}	.02	.4531 ^{**}
Reps within years	6	21.9	611.00 ^{**}	2.12	.000927	.000639 ^{**}	3.14 ^{**}	.20 ^{**}	.0263
Parents	9	44.7	1332.76 ^{**}	12.54 [*]	.010849 ^{**}	.002029 ^{**}	8.83 ^{**}	1.19 ^{**}	.2301 ^{**}
Years by parents	9	39.3 ^{**}	226.65	2.83 [*]	.001493 ^{**}	.000187	.96	.09	.0095
Error	54	10.7	109.96	1.08	.000485	.000170	.59	.06	.0137

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

TABLE XVIII

GENOTYPE BY YEAR ANALYSES OF THE DOMINANCE COMPONENTS OF VARIATION

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length	50% Span Length	Length Uniformity	Fiber Fineness	Fiber Strength
Years	1	15.5813**	.3115*	.1981*	.2023*	.0951	.6363**	.3349**	.9734**
Reps within years	6	14.6759**	.1640*	.2658**	.1843*	.8506**	.3209**	.0415	.1248**
Dominance	1	63.1643**	4.0450**	2.2302**	.2984**	4.1365**	2.8329**	.2161**	.5929**
Years by dominance	1	10.8004**	1.0433**	.6877**	.1108	.1188	.0328	.2512**	.4223**
Arrays	9	.5940	.3795**	.2099**	.0575	.1517	.1078*	.1795**	.1224**
Years by arrays	9	.7047	.1841**	.1317**	.1078**	.1827	.0419	.0709**	.1371**
Dominance by arrays	9	.4658	.0335	.0544	.0215	.0734	.0361	.0123	.0244
Years by dominance by arrays	9	.3171	.0114	.0421	.0195	.0316	.0443	.0101	.0191
Error	114	1.0485	.0609	.0385	.0362	.0981	.0472	.0241	.0371

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

The years mean square was significant for all characters except 50% span length indicating that rescaling of the data did not completely balance the differences between mean additive effects in the two years for those characters. Significance of the dominance mean square for all the traits indicates that the mean degree of dominance for each trait was either in the partial dominance or overdominance range. (The two degrees of dominance will be differentiated at a later stage in the analysis.) The significance of the years by dominance interaction for yield, earliness, lint percent, fiber fineness, and fiber strength suggests that mean degree of dominance for those traits was not consistent over the two seasons whereas it was consistent for the other traits.

The significance of the arrays component of variation for earliness, lint percent, length uniformity, fiber fineness, and fiber strength indicates that at least some of the parents differed from one another in dominance effects. Such differences were not apparent for yield and for 2.5% and 50% span length. The significance of the years by arrays item for earliness, lint percent, 2.5% span length, fiber fineness, and fiber strength shows that the parents did not maintain the same dominance relationships over the two years. However, this relationship among the parents was relatively constant from year to year for yield, 50% span length, and length uniformity. The lack of significance for the dominance by arrays and the years by dominance by arrays mean squares for each character provides additional evidence that epistasis was not important in the inheritance of these characters in this material.

A detailed analysis of variance of the second-degree statistics was calculated for all characters. This analysis provides a test for

multiple allelism (m.a.) in the absence of interaction (i.) (i.e., when the chi-square test for epistasis is not significant); and when both epistasis and multiple allelism are absent, parental heterozygosity (p.h.) and gene correlation (g.c.) can be tested (24).

The components D , H_{r1} , F_r , and H_{r2} (substituting H_{r1} for H_1) were fitted to block totals and individual blocks as described in the analysis of variance of deviations. This results in sum of squares for R_1' with 59 d.f. based on $[9n - (3n + 1) = 6n - 1]$ and for R_2' with 236 d.f. based on $4(6n - 1)$, respectively. Sums of squares of observed statistics and also the block totals of observed statistics, were calculated using 360 d.f. ($9n \times 4$ blocks) and 90 d.f. ($9n$), respectively. Finally, all of these sums of squares were used to derive mean squares for the following analysis of variance:

<u>Source</u>	<u>d.f.</u>	<u>SS</u>
Total	$9nb = 360$	T
Entries	$9n = 90$	E
Components	$2n + 2 = 22$	$E - R_1$
Interaction and multiple allelism	$6n - 1 = 59$	R_1'
I., m.a., parental heterozygosity, and gene correlation	$n - 1 = 9$	$R_1 - R_1'$
Error	$9n(b - 1) = 270$	$T - E$
Reps by components	$(b - 1)(2n + 2) = 66$	$(T - E) - R_2 + R_1$
Reps by i. and m.a.	$(b - 1)(6n - 1) = 177$	$R_2' - R_1'$
Reps by i., m.a., p.h., and g.c.	$(b - 1)(n - 1) = 27$	$R_2 - R_2' - R_1 + R_1'$

where n equals the number of parents.

If R_1' is significant against its block interaction ($R_2' - R_1'$), this suggests multiple allelism and/or epistasis. If R_1' is not significant, then significance of ($R_1 - R_1'$) against its block interaction ($R_2 - R_2' - R_1 + R_1'$) probably indicates parental heterozygosity and/or gene correlation.

The components mean squares (Table XIX) were significant for all traits. The interaction-multiple allelism mean squares were significant in all instances with the exception of fiber fineness. Since epistasis has been previously ruled out for all traits by the chi-square test, the significance of interaction-multiple allelism must be due to the presence of multiple alleles. Since multiple allelism was present for these traits, independent tests for parental heterozygosity and gene correlation could not be conducted. Therefore, this test indicated that the assumption of no multiple alleles was invalid for all traits except fiber fineness but that no statements regarding parental heterozygosity and gene correlations were possible for those traits. Apparently, all four of the assumptions involved in this test were met by fiber fineness.

Estimates of Environmental and Genetic Parameters

When partial failures of the assumptions have been demonstrated for a character, Hayman (22) postulates a more complex genetical system than the simple theory describes. However, he states that it is still possible to make estimates of the population parameters and genetic components for such a trait although it is realized that such estimators are less reliable than they would have been had all the assumptions been fulfilled. Therefore, those parameters were estimated and are listed

TABLE XIX

DETAILED ANALYSES OF VARIANCE OF THE SECOND-DEGREE STATISTICS

Source	d.f.	Mean Squares							
		Yield	Earliness	Lint Percent	2.5% Span Length (X 10 ⁻⁶)	50% Span Length (X 10 ⁻⁶)	Length Uniformity	Fiber Fineness (X 10 ⁻²)	Fiber Strength (X 10 ⁻⁴)
Components	22	272.43 ^{**}	48029.47 ^{**}	5.5236 ^{**}	8.7000 ^{**}	.3291 ^{**}	2.9794 ^{**}	5.8904 ^{**}	28.4427 ^{**}
Interaction and multiple allelism	59	22.98 ^{**}	4780.14 ^{**}	.5391 ^{**}	.1953 ^{**}	.0190 ^{**}	.2139 ^{**}	.1040	.5968 ^{**}
I., m.a., parental heterozygosity, and gene correlation	9	25.59	2679.34	.4884 [*]	.0711	.0000	.0414	.0602	.3983 [*]
Reps by components	66	30.41	7557.03	.7413	.4892	.0144	.2656	.1673	1.0430
Reps by i. and m.a.	177	13.73	2050.48	.2627	.0862	.0068	.0826	.0862	.3259
Reps by i., m.a., p.h., and g.c.	27	17.03	1816.33	.1698	.0837	.0100	.0839	.1110	.1709

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

and interpreted on subsequent pages for each of the traits studied. Tests for significance among parameter estimates were made using the standard errors over blocks as suggested by Nelder (57). Each block was treated as a separate experiment with its own estimate of environmental variation. In this way, each block provides an estimate of each genetic parameter for each trait, and standard errors of the mean could be calculated by the variation of the individual estimates around the overall mean.

The parameters estimated were E_0 , E_1 , E_2 , D , F , H_1 , and H_2 . As previously stated, the E_0 , E_1 , and E_2 parameters are estimates of parental, F_1 , and F_2 environmental variances, respectively. Estimates of the respective environmental variances were obtained from between plot-within plot analyses of variance of the respective parental, F_1 , and F_2 entries within each block. Since the other parameters were estimated on a plot mean basis, it was necessary to convert the estimates of each environmental variance to an equivalent basis by dividing the within plot mean square by the mean number of plants per plot within that block.

The genetic parameters (D , F , H_1 , and H_2) are as defined by Jinks and Hayman (28) using the notation of Mather (42). An estimate of each parameter was obtained in each population. Here, one has the alternative of combining F_1 and F_2 data in 1970 to obtain parameter estimates; however, this was not done because it was concluded that estimates from each population, rather than combined estimates, were more meaningful. The reasoning for this decision was based on the fact that the F_1 generation is non-segregating while the F_2 is segregating, and therefore, the estimates of within plot (environmental) variation should be quite

different in the two situations. The results in Tables XX, XXI, and XXII confirm this reasoning. A combined analysis would, in all likelihood, present biased estimates of genetic variance components which would produce biased genetic ratios and estimators and which, in turn, could also lead to incorrect decisions in regard to breeding.

The additive genetic variance is estimated by D while H_1 and H_2 are dominance genetic variances. D may also include a portion of the additive by additive epistatic effects while H_1 and H_2 may include a portion of the additive by additive variation not included in D plus additive by dominance and dominance by dominance epistatic effects. The estimates of D , H_1 , and H_2 are variances and, as such, are expected to be positive. F is an indicator of the relative frequencies of dominant versus recessive alleles in the parents and may take sign. A positive F indicates an excess of dominant alleles while a negative value suggests an excess of recessives. If no genes exhibit dominance effects and if the dominant and recessive alleles of each gene are distributed equally among the parents, then F is near to or equal to zero. Estimates of these four parameters were obtained from the F_1 and parents by solving the equations of the mean statistics which follow:

1. $(\text{var } p_r) = \text{Variance of the parents} = V_{OLO} = D + E_0,$
2. $(\text{cov } p_s, \bar{F}_s) = \text{Mean covariance of } W_r \text{'s} = W_{OLO1} =$
 $1/2 D - 1/4 F + E_0/n,$
3. $(\sum_s \text{var } f_{rs}) = \text{Mean variance of } V_r \text{'s} = V_{1L1} = 1/4 D + 1/4 H_1$
 $- 1/4 F + [E_0 + (n - 1)E_1]/n,$ and
4. $(\text{var } \bar{F}_s) = \text{Variance of the array means} = V_{OL1} = 1/4 D$
 $+ 1/4 H_1 - 1/4 H_2 - 1/4 F + [E_0 + (n - 2)E_1]/n^2.$

TABLE XX

ESTIMATES OF GENETIC AND ENVIRONMENTAL VARIANCE COMPONENTS FROM F₁ AND PARENTAL DATA IN 1969

Parameter	Trait							
	Yield	Earliness	Lint Percent	2.5% Span Length (X 10 ⁻²)	50% Span Length (X 10 ⁻²)	Length Uniformity	Fiber Fineness (X 10 ⁻¹)	Fiber Strength (X 10 ⁻¹)
D	8.9	245.87 ^{**}	2.12 ^{**}	1.067 ^{**}	.260	1.03	1.439 [*]	.274 ^{**}
F	7.5	64.12	1.59 [*]	-.059	.063	.39	.719	.060
H ₁	36.3 ^{**}	259.11 ^{**}	2.15 ^{**}	.748 [*]	.345 [*]	1.45	.667 [*]	.438 ^{**}
H ₂	34.0 ^{**}	225.21 ^{**}	1.52 [*]	.652 [*]	.286 ^{**}	1.30 [*]	.467	.379 ^{**}
E ₀	9.4 ^{**}	48.08 ^{**}	.33 ^{**}	.133 ^{**}	.078 ^{**}	.30 ^{**}	.235 ^{**}	.030 ^{**}
E ₁	9.5 ^{**}	40.07 ^{**}	.26 ^{**}	.126 ^{**}	.052 ^{**}	.25 ^{**}	.168 ^{**}	.027 ^{**}

^{*}, ^{**} Significantly different from zero at the 0.05 and 0.01 levels of probability, respectively.

TABLE XXI

ESTIMATES OF GENETIC AND ENVIRONMENTAL VARIANCE COMPONENTS FROM F₁ AND PARENTAL DATA IN 1970

Parameter	Trait							
	Yield	Earliness	Lint Percent	2.5% Span Length (X 10 ⁻²)	50% Span Length (X 10 ⁻²)	Length Uniformity	Fiber Fineness (X 10 ⁻¹)	Fiber Strength (X 10 ⁻¹)
D	14.7*	206.16**	2.13*	2.363*	.388*	1.51**	2.020**	.451**
F	23.4	291.23**	2.03	1.310	.149	1.03*	.809*	.186
H ₁	41.0*	551.72**	3.57**	2.504*	.741*	2.13*	2.260**	.330**
H ₂	25.3**	424.72**	2.44**	1.866*	.631*	1.65*	1.882**	.251**
E ₀	4.7**	54.58**	.89**	.249**	.083**	.49**	.367**	.050**
E ₁	5.4**	40.20**	.70**	.235**	.063**	.35**	.341**	.037**

*, ** Significantly different from zero at the 0.05 and 0.01 levels of probability, respectively.

TABLE XXII

ESTIMATES OF GENETIC AND ENVIRONMENTAL VARIANCE COMPONENTS FROM F₂ AND PARENTAL DATA IN 1970

Parameter	Trait							
	Yield	Earliness	Lint Percent	2.5% Span Length (X 10 ⁻²)	50% Span Length (X 10 ⁻²)	Length Uniformity	Fiber Fineness (X 10 ⁻¹)	Fiber Strength (X 10 ⁻¹)
D	14.7*	206.16**	2.13*	2.363*	.388*	1.51**	2.020**	.451**
F	33.8	537.40**	4.79	1.331	.345	2.34*	1.705	.344
H ₁	127.1*	1933.38*	18.02	9.022*	2.802**	8.60*	4.641	1.745**
H ₂	92.5*	1472.68*	14.39*	7.185**	2.212**	5.65	3.204	1.423**
E ₀	4.7**	54.58**	.89**	.249**	.083**	.49**	.367**	.050**
E ₂	6.1**	53.39**	1.00**	.295**	.077**	.54**	.425**	.049**

*, ** Significantly different from zero at the 0.05 and 0.01 levels of probability, respectively.

The same parameters were also estimated in the F_2 and parental data by solving the following equations:

5. $(\text{var } p_r) = \text{Variance of the parents} = V_{OL0} = D + E_0,$
6. $(\text{cov } p_s, \bar{g}_s) = \text{Mean covariance of } W_r \text{'s} = W_{OL02} =$
 $1/2 D - 1/8 F + E_0/n,$
7. $(\sum_s \text{var } g_{rs}) = \text{Mean variance of } V_r \text{'s} = V_{1L2} = 1/4 D + 1/16 H_1$
 $- 1/8 F + [E_0 + (n - 1)E_2]/n,$ and
8. $(\text{var } \bar{g}_s) = \text{Variance of the array means} = V_{OL2} = 1/4 D$
 $+ 1/16 H_1 - 1/16 H_2 - 1/8 F + [E_0 + (n - 2)E_2]/n^2.$

As mentioned in a previous section, the estimates of V_{OL0} , W_{OL01} , V_{1L1} , and V_{OL1} are obtained from L_1 diallel tables while W_{OL02} , V_{1L2} , and V_{OL2} are obtained from L_2 tables. Equations one and five are identical since they are estimated on the basis of the parents and are independent of whether F_1 's or F_2 's are being investigated. Weighting estimates of environmental variance was necessary because parents and offspring do not make equal contributions to V_{1L1} , V_{OL1} , V_{1L2} , and V_{OL2} .

All estimates of environmental variance were significantly different from zero at the 0.01 level of probability. The mean of E_0 exceeded that of E_1 for all characters except yield in both years. The estimates of E_2 were larger than E_1 for all traits in 1970 and larger than E_0 for all traits except earliness, 50% span length, and fiber strength. These results are largely in contrast to those of Verhalen and Murray (71) and Verhalen *et al.* (72) where E_2 was generally intermediate between E_0 and E_1 . Here only earliness, 50% span length, and fiber strength had intermediate estimates. D was significant in both years for earliness, lint percent, 2.5% span length, fiber fineness, and fiber strength; but only in 1970 for yield, 50% span length, and

length uniformity. The F values were consistently positive in sign over all three sets of data for all traits except in one case for 2.5% span length and that estimate was not significantly different from zero. In fact, F was significant only for lint percent in the 1969 F_1 , for fiber fineness in the 1970 F_1 , and for earliness and length uniformity in both F_1 and F_2 data in 1970. The positive and significant estimates suggest a greater frequency of dominant alleles in the parents for those traits. However, conclusive statements cannot be made because of the lack of uniformity between sets of data.

H_1 and/or H_2 were significantly different from zero in at least one set of data for each character. In fact, both were significant in every instance for yield, earliness, 2.5% and 50% span length, and fiber strength. H_2 was smaller than H_1 in every case. This was not unexpected since theoretically H_2 should be equal to or smaller than H_1 (22). H_1 greater than H_2 indicates that positive and negative alleles at the loci for the trait in question are not in equal proportion in the parents. Estimates of H_1 were also generally greater than the estimates of D and F obtained in the same year in the F_1 . Estimates of F, H_1 , and H_2 for each of the traits were larger in the F_2 than in the 1970 F_1 . This is to be expected for these particular parameters since the F_2 is a segregating generation whereas the F_1 is not. Since H_1 was greater than D in most instances, this suggests that dominant gene action is more important for most traits in this material than is additive gene action.

Investigation of Genetic Systems

Estimator ratios were calculated using the genetic parameters in

Tables XX, XXI, and XXII to provide further information about the genetic systems operating for each trait. An estimate of each ratio was obtained in each replication. Then overall means and standard errors of the mean, used for setting confidence limits, were calculated for each estimate as was done earlier for the population parameters. These values are presented in Table XXIII.

Dominance. The ratios $(H_1/D)^{\frac{1}{2}}$ and $[(1/4 H_1)/D]^{\frac{1}{2}}$ in the F_1 and F_2 , respectively, are weighted overall measures of the average degree of dominance at each locus where estimates of zero indicate no dominance, between zero and one indicate partial dominance, of one indicate complete dominance, and greater than one indicate overdominance.

All estimates for yield, earliness, lint percent, 50% span length, and length uniformity were in the overdominance range though in most cases the estimates were not significantly different from one. However, these estimates would suggest overdominance for those five traits. Two of three estimates for 2.5% span length were barely in the overdominance range and not significantly different from one. The 0.84 estimate in the 1969 F_1 was significantly different from one and therefore would suggest partial dominance. However, taking into consideration the average of the data from both years, 0.98, one could probably with some degree of confidence suggest complete dominance for this trait in this material. Two of the three estimates for fiber fineness were in the partial dominance range, and none of the three were significantly different from one. However, a 0.81 average estimate over the two years suggests partial dominance controlling this character. Two of three estimates for fiber strength were greater than one. However, the overdominance estimate for the 1969 F_1 did not include one within its

TABLE XXIII
MEAN RATIOS ESTIMATING GENETIC CHARACTERISTICS
OF THE POPULATION

Ratio	Yield					
	F ₁ (1969)	95% Confidence Limits	F ₁ (1970)	95% Confidence Limits	F ₂ (1970)	95% Confidence Limits
Dominance	1.87 ¹	1.15-2.59 ¹	1.81	1.11-2.51	1.66	.58-2.74
($\bar{F} - \bar{P}$) [*]	3.2	(-0.3)-6.7	3.8	2.3-5.3	2.6	0.9-4.3
$\bar{u} \bar{v}$	.2400	.1589-.3211	.1605	.1204-.2006	.1797	.1313-.2281
K _D /K _R	1.99 ¹	.88-3.10 ¹	2.75	1.19-4.31	2.49	.61-4.37
K	1.60	(-.15)-3.35	2.79	(-.20)-5.70	1.59	(-.70)-3.90
Heritability	.12	(-.03)-.27	.27	.01-.54	.29	.06-.51

*Mean of the 45 F₁ (or F₂) versus midparent comparisons within each replication.

¹Means based on three replications. Because of a zero estimate of D in replication two, the estimates of $(H_1/D)^{1/2}$ and $[(4DH_1)^{1/2} + F/(4DH_1)^{1/2} - F]$ were undefined therein and could not be used.

Ratio	Earliness					
	F ₁ (1969)	95% Confidence Limits	F ₁ (1970)	95% Confidence Limits	F ₂ (1970)	95% Confidence Limits
Dominance	1.07	.66-1.48	1.65	1.20-2.09	1.51	1.16-1.86
($\bar{F} - \bar{P}$)	10.10	(-1.77)-21.98	9.86	(-2.45)-22.17	4.37	(-6.89)-15.63
$\bar{u} \bar{v}$	.2172	.1730-.2614	.1899	.1530-.2268	.1877	.1626-.2128
K _D /K _R	1.31	.56-2.06	2.64	1.65-3.63	2.65	1.73-3.57
K	2.25	(-1.39)-5.89	1.19	(-.59)-2.97	.53	(-.49)-1.55
Heritability	.40	.15-.65	.34	.11-.57	.33	.23-.43

Ratio	Lint Percent					
	F ₁ (1969)	95% Confidence Limits	F ₁ (1970)	95% Confidence Limits	F ₂ (1970)	95% Confidence Limits
Dominance	1.01	.70-1.32	1.41	.93-1.89	1.67	.49-2.85
($\bar{F} - \bar{P}$)	.85	.57-1.13	.27	(-.27)-.81	.003	(-.83)-.84
$\bar{u} \bar{v}$	.1771	.1453-.2089	.1775	.1030-.2519	.2067	.1612-.2522
K _D /K _R	2.30	1.00-3.60	2.27	.07-4.47	2.28	.75-3.81
K	1.93	1.57-2.27	.25	.03-.47	.33	(-.31)-.87
Heritability	.57	.28-.86	.31	.06-.55	.28	.06-.50

TABLE XXIII (Continued)

Ratio	2.5% Span Length					
	F_1	95%	F_1	95%	F_2	95%
	(1969)	Confidence Limits	(1970)	Confidence Limits	(1970)	Confidence Limits
Dominance	.84	.73-.95	1.07	.59-1.55	1.02	.80-1.24
$(\bar{F} - \bar{P})$	.014	(-.004)-.032	.026	.005-.047	.013	(-.002)-.029
$\bar{u} \bar{v}$	.2177	.1315-.3039	.1840	.1496-.2184	.2058	.1562-.2554
K_D/K_R	.95	.35-1.55	1.71	.75-2.67	1.30	.00-2.60
K	1.66	(-.98)-4.30	1.52	(-.20)-3.24	.66	(-.83)-2.15
Heritability	.45	.28-.62	.51	.14-.89	.46	.09-.83

Ratio	50% Span Length					
	F_1	95%	F_1	95%	F_2	95%
	(1969)	Confidence Limits	(1970)	Confidence Limits	(1970)	Confidence Limits
Dominance	1.27	.70-1.84	1.49	.53-2.44	1.48	.56-2.40
$(\bar{F} - \bar{P})$	.006	.002-.010	.009	(-.005)-.022	.004	(-.008)-.015
$\bar{u} \bar{v}$	.2330	.1048-.3612	.2088	.1703-.2473	.1956	.1482-.2430
K_D/K_R	1.00	.85-1.15	1.37	.61-2.13	1.41	.55-2.27
K	.70	(-.41)-1.81	.63	(-.83)-2.09	.31	(-.33)-.95
Heritability	.31	.03-.59	.33	.06-.60	.33	.08-.57

Ratio	Length Uniformity					
	F_1	95%	F_1	95%	F_2	95%
	(1969)	Confidence Limits	(1970)	Confidence Limits	(1970)	Confidence Limits
Dominance	1.23	.92-1.54	1.17	.91-1.42	1.20	.63-1.77
$(\bar{F} - \bar{P})$	-.03	(-.38)-.44	-.34	(-1.04)-.36	-.23	(-1.09)-.63
$\bar{u} \bar{v}$	.2460	.1731-.3189	.1931	.1451-.2411	.1540	.0878-.2202
K_D/K_R	1.19	(-.26)-2.64	1.80	1.48-2.12	2.02	1.19-2.85
K	.25	(-.29)-.80	.43	(-.56)-1.42	1.23	(-2.65)-5.11
Heritability	.30	.04-.56	.35	.29-.41	.34	.17-.51

TABLE XXIII (Continued)

Ratio	Fiber Fineness					
	F ₁ (1969)	95% Confidence Limits	F ₁ (1970)	95% Confidence Limits	F ₂ (1970)	95% Confidence Limits
Dominance	.69	.33-1.05	1.05	.95-1.15	.71	.30-1.12
$(\bar{F} - \bar{P})$	.11	(-.04)-.26	-.09	(-.25)-.07	-.02	(-.18)-.14
$\bar{u} \bar{v}$	.1647	.0794-.2500	.2119	.1648-.2598	.1945	.0796-.3094
K _D /K _R	2.60	(-.37)-5.57	1.46	1.11-1.81	1.76	1.15-2.36
K	1.25	.18-2.32	.31	(-.39)-1.01	.71	(-.25)-1.66
Heritability	.66	.22-1.10	.41	.37-.46	.52	.50-.54

Ratio	Fiber Strength					
	F ₁ (1969)	95% Confidence Limits	F ₁ (1970)	95% Confidence Limits	F ₂ (1970)	95% Confidence Limits
Dominance	1.27	1.08-1.46	.87	.71-1.03	1.01	.75-1.26
$(\bar{F} - \bar{P})$	-.001	(-.082)-.081	.023	(-.060)-.106	.012	(-.071)-.095
$\bar{u} \bar{v}$	.2183	.1982-.2434	.1896	.1358-.2434	.2012	.1582-.2441
K _D /K _R	1.17	.57-1.77	1.73	.65-2.81	1.61	.81-2.41
K	.18	(-.12)-.47	.38	(-.41)-1.17	.24	(-.24)-.72
Heritability	.35	.25-.45	.60	.28-.92	.52	.24-.80

confidence interval. The mean of the estimates from the three sets of data was 1.05 so complete dominance is probably the most reasonable interpretation for this character. Since a discussion of the direction of dominance necessitates tables of data in addition to that included in Table XXIII, it was decided to delay discussing this topic until the remaining estimators in Table XXIII had been considered.

Distribution of alleles. The quantity $H_2/4H_1 = \bar{u}\bar{v}$ is an estimator of the average frequency of negative versus positive alleles (at loci exhibiting dominance) in the parents (22). It has a maximum value of 0.25 when $u_i = v_i = 0.5$ and is less than 0.25 when $u_i \neq v_i$. Fiber fineness was the only trait in which no estimate was significantly different from 0.25. The remaining traits had either one or two estimates which were significantly different from 0.25. One may reasonably conclude that for all traits except fiber fineness, some doubt exists as to whether the parents had an equal distribution of alleles.

Ratio of dominant to recessive genes. The ratio of total number of dominant to recessive alleles in the parents is estimated by K_D/K_R (22). This ratio is calculated using the following formula:

$$K_D/K_R = [(4DH_1)^{\frac{1}{2}} + F/(4DH_1)^{\frac{1}{2}} - F].$$

The estimates were greater than one for all traits. This implies an excess of dominant genes in the parents for each trait. Only the estimates for length uniformity and fiber fineness in the 1969 F_1 data were not significantly different from zero. These data are a necessary consequence of the foregoing results which showed an unequal distribution of alleles in the parents for all traits except possibly fiber fineness.

Number of effective factors. The number of effective factors, K , has been described by Mather (42) as the smallest unit of hereditary

material that is capable of being recognized by the methods of biometrical genetics. It is an estimator of the number of groups of closely linked genes, or at the lower limit a single gene, which control the trait and exhibit dominance to some degree. The value of K will be underestimated unless the dominance effects of all genes are equal in sign and magnitude of effects and unless the distribution of the genes is uncorrelated (27, 42). The formulas used in the F_1 and F_2 to obtain these estimates are

$$K_{F_1} = (\bar{F}_1 - \bar{P})^2 / (1/4 H_2) \text{ and}$$

$$K_{F_2} = (\bar{F}_2 - \bar{P})^2 / (1/16 H_2).$$

Estimates for yield, earliness, and 2.5% span length were relatively high; however, none were significantly different from zero. Estimates were fairly uniform from year to year in the F_1 for those three characters and from the F_1 to the F_2 for yield. The estimates for 50% span length and fiber strength were quite small and fairly uniform between sets of data although none were significant. The estimates for lint percent, length uniformity, and fiber fineness were somewhat erratic both within and between sets of data. Dominance effects unequal in size could have been responsible for deflating any of these estimates.

Heritability. Narrow-sense heritability estimates on a plot mean basis were calculated for each trait in the F_1 using the formula defined by Crumpacker and Allard (14) which follows:

$$\text{Heritability} = (1/4 D) / (1/4 D + 1/4 H_1 - 1/4 F + E).$$

In the F_2 , the formula as modified by Verhalen and Murray (71) was used

and is presented below:

$$\text{Heritability} = (1/4 D)/(1/4 D + 1/16 H_1 - 1/8 F + E).$$

All heritabilities, with the exception of the 1969 F_1 for yield were significantly different from zero. Estimates were medium to high for all characters except yield. This suggests that a substantial proportion of the total phenotypic variance for those traits was additive. The heritabilities averaged over the three sets of data reveal that about one-fifth of the variance exhibited by yield, one-third that by 50% span length and length uniformity, two-fifths that by earliness and lint percent, and one-half of that by 2.5% span length, fiber fineness, and fiber strength is additive in nature. Letting "<" represent a mean heritability difference of approximately 0.10 units, these traits in this material may be ranked by their heritabilities as to selection efficiency in a breeding program as follows: yield < (50% span length, length uniformity) < (earliness, lint percent) < (2.5% span length, fiber fineness, and fiber strength).

The choice of selection and breeding procedures to improve a trait in a crop should be influenced primarily by the types and relative amounts of genetic variance components for that trait. The variation due to additive gene action apparently accounted for most of the genetic variance for 2.5% span length, fiber fineness, and fiber strength. This suggests that an effective breeding method for improving those characters within this material would be one which allows for the accumulation of desirable genes displaying principally additive effects. Therefore, mass selection (or possibly recurrent selection for GCA) should be effective. On the other hand, these two methods would become somewhat less effective for 50% span length, length uniformity, earliness, and

lint percent and a great deal less effective for yield. In fact, alternative possibilities such as half- and/or full-sib family selection, pedigrees, and/or progeny tests should be considered to obtain a high degree of genetic progress in a selection program for yield.

Direction and order of dominance. The direction of dominance can be estimated by the quantity $(\bar{F} - \bar{P})$. From a comparison of the $(\bar{F}_2 - \bar{P})$ and $(\bar{F}_1 - \bar{P})$ results in 1970, it is obvious that a portion of the hybrid vigor observed in the F_1 was lost in the F_2 for yield, earliness, lint percent, 2.5% and 50% span length, and fiber strength. Negative heterosis was observed in the F_1 for length uniformity and fiber fineness, but this was also reduced in the F_2 . The variation was such that in most sets of data the differences between offspring and midparent values were not significantly different from zero.

Perhaps, a more meaningful estimate of the direction of dominance is obtained by $(V_r + W_r)$ correlations with parental means. This estimate is obtained by calculating a linear correlation coefficient between the mean values of $(V_r + W_r)$ of each array averaged over blocks and the corresponding parental means averaged over blocks. These coefficients are given in Table XXIV. A high correlation is indicative that most of the dominant alleles act in one direction and most recessive alleles act in the opposite direction. A small correlation indicates approximately equal proportions of dominant and recessive alleles operating in each direction (22).

Only three coefficients were significantly different from zero at the 0.05 and/or 0.01 probability levels. The coefficients for yield and earliness in each population were all negative in sign. Since parents with a preponderance of dominant alleles will have a lower array

TABLE XXIV
 $(V_r + W_r)$ CORRELATIONS WITH PARENTAL MEANS

Trait	Generation and Year		
	F ₁ (1969)	F ₁ (1970)	F ₂ (1970)
Yield	-.369	-.961 ^{**}	-.216
Earliness	-.904 ^{**}	-.754 [*]	-.477
Lint Percent	-.402	.579	.024
2.5% Span Length	.261	.025	.441
50% Span Length	.059	.374	.242
Length Uniformity	-.491	.473	.485
Fiber Fineness	.433	.440	.433
Fiber Strength	.213	-.069	.528

^{*}, ^{**} Significantly different from zero at the 0.05 and 0.01 levels of probability, respectively.

variance and covariance than will highly recessive parents (14), the negative coefficients would indicate that the dominant alleles are positive in direction, i.e., operating in the direction of greater yield and increased earliness. The correlations for the other traits except fiber fineness were quite erratic. The consistent positive coefficients would suggest that recessive alleles are operating in the direction of decreased fiber fineness.

The quantity $(V_r + W_r)$ is an estimate of the order of dominance of the parent. The comparison of the order of dominance of the parents with their mean performance for each trait in each population is shown in Tables XXV and XXVI. A breeder in a hybrid program would be interested in identifying those parents that combine high mean performance with a high order of dominance for future breeding material. For example, in fiber strength it appears over two years of performance that parent 10 had the greatest strength and carries the most dominance. Thus, it would be the most desirable for improving fiber strength in a hybrid program.

Cause for expression of heterosis. The information obtained about D , H_1 , and degree of dominance as well as the results derived from testing the assumptions of the analysis make it possible to speculate as to the cause of the heterosis observed in this study. Heterosis (whether positive or negative) for all traits was caused by dominance alone since H_1 and the degree of dominance were significantly different from zero in almost every instance while epistasis was not detected for any trait. Therefore, dominance should receive primary attention in any future breeding program utilizing heterosis in this material. However, the results indicate that additive gene action has more influence

TABLE XXV

RANKS OF PARENTS WITH RESPECT TO DOMINANCE AND MEAN PERFORMANCE IN 1969*

Trait	Order of Dominance ($V_{r_1} + W_{r_1}$) of the Parent	Order of the Parents Based on Mean Performance
	dominance → recessive	high → low
Yield	2 8 3 10 9 1 7 4 5 6	3 6 10 1 4 5 7 9 8 2
Earliness	1 3 2 10 9 8 6 7 4 5	7 4 6 5 10 8 9 2 3 1
Lint Percent	5 4 8 7 9 3 6 2 1 10	3 1 4 10 2 7 6 9 5 8
2.5% Span Length	4 8 1 3 10 9 7 5 2 6	10 9 3 1 2 4 8 6 7 5
50% Span Length	4 1 10 5 9 3 8 7 6 2	10 9 8 7 1 6 2 3 4 5
Length Uniformity	1 4 6 3 8 9 2 5 7 10	7 8 10 6 2 5 1 9 4 3
Fiber Fineness	7 1 8 6 5 3 9 2 4 10	7 1 3 2 6 4 10 8 5 9
Fiber Strength	10 2 5 3 4 9 1 8 7 6	10 2 9 8 7 4 1 6 5 3

*Parents are identified in Chapter III.

TABLE XXVI

RANKS OF PARENTS WITH RESPECT TO DOMINANCE AND MEAN PERFORMANCE IN 1970*

Trait	Order of Dominance												Order of the Parents Based on Mean Performance																	
	$(V_{r_1} + W_{r_1})$ of the Parent						$(V_{r_2} + W_{r_2})$ of the Parent																							
	dominance → recessive						dominance → recessive						high → low																	
Yield	4	8	5	3	7	2	1	10	9	6	1	5	10	8	2	4	6	7	3	9	6	10	9	7	2	1	3	5	4	8
Earliness	1	3	7	5	2	10	8	4	9	6	4	1	3	10	2	7	8	5	6	9	9	6	7	4	2	8	10	5	1	3
Lint Percent	10	5	4	9	8	2	3	1	6	7	4	10	5	3	2	9	6	7	1	8	3	10	1	9	8	7	4	6	2	5
2.5% Span Length	2	5	3	7	9	8	6	4	1	10	2	5	9	1	3	4	7	10	8	6	9	2	1	3	10	8	6	4	7	5
50% Span Length	9	8	3	1	2	6	5	4	7	10	2	1	9	5	3	10	8	7	4	6	9	10	8	2	1	3	7	6	4	5
Length Uniformity	8	7	1	2	6	10	9	4	5	3	8	2	7	10	3	9	6	5	4	1	7	8	10	6	5	9	4	1	3	2
Fiber Fineness	2	6	8	1	7	9	3	5	4	10	2	8	7	5	1	4	10	3	9	6	2	1	7	3	10	6	8	9	4	5
Fiber Strength	9	6	3	10	4	5	8	2	1	7	9	10	2	4	6	5	7	3	8	1	10	9	8	2	4	7	1	6	5	3

*Parents are identified in Chapter III.

on the expression of 2.5% span length, fiber fineness, and fiber strength in this material and that they would be improved most easily in a selection program leading towards a pure-line variety.

CHAPTER V

SUMMARY AND CONCLUSIONS

A diallel cross consisting of the 45 possible F_1 combinations (ignoring reciprocals) among 10 selected upland cottons (Gossypium hirsutum L.) was studied in replicated, randomized experiments at Perkins, Oklahoma, in 1969 and 1970. The 45 F_2 combinations were included in the second year. The objective of the study was to obtain information on the inheritance of yield, earliness, lint percent, 2.5% and 50% span length, length uniformity, fiber fineness, and fiber strength in this material and to derive such breeding implications as the data warranted.

Analyses of variance were significant among entries at the 0.01 probability level for each trait in each year and over years. The frequency and magnitude of heterosis, inbreeding depression, and F_2 deviations were investigated; and then the Jinks-Hayman diallel analysis was conducted for each trait in the F_1 each year and in the F_2 the second year.

Heterosis (measured as departure from the midparent value) and inbreeding depression (calculated as reduction of the F_2 below the performance of the F_1) were consistently observed for most of the traits evaluated. However, their magnitude was generally at a relatively low level. The F_2 deviations (measured as F_2 deviation from the average of the F_1 and midparent) were nil for most traits. The latter suggests

that epistasis was probably not important in this material in the expression of heterosis.

Four broad, general tests of the diallel assumptions as a whole were applied to each trait in the three sets of data. Partial failures were noted for all traits among at least some of the tests. However, several traits more nearly complied with the assumptions than did others. The two fiber length traits were the most satisfactory; yield and lint percent the least so while the remaining traits were intermediate.

In specific tests of the assumptions, three of the assumptions were not tested because they were deemed met on the basis of prior experience, knowledge of the materials, and/or lack of a suitable test. Those assumptions were diploid segregation, no reciprocal differences, and homozygous parents. Epistasis was tested in the 1970 F_1 and F_2 data and was found to be either absent in or to make trivial contributions to the expression of each trait in that year.

The assumption of no genotype-environment interaction could only be tested over years since a single location was used in these experiments. Differences in the additive effects among parents were significant for all traits except yield. Those effects were constant over years for earliness, 50% span length, length uniformity, fiber fineness, and fiber strength but not for the other traits. Mean dominance was constant over seasons only for 2.5% and 50% span length and length uniformity. Significant differences in dominance among the parents were also noted for earliness, lint percent, length uniformity, fiber fineness, and fiber strength. These effects varied from year to year for all traits except length uniformity.

Multiple allelism appeared to be present in all traits except fiber fineness. Gene correlation and/or parental heterozygosity could not be detected in the presence of multiple allelism; neither appeared to be operative in fiber fineness.

All estimates of E_0 , E_1 , and E_2 were significantly different from zero. Estimates of E_0 exceeded E_1 for all traits except yield in both years. The estimates of E_2 were larger than E_1 for all traits and larger than E_0 except for earliness, 50% span length, and fiber strength. The estimates of D were significantly different from zero for all traits in 1970 and for all traits except yield, 50% span length, and length uniformity in 1969. The F values were consistent in sign over all three sets of data for all characters except 2.5% span length. However, none of the estimates were significantly different from zero. Estimates of H_2 were smaller than H_1 in every instance. Generally, the estimates of H_1 also exceeded the estimates of D , F , and H_2 obtained in the same year. Estimates of F , H_1 , and H_2 were larger in the F_2 than in the F_1 in the same year for each of the characters.

In the investigation of dominance, estimates were in the over-dominance range for yield, earliness, lint percent, 50% span length, and length uniformity. Partial dominance appeared to be operating for fiber fineness. The situation is somewhat more vague for 2.5% span length, but complete dominance is postulated for it and fiber strength. Yield and earliness in the F_1 appeared to have most of their dominant alleles operating in one direction, and most of their recessive alleles operating in the opposite direction. The direction of dominance was toward higher yield and earlier maturity. Recessive alleles appeared to be operating in the direction of decreased fiber fineness.

The average frequency of negative versus positive alleles in the parents is apparently unequal for all traits except fiber fineness. Results imply that there is an excess of dominant alleles in the parents for all traits in this material. In the estimation of number of effective factors, the estimates were relatively low for most characters, somewhat erratic in size for others, and were seldom significantly different from zero.

In the investigation of narrow-sense heritabilities, mass selection and possibly recurrent selection for general combining ability were suggested as efficient breeding methods for improving 2.5% span length, fiber fineness, and fiber strength within this population. However, these two methods would be somewhat less effective for 50% span length, length uniformity, earliness, and lint percent and significantly less effective for yield. In fact, for yield alternative possibilities such as pedigrees, sib tests, and/or progeny tests should be actively considered to obtain a satisfactory degree of genetic progress.

The Jinks-Hayman analysis permitted the determination that dominance made the greater contribution to heterosis in this material. Dominance should be of primary importance in any breeding program in the future utilizing heterosis in this material. Additive gene action influences the expression of 2.5% span length, fiber fineness, and fiber strength to a significant degree in this material, and those traits would be improved most easily in a selection program leading towards a pure-line variety.

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APPENDIX

TABLE XXVII

PARENTAL MEANS AND THEIR MEAN PERFORMANCE IN CROSSES OVER 1969 AND 1970

Parent	Yield		Earliness		Lint Percent		2.5% Span Length	
	P_j^*	C_j^*	P_j	C_j	P_j	C_j	P_j	C_j
1 Deltapine 16	26.1	28.3	41.7	64.7	37.0	37.0	1.057	1.063
2 Mo-Del	22.5	27.8	63.4	73.3	34.9	35.9	1.062	1.059
3 Stoneville 7A	27.7	28.3	41.5	64.7	38.2	37.1	1.059	1.067
4 Tamcot 788	23.3	27.8	74.0	76.7	35.5	36.1	1.020	1.047
5 Westburn	23.9	29.3	66.0	75.8	34.0	36.1	.968	1.022
6 Lockett 4789A	27.8	28.9	75.2	76.3	35.0	35.6	1.022	1.047
7 Quapaw	25.6	28.7	79.2	78.5	35.2	35.7	.991	1.026
8 Dunn 56C	20.6	26.7	62.5	73.0	34.7	35.7	1.029	1.061
9 S65-391	25.0	26.7	69.3	71.7	35.5	36.1	1.085	1.072
10 S65-396	26.6	27.9	63.2	71.1	36.7	36.1	1.068	1.077

* P_j = Parental mean; C_j = F_1 mean over all crosses involving the j^{th} parent.

Parent	50% Span Length		Length Uniformity		Fiber Fineness		Fiber Strength	
	P_j	C_j	P_j	C_j	P_j	C_j	P_j	C_j
1 Deltapine 16	.483	.488	45.7	45.9	4.5	4.3	2.13	2.17
2 Mo-Del	.483	.488	45.5	46.1	4.4	4.2	2.29	2.27
3 Stoneville 7A	.476	.485	44.9	45.5	4.4	4.3	1.89	2.05
4 Tamcot 788	.466	.481	45.7	45.9	3.8	3.9	2.18	2.21
5 Westburn	.445	.467	46.0	45.7	3.6	3.9	2.01	2.07
6 Lockett 4789A	.475	.483	46.4	46.1	3.9	4.0	2.02	2.12
7 Quapaw	.480	.483	48.5	47.1	4.6	4.3	2.18	2.15
8 Dunn 56C	.489	.495	47.5	46.7	3.8	4.0	2.32	2.27
9 S65-391	.498	.493	45.9	46.0	3.6	3.9	2.32	2.25
10 S65-396	.500	.496	46.8	46.1	3.9	3.9	2.44	2.29

TABLE XXVIII

F₁ MEANS OVER 1969 AND 1970

Yield: Upper right-hand corner
Earliness: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		29.3	29.5	29.6	29.5	29.0	30.1	28.2	26.0	25.9
2	62.4		26.2	28.8	28.2	28.8	31.1	27.7	27.3	26.9
3	52.9	60.5		28.7	32.2	28.5	29.1	25.8	26.7	28.3
4	74.5	79.7	68.7		29.2	30.0	27.3	24.3	26.7	29.7
5	75.3	77.3	76.0	72.8		28.9	29.5	29.4	31.5	31.5
6	76.8	75.0	70.3	76.9	79.2		28.8	29.5	27.4	30.3
7	74.5	84.1	74.9	85.5	81.3	80.2		28.4	28.3	28.7
8	63.3	76.7	71.5	72.3	78.2	76.7	75.5		25.6	27.8
9	64.2	71.2	65.2	81.3	78.9	77.2	75.0	77.7		23.9
10	61.4	83.1	66.3	81.4	73.1	75.7	74.5	75.5	56.5	

Lint Percent: Upper right-hand corner
2.5% Span Length: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		37.0	37.8	37.5	37.9	35.9	36.2	37.4	37.2	36.1
2	1.063		36.9	36.7	36.1	35.4	36.1	35.3	36.1	35.2
3	1.070	1.095		37.4	37.1	36.9	37.0	36.1	37.1	37.3
4	1.059	1.051	1.063		35.7	36.1	34.9	36.2	35.9	36.0
5	1.021	1.027	1.030	1.015		35.5	36.2	34.9	35.8	37.5
6	1.062	1.056	1.055	1.043	1.022		35.3	35.2	35.7	35.2
7	1.048	1.028	1.034	1.013	.996	1.018		35.2	35.9	35.6
8	1.089	1.046	1.083	1.061	1.048	1.049	1.032		35.8	35.5
9	1.079	1.085	1.082	1.065	1.043	1.070	1.045	1.078		36.3
10	1.078	1.072	1.095	1.076	1.048	1.078	1.057	1.100	1.091	

TABLE XXVIII (Continued)

50% Span Length: Upper right-hand corner Length Uniformity: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		.488	.482	.483	.465	.487	.497	.506	.495	.495
2	45.9		.501	.481	.479	.485	.485	.490	.499	.489
3	45.0	45.8		.482	.464	.480	.482	.498	.491	.495
4	45.6	45.8	45.3		.456	.476	.478	.496	.493	.493
5	45.6	46.7	45.0	45.0		.468	.460	.483	.474	.480
6	45.8	46.0	45.5	45.7	45.8		.484	.491	.490	.496
7	47.4	47.2	46.6	47.2	46.2	47.5		.491	.488	.489
8	46.5	46.8	46.0	46.7	46.1	46.8	47.6		.495	.513
9	45.9	46.0	45.4	46.3	45.5	45.8	46.7	45.9		.509
10	46.0	45.7	45.1	45.8	45.8	46.0	46.3	46.6	46.6	

Fiber Fineness: Upper right-hand corner Fiber Strength: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		4.3	4.5	4.1	4.2	4.1	4.7	4.4	4.1	4.1
2	2.25		4.5	4.0	4.0	4.3	4.3	4.1	4.1	3.9
3	2.04	2.18		4.0	4.0	4.4	4.5	4.1	4.2	4.1
4	2.26	2.30	2.11		3.8	3.9	4.1	3.7	3.8	3.9
5	2.03	2.23	1.88	2.09		3.9	4.0	4.0	3.5	3.9
6	2.19	2.17	2.00	2.11	2.01		4.3	4.0	3.9	3.8
7	2.17	2.17	2.01	2.19	2.09	2.07		4.4	4.0	3.9
8	2.20	2.30	2.16	2.34	2.18	2.23	2.22		3.8	3.9
9	2.24	2.40	2.13	2.21	2.12	2.19	2.19	2.29		3.9
10	2.26	2.43	2.19	2.35	2.12	2.20	2.16	2.40	2.43	

TABLE XXIX

PARENTAL MEANS AND THEIR MEAN PERFORMANCE IN CROSSES IN 1969

Parent	Yield		Earliness		Lint Percent		2.5% Span Length	
	P_j^*	C_j^*	P_j	C_j	P_j	C_j	P_j	C_j
	1 Deltapine 16	34.2	36.5	29.6	54.2	38.7	38.5	1.056	1.058
2 Mo-Del	26.8	35.2	49.4	63.7	36.5	37.6	1.039	1.050
3 Stoneville 7A	39.5	37.2	30.0	52.3	39.7	38.6	1.063	1.063
4 Tamcot 788	34.1	35.9	67.8	69.9	37.4	37.8	1.038	1.052
5 Westburn	32.8	36.3	65.1	70.8	35.5	37.7	.979	1.021
6 Lockett 4789A	35.1	36.8	67.1	70.1	36.5	37.1	1.032	1.049
7 Quapaw	32.6	36.2	76.6	74.0	36.5	37.2	1.006	1.029
8 Dunn 56C	30.3	34.9	52.5	63.7	35.3	37.2	1.035	1.061
9 S65-391	31.1	35.0	51.1	60.1	36.2	37.4	1.072	1.072
10 S65-396	34.3	35.4	58.1	59.1	36.7	37.5	1.087	1.076

* P_j = Parental mean; $C_j = F_1$ mean over all crosses involving the j^{th} parent.

Parent	50% Span Length		Length Uniformity		Fiber Fineness		Fiber Strength	
	P_j	C_j	P_j	C_j	P_j	C_j	P_j	C_j
1 Deltapine 16	.493	.495	46.7	46.8	4.5	4.4	2.22	2.24
2 Mo-Del	.489	.494	47.0	47.1	4.3	4.3	2.37	2.33
3 Stoneville 7A	.483	.493	45.4	46.3	4.3	4.3	1.96	2.12
4 Tamcot 788	.482	.493	46.4	46.8	4.0	4.1	2.26	2.29
5 Westburn	.458	.477	46.8	46.7	3.7	4.1	2.13	2.15
6 Lockett 4789A	.489	.493	47.4	47.0	4.1	4.1	2.13	2.19
7 Quapaw	.493	.494	49.0	48.0	4.6	4.4	2.28	2.22
8 Dunn 56C	.495	.503	47.7	47.4	3.9	4.1	2.35	2.32
9 S65-391	.500	.503	46.6	46.9	3.6	4.0	2.35	2.30
10 S65-396	.516	.506	47.4	47.0	3.9	4.0	2.48	2.35

TABLE XXX

PARENTAL MEANS AND THEIR MEAN PERFORMANCE IN CROSSES IN 1970

Parent	Yield			Earliness			Lint Percent			2.5% Span Length		
	P _j [*]	C _j [*]		P _j	C _j		P _j	C _j		P _j	C _j	
		F ₁	F ₂		F ₁	F ₂		F ₁	F ₂		F ₁	F ₂
1 Deltapine 16	18.1	20.1	19.0	53.8	75.1	71.1	35.3	35.5	34.8	1.057	1.067	1.050
2 Mo-Del	18.1	20.4	18.4	77.3	82.9	73.1	33.2	34.3	34.3	1.085	1.067	1.059
3 Stoneville 7A	15.9	19.3	17.5	52.9	77.0	72.0	36.7	35.7	35.3	1.056	1.070	1.062
4 Tamcot 788	12.6	19.7	17.7	80.3	83.5	77.3	33.5	34.5	34.3	1.002	1.042	1.031
5 Westburn	15.0	22.4	20.1	66.9	80.8	77.4	32.5	34.4	34.5	.957	1.023	1.014
6 Lockett 4789A	20.5	21.1	19.7	83.4	82.5	81.4	33.5	34.1	34.0	1.012	1.046	1.023
7 Quapaw	18.7	21.1	20.4	81.9	83.0	77.4	33.8	34.3	34.0	.976	1.023	1.013
8 Dunn 56C	11.0	18.6	17.1	72.4	82.3	79.1	34.2	34.1	34.1	1.024	1.062	1.041
9 S65-391	18.8	18.4	17.9	87.5	83.2	80.4	34.8	34.9	34.1	1.098	1.072	1.074
10 S65-396	18.9	20.5	19.1	68.3	83.0	74.5	36.5	34.7	34.7	1.049	1.077	1.069

* P_j = Parental mean; C_j = F₁ or F₂ mean over all crosses involving the jth parent.

TABLE XXX (Continued)

Parent	50% Span Length			Length Uniformity			Fiber Fineness			Fiber Strength		
	P _j	C _j		P _j	C _j		P _j	C _j		P _j	C _j	
		F ₁	F ₂		F ₁	F ₂		F ₁	F ₂		F ₁	F ₂
1 Deltapine 16	.472	.481	.473	44.7	45.1	45.1	4.6	4.2	4.2	2.04	2.11	2.09
2 Mo-Del	.478	.482	.482	44.0	45.2	45.5	4.6	4.1	4.3	2.21	2.21	2.22
3 Stoneville 7A	.468	.477	.476	44.4	44.6	44.9	4.5	4.2	4.3	1.82	1.99	2.01
4 Tamcot 788	.451	.468	.465	45.1	45.0	45.2	3.6	3.7	3.9	2.09	2.14	2.15
5 Westburn	.432	.458	.458	45.1	44.8	45.2	3.6	3.7	4.0	1.88	2.00	1.99
6 Lockett 4789A	.460	.473	.461	45.5	45.2	45.1	3.8	3.9	3.9	1.91	2.05	2.01
7 Quapaw	.468	.473	.470	48.0	46.2	46.5	4.5	4.1	4.2	2.08	2.07	2.09
8 Dunn 56C	.484	.487	.476	47.2	45.9	45.7	3.7	3.9	3.9	2.29	2.21	2.15
9 S65-391	.495	.483	.479	45.1	45.1	44.6	3.6	3.8	3.7	2.29	2.20	2.18
10 S65-396	.484	.486	.485	46.2	45.1	45.5	3.9	3.8	4.0	2.41	2.24	2.25

TABLE XXXI

F₁ MEANS IN 1969 AND IN 1970

Yield

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		40.0	40.9	38.3	35.6	35.9	36.9	36.8	34.4	32.3
2	18.7		33.3	37.2	37.1	36.7	36.5	37.7	34.7	32.1
3	18.2	19.0		37.7	39.3	37.1	35.8	35.1	37.1	36.9
4	20.9	20.4	19.6		37.6	36.4	33.2	31.7	33.7	38.6
5	23.3	19.3	25.1	20.7		34.6	35.8	33.1	40.8	36.8
6	22.1	21.0	19.8	23.6	23.3		37.9	37.9	37.1	38.9
7	23.3	25.7	22.4	21.4	23.1	19.8		37.7	38.2	37.7
8	19.5	17.7	16.6	16.9	25.7	21.2	19.1		33.6	34.9
9	17.6	19.9	16.3	19.7	22.2	17.7	18.4	17.6		31.7
10	19.5	21.7	19.8	20.9	26.2	21.8	19.6	20.6	16.0	

Earliness

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		52.3	35.7	63.3	77.2	69.2	70.3	52.9	48.8	43.1
2	72.6		42.0	76.7	70.7	65.5	75.4	69.5	63.5	72.5
3	70.1	79.1		59.3	64.4	67.3	69.5	58.6	50.1	46.3
4	85.6	82.8	78.2		70.5	75.6	75.4	64.8	75.6	70.4
5	73.4	83.8	87.7	75.1		77.9	83.8	66.4	68.1	64.5
6	84.5	84.5	73.3	78.2	80.5		81.4	65.9	67.2	64.5
7	78.7	92.8	80.3	95.6	78.9	78.9		74.0	66.3	66.9
8	73.7	83.8	84.4	79.9	90.0	87.5	77.0		69.2	63.2
9	79.5	79.0	80.2	86.9	89.6	87.3	83.7	86.3		41.2
10	79.6	93.8	86.2	92.4	81.7	86.9	82.1	87.7	71.7	

TABLE XXXI (Continued)

<u>Lint Percent</u>										
1969: Upper right-hand corner										
1970: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		38.3	39.7	39.2	39.5	37.7	38.0	38.5	38.2	37.7
2	35.7		38.5	38.0	37.8	37.1	37.7	37.6	37.1	37.1
3	35.9	35.2		38.9	38.7	38.1	38.5	37.6	38.4	38.1
4	35.9	35.4	35.8		37.4	37.6	36.3	37.9	37.4	38.1
5	36.3	34.3	35.5	33.9		36.8	37.7	36.7	37.9	39.0
6	34.1	33.7	35.7	34.5	34.3		36.4	37.1	37.2	37.0
7	34.5	34.4	35.6	33.5	34.7	34.2		36.5	36.9	37.2
8	36.4	33.0	34.5	34.5	33.2	33.3	33.8		37.1	37.3
9	36.2	35.0	35.7	34.5	33.7	34.3	34.9	34.5		37.2
10	34.4	33.2	36.6	33.9	35.9	33.5	34.0	33.6	35.4	

<u>2.5% Span Length</u>										
1969: Upper right-hand corner										
1970: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		1.055	1.063	1.056	1.012	1.053	1.040	1.083	1.080	1.083
2	1.070		1.077	1.049	1.031	1.054	1.024	1.041	1.067	1.060
3	1.078	1.113		1.069	1.028	1.059	1.027	1.074	1.081	1.093
4	1.063	1.052	1.057		1.007	1.048	1.019	1.063	1.083	1.085
5	1.030	1.023	1.032	1.023		1.026	1.005	1.046	1.043	1.032
6	1.070	1.057	1.051	1.039	1.018		1.025	1.053	1.072	1.068
7	1.055	1.031	1.041	1.007	.986	1.011		1.035	1.048	1.057
8	1.094	1.051	1.092	1.059	1.049	1.044	1.028		1.081	1.098
9	1.078	1.103	1.083	1.047	1.044	1.068	1.043	1.076		1.097
10	1.072	1.084	1.099	1.067	1.065	1.089	1.057	1.101	1.085	

TABLE XXXI (Continued)

<u>50% Span Length</u>										
1969: Upper right-hand corner										
1970: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		.489	.487	.491	.469	.494	.506	.510	.508	.508
2	.487		.499	.490	.493	.491	.496	.491	.504	.501
3	.478	.504		.493	.473	.493	.490	.505	.498	.507
4	.476	.472	.470		.463	.485	.490	.511	.517	.504
5	.462	.466	.454	.449		.484	.469	.491	.492	.480
6	.480	.480	.470	.467	.453		.495	.503	.499	.501
7	.487	.475	.473	.467	.450	.474		.503	.499	.498
8	.502	.488	.491	.481	.476	.478	.479		.494	.525
9	.481	.493	.484	.468	.456	.482	.476	.497		.520
10	.483	.478	.483	.481	.480	.490	.481	.500	.497	

<u>Length Uniformity</u>										
1969: Upper right-hand corner										
1970: Lower left-hand corner										
1	2	3	4	5	6	7	8	9	10	
1		46.3	45.8	46.4	46.3	46.9	48.6	47.1	47.0	46.9
2	45.6		46.3	46.7	47.7	46.6	48.4	47.1	47.2	47.2
3	44.3	45.3		46.2	46.0	46.5	47.7	47.0	46.1	46.3
4	44.8	44.9	44.5		46.0	46.4	48.1	48.1	47.7	46.5
5	44.8	45.6	44.0	44.0		47.1	46.7	46.9	47.2	46.4
6	44.8	45.4	44.5	45.0	44.5		48.2	47.8	46.5	46.9
7	46.2	46.1	45.5	46.3	45.7	46.9		48.6	47.7	47.1
8	45.9	46.5	45.0	45.4	45.3	45.8	46.5		45.7	47.8
9	44.7	44.8	44.8	44.8	43.7	45.1	45.7	46.2		47.4
10	45.0	44.1	43.9	45.1	45.2	45.0	45.5	45.4	45.8	

TABLE XXXI (Continued)

Fiber Fineness

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		4.3	4.5	4.2	4.3	4.4	4.8	4.4	4.1	4.2
2	4.3		4.5	4.1	4.2	4.2	4.4	4.3	4.3	4.1
3	4.4	4.6		4.1	4.2	4.3	4.7	4.2	4.2	4.2
4	4.0	3.8	4.0		4.1	4.0	4.3	4.0	4.0	4.1
5	4.1	3.7	3.8	3.5		4.1	4.1	4.1	3.8	3.9
6	3.9	4.4	4.4	3.8	3.6		4.4	4.1	4.0	3.9
7	4.5	4.1	4.1	3.9	3.8	4.3		4.6	4.1	4.1
8	4.5	4.1	4.0	3.4	3.8	3.9	4.2		3.9	3.9
9	4.1	4.0	4.2	3.6	3.3	3.7	3.9	3.7		3.9
10	3.9	3.6	4.1	3.7	3.9	3.7	3.8	3.9	3.8	

Fiber Strength

1969: Upper right-hand corner
1970: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		2.30	2.10	2.35	2.06	2.25	2.27	2.23	2.29	2.34
2	2.20		2.21	2.35	2.26	2.20	2.27	2.36	2.45	2.57
3	1.97	2.17		2.17	1.93	2.12	2.11	2.20	2.20	2.23
4	2.17	2.25	2.05		2.14	2.22	2.28	2.43	2.37	2.34
5	1.99	2.19	1.83	2.05		2.10	2.17	2.30	2.22	2.20
6	2.13	2.13	1.88	2.01	1.92		2.13	2.30	2.24	2.22
7	2.08	2.06	1.92	2.10	2.01	2.01		2.29	2.18	2.19
8	2.18	2.24	2.12	2.25	2.05	2.15	2.14		2.26	2.47
9	2.19	2.35	2.06	2.06	2.01	2.14	2.19	2.32		2.48
10	2.17	2.30	2.15	2.35	2.05	2.18	2.12	2.33	2.37	

TABLE XXXII
 F_2 MEANS IN 1970

Yield: Upper right-hand corner
Earliness: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		16.9	19.0	18.7	23.9	18.6	21.2	18.1	16.6	21.0
2	64.8		15.6	16.1	21.4	18.1	22.4	18.2	17.5	20.0
3	73.0	72.8		18.7	19.5	18.7	19.5	15.5	14.6	18.0
4	69.5	71.8	77.1		18.1	20.0	18.5	17.1	20.4	16.5
5	77.3	76.7	73.6	71.4		22.9	20.9	19.0	19.4	21.1
6	71.4	76.6	71.6	89.7	81.6		22.4	17.6	19.0	19.0
7	82.3	65.8	70.3	85.6	80.4	85.4		19.0	18.2	23.0
8	77.7	84.9	74.1	67.8	83.5	86.0	80.5		18.3	17.2
9	71.7	73.4	83.8	88.2	81.8	89.3	63.0	87.3		16.5
10	69.1	67.3	75.6	71.1	81.2	78.9	78.3	77.0	78.1	

Lint Percent: Upper right-hand corner
2.5% Span Length: Lower left-hand corner

	1	2	3	4	5	6	7	8	9	10
1		35.1	35.8	35.4	35.0	35.0	34.6	33.6	34.3	34.1
2	1.046		34.4	34.7	34.4	33.1	34.9	34.2	34.5	34.9
3	1.057	1.102		36.0	36.6	33.9	35.7	34.6	34.3	35.3
4	1.014	1.054	1.053		34.7	34.3	33.0	34.4	32.3	34.9
5	1.026	1.027	1.018	1.014		34.6	33.4	34.4	34.4	34.6
6	1.019	1.035	1.054	1.014	1.003		33.3	33.5	33.7	35.3
7	1.024	.992	1.041	1.009	.983	1.004		34.5	33.7	33.4
8	1.060	1.041	1.075	1.031	1.017	1.031	1.001		34.3	33.1
9	1.094	1.123	1.081	1.073	1.047	1.039	1.036	1.049		34.6
10	1.099	1.089	1.083	1.049	1.046	1.021	1.067	1.082	1.103	

TABLE XXXII (Continued)

50% Span Length: Upper right-hand corner Length Uniformity: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		.471	.471	.455	.469	.458	.465	.481	.485	.501
2	45.1		.505	.479	.472	.458	.468	.481	.506	.501
3	44.5	45.8		.473	.455	.471	.477	.491	.473	.479
4	44.9	45.4	44.9		.452	.460	.465	.466	.477	.475
5	45.7	46.0	44.8	44.7		.447	.454	.462	.468	.467
6	45.0	44.3	44.8	45.4	44.6		.460	.464	.460	.470
7	45.4	47.3	45.8	46.1	46.2	45.9		.480	.473	.494
8	45.5	46.2	45.7	45.3	45.4	45.0	47.9		.457	.491
9	44.3	45.1	43.8	44.5	44.7	44.3	45.8	43.5		.493
10	45.7	46.1	44.3	45.3	44.7	46.0	46.3	45.4	44.7	

Fiber Fineness: Upper right-hand corner Fiber Strength: Lower left-hand corner										
	1	2	3	4	5	6	7	8	9	10
1		4.4	4.5	4.1	4.3	4.0	4.1	4.1	3.7	4.1
2	2.12		4.5	3.9	4.1	3.9	4.6	4.2	4.1	4.2
3	2.02	2.17		4.1	4.1	4.4	4.4	4.1	3.9	4.3
4	2.07	2.43	2.09		4.1	3.8	4.1	3.6	3.5	3.7
5	2.07	2.12	1.89	1.95		3.9	4.1	4.0	3.7	4.0
6	2.05	2.09	1.90	2.04	1.83		4.1	3.8	3.6	3.9
7	2.04	2.11	2.04	2.13	1.95	1.97		4.3	3.8	4.1
8	2.07	2.19	2.15	2.20	2.06	2.02	2.23		3.5	3.9
9	2.22	2.38	1.96	2.22	2.10	2.08	2.16	1.97		3.6
10	2.22	2.37	2.04	2.23	2.09	2.20	2.22	2.28	2.41	

VITA

Jerry Lee Baker

Candidate for the Degree of

Doctor of Philosophy

Thesis: A QUANTITATIVE GENETIC STUDY OF SEVERAL AGRONOMIC AND FIBER PROPERTIES AMONG SELECTED LINES OF UPLAND COTTON, GOSSYPIUM HIRSUTUM L.

Major Field: Crop Science

Biographical:

Personal Data: Born April 14, 1938, at Van Nuys, California, the son of Aubra L. and Josephine R. Baker.

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