DISCUSSION

The genus *Gossypium* to which the cultivated cotton belongs, comprise approximately 34 tropical and sub-tropical species. Botanically the varieties of cotton cultivated in India belong to the main four cultivated species of *Gossypium*, namely, *G. arboreum*, *G. herbaceum*, in the old world group, *G. hirsutum* and *G. barbadense* in the New World group.

*G. hirsutum* L. was differentiated into seven geographical races by Hutchinson (1951), namely, (1) *morrilli*, (2) *richmondii*, (3) *palmeri*, (4) *punctatum*, (5) *yucatanense*, (6) *mariegalante* and (7) *latifolium*. *Latifolium* includes a great range of types with medium large to very large bolls, and copious lint of fair to good quality and is believed to have been the progenitor of the present cultivars.

The present commercial cultivars were developed by suitably modifying the genetic architecture of the varieties belonging to *latifolium* race. The monitoring of the genetic base provides information on the gene action and their utilization for the improvement of different characters.

In the present study, in diallel analysis ten varieties belonging to geographically diverse origin namely, 'Gujarat 67', 'Laxmi', 'MCU 1', 'MCU 5', 'Reba B 50', 'Albar 49', 'Acala 4-42' 'Paymaster', '108 F and 'C 1998' were selected for the purpose of
a full diallel mating system, to obtain genetic information among the cultivated types of diverse origin. In the second experiment, leaving the first three varieties, other 4 varieties namely, ROIL 3, MCU 7, Bikaneri Nerma and SRT 1 were crossed as eleven lines (females) with three primitive non-cultivated races namely, palmeri, morrilli and richmondii as testers (males), to know the nature of gene action involved in the inter-racial hirsutum cultures.

It appears that a diallel cross containing ten parents would supply useful estimates of parameters as long as the estimates of $E_0$, and $E_1$ are relatively accurate (Hayman, 1960). The diallel analysis gives an overall estimate of the genetic relationship among parents and the distribution of dominant and recessive alleles in the parental lines.

Among the various genetic methods, the diallel analysis technique had been extensively used in a number of self-pollinated crops to understand the genetic architecture of quantitatively inherited traits (Allard, 1956b; Leffel and Weiss, 1958; Whitehouse, Thompson and Rebeiro, 1958; Lupton, 1960; Aksel and Johnson, 1962).

In cotton Marani (1961), Ramey (1963), White and Richmond (1963), Miller and Marani (1963); White and Kohel, Miller and Lee (1964); White (1966); Verhalen and Murray (1967); Lee, Miller and Rawlings (1967); Al-Rawi and Kohel (1969); Meredith, Bridge and Chism (1970); Al-Rawi and Kohel (1970); Verhalen et al. (1971) Baker and Verhalen (1973, 1975) used the diallel techniques for estimating the nature of gene action.
PART A

DIALLEL ANALYSIS

Validity of assumptions

The first and foremost important aspect is to test the validity of the hypothesis. Hayman (1954a) outlined the following assumptions before proceeding with the analysis. They are (a) diploid segregation, (b) absence of reciprocal differences, (c) independent action of non-allelic genes, (d) no multiple allelism, (e) homozygous parents and (f) genes independently distributed between parents.

(a) *G. hirsutum* is an amphidiploid that segregates in a diploid manner (Kimber, 1961 and Endrizzi, 1962).

(b) Even though no reciprocal differences were detected the $F_1$ entries in the diallel table were replaced by the mean of the reciprocals for all the characters.

(c), (d) and (f) are very difficult assumptions to establish.

(e) The parental lines have been maintained by controlled self-fertilization and were assumed homozygous.

No genotype x environment interaction was detected as the experiment was conducted during one season.
Further the validity of the assumptions was tested by 't^2' test for all the characters. The non-significance of 't^2' test indicated the homogeneity of Wr-Vr values. Validity of assumptions were verified with regression values 'b' Wr/Vr and 'b' Wr'/Wr. The significant deviation of regression value 'b' Wr, Vr from zero was observed in all the characters except seed index, lint index and yield per plant.

The significant deviation from one was observed in number of bolls per plant, seed index and yield per plant. Other characters did not show any significant deviation indicating the adequancy of the simple additive dominance model and fulfilment of the assumptions.

Similarly the significant deviation of regression value 'b' Wr', Wr from zero was observed for all the characters. Significant deviation of 'b' from 0.5 was observed for bolls per plant, number of seeds per boll, boll weight, yield per plant and mean halo length. Non-significant deviation of 'b' from 0.5 was seen for the characters locules per boll, seed index, lint index and ginning per cent.

Bolls per plant, seed index and yield per plant showed partial failure of the assumptions. When partial failure of the assumptions have been demonstrated, Hayman (1954) postulates a more complex genetical systems than the simple theory describes. However, he does state that it is still possible to make estimates of the population parameters and genetic components for such a
trait, although it should be realised that such estimates are probably less reliable than they would have been had all the assumptions been fulfilled. Crumpacker and Allard (1962) opined that such partial failure of certain assumptions, where they are small is not likely to affect the genetic analysis.

**Graphical and genetical analysis**

The implications of graphical and genetic analysis, \( W_r \) and \( V_r \) statistics have been discussed by Jinks and Hayman in a series of papers since 1953, and more recently by Mather and Jinks (1971, 1977). The essential points to be gained from the graphical analysis are:

(a) the \( W_r \) intercept is an indicator of the average degree of dominance in the experimental materials,

(b) the relative proportion of dominant and recessive genes in the parent from the distribution of their respective array points along the regression line and

(c) the measure of genetical diversity among the parents from the distance between array points.

Likewise the genetic analysis provides certain other information:

(a) the mean degree of dominance,

(b) the proportion of genes with positive and negative effects in the parents,

(c) the proportion of dominant and recessive genes in the parents and

(d) heritability estimates in a narrow sense.

It is well known that the above interpretation are possible and meaningful when a simple additive-dominance model of gene action is adequate to account for the behaviour of this diallel
(Mather and Jinks, 1977). In the presence of non-allelic interactions, the most useful information to be gained is about the existence of such interactions, since the graph itself being sensitive to interactions, often permits their detection (Jana, 1975).

As Jinks (1954) and Hayman (1954) have shown if there are only two alleles at each locus, non-additive genetic variance is in the form of dominance only and the genes at the loci involved are distributed independently among the parents, then the regression of Wr on Vr has a unit slope. However, it becomes difficult to discriminate this possible phenomenon affecting rectilinearity of the Wr/Vr relation.

In this context, the views presented by Gilbert (1958), Arunachalam (1976) and Baker (1978) are worth discussing. Evaluation of the consequences of failure of independent distribution of genes in parents have usually been restricted to assessing the effects on the Vr-Wr graphical analysis of Hayman (1954). Hayman himself pointed out that the estimate of the average degree of dominance may be increased or decreased by lack of independence of genes in the parents. Serious over-estimation of the degree of dominance will occur in the case where dominance at all loci is in the direction of the positive (favourable) allele and where the correlation between gene frequencies at different loci is primarily to dispersion (Baker, 1978).

Except seed index all other characters are represented graphically in Figs. 1 to 16.
Overdominance was seen for bolls per plant and yield per plant, complete dominance for lint index, and rest of the characters showed partial dominance. Array points of MCU 1 and MCU 5 for boll number, Laxmi, 108 F, Paymaster, C 1998 and Reba B 50 for seeds per boll, Acala 4-42, 108 F and Paymaster for boll weight, Acala 4-42 and Paymaster for lint index, Paymaster, Reba B 50 and Acala 4-42 for yield per plant lying near the origin showed higher dominant genes.

Correlation coefficients between Yr and Wr + Vr (Table 26) showed negative significance for boll number, boll weight, lint index, yield per plant and ginning per cent. Negative values were seen for seeds per boll, and seed index. Positive but non-significant values were observed for locules per boll and mean halo length. Negatively significant values indicated that the dominant genes were towards the improvement of the characters. The negative values provided an indication of dominance effects of genes. The positive effects suggested that the characters were under the operation of recessive genes.

Thus in the present study the most dominant parents, namely, MCU 1 (16.00) and MCU 5 (14.00) for boll number, Paymaster (6.20 g) and Acala 4-42 (5.67 g) for boll weight, Paymaster (6.47 g) and Acala 4-42 (5.87 g) for lint index, Paymaster (53.50 g) and Reba B 50 (53.60 g) for yield per plant and Paymaster (38.67) and Acala 4-42 (36.53) for ginning per cent showed positive effects for the respective characters.
Paymaster (38.00) and 108 F (35.00) for seeds per boll, 108 F (10.00) and Laxmi (10.13) for seed index contained few dominant genes towards increasing the seeds per boll and optimum seed index.

Parents Reba B 50, MCU 5, Laxmi and Gujarat 67 (4.00) for locules per boll and MCU 5 (31.03) and Gujarat 67 (30.17) for mean halo length contained the dominant genes towards lowering the values of these two characters.

Significant positive additive effects (D) (Table 25) were seen operating for locules per boll, seeds per boll, boll weight, lint index, mean halo length and ginning per cent. Significant negative additive effects were found operating for bolls per plant and seed index.

Significant positive dominance component (H₁) (Table 25) was operating for lint index and yield per plant. Significant negative dominance component was operating for seeds per boll, seed index and mean halo length.

Significant positive \( H_2 \) (dominance indicating the proportion of positive and negative alleles) (Table 25) for yield per plant indicated that more number of positive alleles were present. Significant negative \( H_2 \) for seeds per boll indicated more number of negative alleles present in the parent material. Positive and significant \( F_\), (frequency of dominant to recessive alleles) (Table 25) for seeds per boll indicated that dominant alleles were
higher. Significantly negative $F$ for bolls per plant, boll weight, and seed index suggested that more number of recessive alleles were present. Frequency of dominant to recessive alleles ($F$) was negative but not significant for lint index, indicated presence of recessive genes. Similarly $F$ was positive but not significant for locules per boll, yield per plant, mean halo length and ginning per cent indicating the presence of dominant genes.

Significant positive ($h^2$) (Table 25) (dominance effects over all loci) for all the characters except locules per boll and mean halo length suggested that dominance effects over all loci were present in the parent material.

Both additive and dominance effects significantly influenced number of seeds per boll, seed index, lint index and mean halo length. Additive effects alone were significantly higher for boll number, boll weight, locules per boll and ginning per cent and dominance effects were significant for yield. Dominance effects of genes were generally not significantly different from additive effects as measured by $1/2 (D-H_q) \pm SE$. Significance of this value (Table 27) for boll number, locules per boll, seeds per boll, yield per plant, mean halo length and ginning per cent indicated that the dominance effects of genes were generally significantly different from additive effects. For boll weight, seed index, and lint index, it was not significant, suggesting that the dominance effects of genes were generally not significantly different from additive effects.
The ratio of total number of dominant to recessive genes KD/KR (Table 26) in all parents was more than one in yield per plant and ginning per cent suggesting the predominance of dominant genes for these characters.

Estimate of number of groups of genes $h^2/H_2$ (Table 26) which control the character were one for locules per boll, 4 for seeds per boll, 9 for seed index, 8 for lint index, 4 for yield and 14 for ginning per cent and minor gene effects for halo length. The average frequency of negative vs. positive alleles $H_2/4H_1$ (Table 26) for all the characters except seeds per boll showed genes with positive effects whereas, in seeds per boll, negative effects of genes were observed. The average degree of dominance at each locus $(H_1/D)^{1/2}$ (Table 26), partial dominance was seen for characters viz., bolls per plant, locules per boll, seeds per boll, boll weight, mean halo length, and ginning per cent and complete dominance for seed index and lint index and overdominance for yield per plant.

Miller and Marani (1963), White and Kohel (1964), Lee, Miller and Rawlings (1967) obtained significant additive variance for lint per cent and other characters. The present study confirms the earlier findings and provide the nature of additive effects involved in the inheritance of locules per boll, seeds per boll, boll weight and lint index.

White (1966) detected overdominance for lint yield. Verhalen et al. (1971) noted that lint yield, seed cotton yield
and lint per cent were controlled by overdominant gene action. Meredith, Bridge and Chism (1970) observed that yield and its components showed considerable dominance effects. Meredith and Bridge (1972) reported both additive and dominant effects were involved in the inheritance of lint yield and fibre length. Baker and Verhalen (1973) observed overdominance for lint yield. Similar observations were made in the present study. Overdominance governed lint yield, complete dominance was seen for seed index and lint index and partial dominance was observed for bolls per plant, locules per boll, seeds per boll, boll weight, mean halo length and ginning per cent.

**Heritability (Table 26)**

Heritability is defined as the ratio of additive or additive x additive epistatic variance or both to the total phenotypic variance (Crumpacker and Allard, 1962). This is more relevant and fixable than gross genotypic variability.

Heritability was very high for ginning per cent (77.6%), mean halo length (72.0%), locules per boll (71.9%), boll weight (53.7%) and lint index (52.0%) and medium for yield (27.2%) and lower values for boll number (14.8%) and for seed index (11.06%) and negative for seeds per boll (-3.7%).

Stith (1956) reported heritability estimated values were 45.3 to 79 per cent for lint per cent, 50.1 to 62.5 per cent for boll size and 22.2 to 70 per cent for staple length.
Simonguljam (1970) reported in all crosses in cotton, heritability for most of the characters was low whereas, for lint length and boll size it was relatively high. Baker and Verhalen (1973) reported that estimates of heritability were medium to high for all characters except yield. The present study confirms the earlier findings of Sith, Baker and Verhalen. The locules per boll, boll weight and lint index had high heritability values. Seed index and seeds per boll showed lower values.

**Heterosis**

Heterosis is expressed as per cent increase of the $F_1$ hybrids above the average of the parents.

Heterosis for yield and certain other characters had been reported in all the cultivated species of cotton. In the present study true overdominance effects were observed for bolls per plant (120.1%) and yield per plant (143.01%) which are closely correlated. Dominance effects with other interaction effects were observed for boll weight (23.06%), seed index (24.16%) and lint index (32.64%). Locules per boll (8.60%), seeds per boll (16.68%), mean halo length (17.40%) and ginning per cent (11.57%) showed lower heterosis over the mid-parental value. This was due to lower type of dominance and other interaction effects.

Heterosis has been observed for yield and other agronomic characters in cotton. Loden and Richmond (1951) summarized the early evidence of heterosis in all the cultivated species of cotton.
Heterotic expression depended on specific parents. Christidis, (1955); Fryxell, Staten and Porter (1958); Barnes and Staten (1961); White and Richmond (1963); Miller and Lee (1964). Meredith and Bridge (1972) and others have reported additional evidence of heterosis for yield and other agronomic characters in cotton. Joshi et al. (1961) observed that heterosis seems to be a composite phenomenon known to be arising due to various factors viz., true overdominance at single loci; pseudo-overdominance brought about by linkage disequilibrium, epistasis (i.e., non-allelic interaction) and even heterozygosity per se. Peter and Singh (1974) observed that heterosis is a function of sca and hence of non-additive gene action. In the present study high heterosis was observed for bolls per plant and yield per plant due to overdominance effects and all the other characters showed average heterosis.

**Combining ability**

The complete specification analysis and interpretation of this model are given by Griffing (1956). Miller and Marani (1963) suggested that selection based on parental performance can be a way to improve the general combining ability and once such useful lines are made up, non-additive components can be exploited in the hybrids among them. The gca and sca effects and variances are very effective genetic parameters of direct utility to decide the next phase of the breeding programme (Arunachalam, 1976).
Significant gca effects for all the characters (Table 11) and significant sca effects for locules per boll, boll weight, seed index, lint index, mean halo length and ginning per cent indicated that both additive and dominance effects were operating. Bolls per plant and yield per plant showed significant gca, sca and reciprocal differences, indicating the operation of additive, dominance and interaction effects. Whenever additive effects were more high x high gca effects had given correspondingly higher sca effects namely in locules per boll, seeds per boll, boll weight and lint index. When both additive and dominance effects were involved high x low and medium x low types of gca effects had given higher sca effects in mean halo length and ginning per cent. When additive, dominance and other interaction effects were operative, namely, in bolls per plant, seed index and yield per plant, medium x high, low x medium or low x high types of gca effects had given higher sca effects.

Parameters and genetic systems in individual characters

Bolls per plant (Tables 23 and 27 and Figs. 1 and 2)

The 't²' test was not significant and b = 1 was significant indicating some partial failure of the assumptions. The regression line cut the Wr axis below the point of origin indicating over-dominance effects of the parents.

In Wr', Wr graph the regression coefficient for boll number was significantly different from zero and 0.5. This confirms the operation of epistatic effects and the order of dominance was slightly changed.
The correlation coefficient of Yr and Wr + Vr were found to be significantly negative. The position of array points along the line of regression on Wr, Vr depends on the relative frequency of dominant and recessive alleles present in the common parent of each array. Order of dominance was 4, 8, 3, 9, 7, 6, 1, 10, 2, 5 and the parental order of performance was 3, 4, 6, 9, 10, 8, 1, 2, 5 and 7; thus indicating that the parents MCU 1 and MCU 5 contained maximum number of dominant genes towards increasing boll number.

Higher value of $H_1$ and significance of $h^2$ suggested that dominance play more important role than the additive effects. Average degree of dominance at each locus indicated partial dominance. Very low KD/KR enhanced the value of $h^2/H_2$ to 348.5; the groups of genes that control the character and exhibit dominance. This value may not be true. Heritability was very low (14.8%). Dominance effects of genes were generally not significantly different from additive effects as measured by $\frac{1}{2} (D - H_1) \pm SE$; was significant for bolls per plant, suggesting the importance of dominance effects for boll number.

The hybrid combinations low x medium (Reba B 50 x Albar 49) 120.06%, (Reba B 50 x MCU 5) 80.5%, medium x low (Albar 49 x Laxmi) 88.9% and low x low (Laxmi x Acala 4-42) 71.0% had maximum heterosis for boll number.

Significant gca, sca effects and reciprocal differences indicated that additive, dominance and non-allelic interactions were involved in the expression of this character. The crosses
involving parent with high positive gca effect and parent with high negative gca effect did not exhibit high sca effects. Only high x medium gca effects (MCU 1 x C 1998) or low x medium (Laxmi x C 1998) gca effects exhibited comparatively higher sca values for boll number.

Joshi et al. (1961) reported for boll number, additive and dominance and epistatic components seem to be significant with interaction between dominance effects contributing the major portion of the epistatic component. White and Richmond (1963) observed that heterosis for yield was attributed to increased number of bolls. White and Kohel (1964) observed that mean level of dominance (0.79) and a low level of correlation between (Wr + Vr) and Yr indicated that some of the genes showed dominance in the positive direction (greater number of bolls) while some acted in the negative direction. Singh et al. (1976) observed that non-additive gene action was important for boll number.

Low x medium, medium x low and low x low types showed maximum heterosis. In the present study boll number was governed by additive, dominance and interaction effects. Dominance effects were more important than the additive effects. Heritability was low.

Number of locules per boll (Tables 23 and 27; Figs. 3 and 4)

The 't^2' test was not significant and the regression 'b' coefficient did not deviate significantly from unity, thus satisfying some of the inherent assumptions. Parents 1, 5, 2 and 4 lie
near the point of origin indicating the involvement of dominant genes and $P_3$ lie at the opposite end of the regression line. Since the space between the regression line and the limiting parabola was limited, dominance effects in locules per boll were limited.

In $W_{r'}$, $W_r$ graph the regression coefficient was not significantly different from zero but not from 0.5, regression line was parallel to the mid-line and all the points clustered around the regression line, indicating the absence of dominance effects.

Order of dominance was 1, 2, 4, 5, 8, 9, 7, 6, 10, 3 and the parental performance was 8, 9, 10, 7, 3, 6, 5, 4, 2, and 1, thus, Reba B 50, MCU 5, Laxmi and MCU 1 contained dominant alleles which produced lower number of locules per boll and Paymaster, 108 F and Acala 4-42 showed high values due to presence of dominant alleles.

Additive effects alone were significant and other effects were not significant indicating absence of dominance effects and this character was mainly controlled by additive effects. $\frac{1}{2} (D-H_1)$ was significant suggesting the importance of additive effects for locules per boll. Heritability was high (71.9%).

Medium x medium (Acala 4-42 x MCU 1) 7.7% and (MCU 1 x Acala 4-42) 8.60%, medium x high (MCU 1 x 108 F) 7.2% and medium x low (Acala 4-42 x Albar 49) 7.0% had maximum heterosis.
Significant \textit{gca} and \textit{sca} effects indicated that both additive and dominance effects were important for this character. In the combining ability analysis, the significant positive \textit{gca} effects of the parents MCU 1, Acala 4-42 and Paymaster had shown high \textit{sca} effects in MCU 1 x Acala 4-42 and MCU 1 x Paymaster crosses. The negatively significant \textit{gca} effects of Gujarat 67, Laxmi, MCU 5 and Reba B 50 did not exhibit high \textit{sca} effects in their corresponding hybrids.

Singh and Gupta (1970) reported that additive and dominance genetic variances were important in the inheritance of this character and the former being more prevalent. Mohamed Ali and Chandra Mohan (1973) reported that locule number per boll had high influence on yield.

The high and significant estimate of additive effects and high heritability estimate for locules per boll signify the additive gene action which offers good scope for selection in the desired direction.

\textbf{Seed per boll} (Tables 23 and 27; Figs.5 and 6)

Non-significant deviation of 'b', \textit{Wr}, \textit{Vr} from one and non-significance of \textit{t}^2 test indicated the validity of the assumptions. The slope of the line cut the ordinate above the point of origin suggesting slight partial dominance for this character. Parents 2, 9, 10, 8 lie near the point of origin contained dominant genes for seeds per boll. Parent \textbf{P}_1 lie at the opposite end of the regression
line suggesting recessive alleles in it. All the array points except one were clustered around the regression line near the origin indicating the predominance of dominant genes.

Wr', Wr graph confirms the validity of the assumption and dominance effects of the parents.

Order of dominance was 10, 2, 9, 8, 5, 7, 4, 6, 3, 1 and the parental performance was 8, 9, 10, 3, 5, 7, 1, 2, 6, 4. The parents 108 F and C 1998 contained dominant genes towards improving seeds per boll. Parent MCU 5 contained the maximum number of recessive genes towards lowering the seeds per boll.

D, F and h² were positively significant, whereas H₁ and H₂ were negatively significant indicating the operation of both additive and dominance effects. Average degree of dominance at each locus showed partial dominance. At least four groups of genes influenced this character.

Heritability was very low and \( \frac{1}{2} (D - H₁) \) was significant.

The most dominant parents had the value ranging from 17.64 to 17.09 and that of most recessive parent had the value of 0.560 to 0.017. The completely dominant parent had the value of 55.2 and the recessive parent had the value of 24.9 seeds per boll. Only medium x medium combinations showed maximum heterosis for seeds per boll i.e., MCU 1 x 108 F (16.7%); Acala 4-42 x MCU 1 (15.3%) and MCU 1 x Acala 4-42 (14.3%).
Significance of $gca$ effects indicated the predominance of additive effects. Parent MCU 1 exhibited positive $sca$ effects in all the combinations except with Laxmi and with significant $gca$ parents it exhibited maximum $sca$ effects as in MCU 1 x Payamaster (1.139) and MCU 1 x 108 F (1.456).

Miller and Rawlings (1967) found that seeds per boll increased simultaneously as lint yield was increased by selection. Harrell and Culp (1976) observed that seeds per boll is a major yield component and as such must be taken into consideration to improve lint yields. Quisenberry and Kohel (1979) showed that number of seeds per boll showed both additive and dominance components with sufficient additive variance to support directional selection.

In the present study medium x medium types showed maximum heterosis. Significance of $gca$ effects alone indicated the predominance of additive effects. Parent MCU 1 proved to be a good general combiner for seeds per boll. Low heritability suggested, this character was difficult to be fixed even though the additive effects were predominant.

**Boll weight** (Tables 23 and 27; Figs. 7 and 8)

Non-significant deviation of 'b' $Wr$, $Vr$ from one, $t^2$ test was not significant indicated the validity of the assumptions. The slope of the line indicated partial dominance operating for this character. Parents 7, 9 and 8 lie near the point of origin
indicating the dominant genes involved in these varieties. All the points were not far away from the origin and were clustered around the regression line indicating intermediate effects.

In Wr', Wr graph, the regression coefficient was significantly different from zero and 0.5. The position of array points along the regression line had changed. The correlation coefficient of Yr and Wr + Vr were found to be negatively significant indicating that dominant alleles were in the positive direction, i.e., in the direction of higher boll weight. Order of dominance was 7, 9, 8, 5, 1, 3, 6, 4, 2, 10 and that of parental performance was 8, 5, 7, 9, 3, 6, 1, 10, 4 and 2. Thus, parents Paymaster and Acala 4-42 contained dominant genes towards the increase and the parents Laxmi and C 1998 contained the recessive genes towards the lower boll weight.

Both additive and dominance effects were operating for this character. Additive effects were higher than all indicating its importance. The groups of genes that control this character was very high and it was overestimated. Average degree of dominance at each locus indicated partial dominance. Heritability was high.

The most dominant parents had the value ranging from 0.319 to 0.315 and that most recessive parent had 0.0053 to 0.0001. The completely dominant parent had the value of 5.60 and that of recessive parent had 5.11, for boll weight.
Medium x medium, MCU 1 x Acala 4-42 (23.06); Gujarat 67x MCU 1 (21.16); Low x medium, MCU 5 x Acala 4-42 (22.16); and Laxmi x Acala 4-42 (21.51) were the high values observed for heterosis.

Significant gca and sca effects and higher gca effects indicated that additive effects were more than the dominance effects. Incidentally significant sca effects in crosses involving parents with high negative gca effect and parents with high positive gca effect was observed in crosses, Albar 49 x Acala 4-42 and 108 F x C 1998; high positive x positive gca effect in MCU 1 x Acala 4-42.

Earlier studies on the inheritance of boll weight also led to the conclusion that it was highly additive (Harland, 1939; Stith, 1956) and therefore highly heritable. Ramey and Miller (1966) observed significant dominance genetic variance for boll weight. Average degree of dominance was in the partial dominance range. Anwar Mirza (1974) reported that additive effects were more important for boll weight. Singh et al. (1976) observed additive effects for boll weight. Quisenberry and Kohel (1979) observed that boll weight showed both additive and dominance components with sufficient additive variance to support directional selection.

In the present study, medium x medium, and low x medium types gave high heterosis. Significant gca and sca effects and higher gca
effects indicated that additive effects were more than the
dominance effects confirming the earlier findings in the inheritance
of boll weight.

**Seed index (Tables 23 and 27)**

The regression coefficient 'b', Wr, Vr differed significantly
from unity, 't' test was not significant, indicating some partial
failure of the assumptions. The non-significance of 't' test
indicated the homogeneity of Wr-Vr values. The regression
coefficient 'b', Wr', Wr was not significantly different from 0.5.

The correlation coefficient of Yr and Wr + Vr indicated the
operation of dominant genes towards the higher seed index. The
order of dominance was 9, 2, 8, 3, 4, 6, 1, 7, 10, 5 and the
parental performance was 10, 5, 9, 6, 4, 2, 7, 8, 3, and 1. Thus,
the parents Paymaster and MCU 1 contained more dominant alleles
towards imparting higher seed index. Nine groups of negative
genes controlled this character. The relative frequency of
dominant to recessive alleles 'F' was highly significant with
negative value and low KD/KR suggested more recessive genes.

\[ \frac{1}{2} (D - H_1) \] was not significant indicating that additive effects
were not different from dominance effects. Heritability was low.

Low x medium, Acala 4-42 x Reba B 50 (24.2%); high x
medium MCU 5 x Gujarat 67 (23.0%) medium x medium, Acala 4-42 x
Albar 49 (19.5%); and medium x low C 1998 x Acala 4-42 (16.0%)
were the high values observed for heterosis for seed index.
Significant \textit{gca} and \textit{sca} effects indicated that both additive and dominant effects play a part in the inheritance of this character. The parents with high positive \textit{gca} effect with high negative \textit{gca} effect namely, Acala 4-42 x Paymaster and further Gujarat 67 x Laxmi gave high \textit{sca} effects. White and Kohel's studies (1964) showed that seed index had an overall measure of dominance (0.07), partial dominance and had other anomalous values for certain statistics and proportions, as a consequence seed index was eliminated from the characters in which the dominance was ascribed.

Rana and Singh (1974) observed that seed index was generally negatively correlated with all the characters. Thus, selection based on the seed index would adversely affect the improvement of other economic traits.

Quisenberry and Kohel (1979) reported that seed index showed both additive and dominance components. Overdominance effects were seen operating for this character. Low x medium, high x medium, medium x medium and medium x low types showed high heterosis. Combining ability analysis showed that both additive and dominance effects play a part. As mentioned earlier in the present study, seed index was eliminated from graphic analysis.

\textbf{Lint index} (Tables 23 and 27; Figs. 9 and 10)

In the \textit{Wr}, \textit{Vr} graph the slope of the regression line 'b' \textit{Wr}, \textit{Vr} did not differ significantly from unity 't^2' test was not significant indicating the validity of the assumptions. The slope
of the line cut the ordinate near the origin indicating complete dominance effects for lint index. Parental arrays \( P_7 \) and \( P_8 \) lie near the origin indicating the operation of dominant genes in these varieties. Parental arrays \( P_1, P_2 \) and \( P_5 \) lie towards the distal end showing the recessive genes in them. All the points scattered along the regression line indicating genetic diversity.

In \( W_r' \), \( W_r \) graph, the regression coefficient was not significantly different from 0.5, confirming the validity of the assumptions. Array points also showed similar trend along the regression line.

The correlation coefficient of \( Y_r \) and \( W_r + V_r \) were found to be negatively significant indicating that the dominant alleles were in the positive direction operating towards higher lint index. Order of dominance was 8, 7, 4, 3, 10, 9, 6, 1, 2, 5 and that of parental performance was 2, 5, 4, 3, 1, 10, 9, 6, 7, 8. Thus, Paymaster and Acala 4-42 contained most dominant genes for higher lint index. Parents Laxmi and Reba B 50 contained most recessive genes for their lower performance.

Additive effects and dominance components were positively significant indicating that both additive and dominance effects were important for this trait. At least 8 groups of dominant genes were operating for lint index. Average degree of dominance at each locus showed complete dominance. \( \frac{1}{2} (D - H_1) \) was not significant indicating that additive effects were not different from dominance effects. Heritability was 52.0 per cent.
The most dominant parents had the value ranging from 0.300 to 0.248 and that of most recessive parent had 0.045 to 0.006. The completely dominant parent had the value of 5.55 and that of recessive parent had 5.25 for lint index.

Medium x low, Acala 4-42 x Reba B 50 (32.6%), C 1998 x Reba B 50 (23.8%), medium x medium, MCU 1 x Acala 4-42 (27.9%) and C 1998 x 108 F (23.6%) were the high values observed for heterosis.

Combining ability analysis indicated that high positive x high negative effects of gca i.e., 108 F x C 1998 and Acala 4-42 x Albar 49 gave high positive sca effects. Negative x negative gca effects also gave higher positive sca effects, i.e., Gujarat 67 x MCU 1 and Gujarat 67 x MCU 5.

Marani (1963) observed that relationships between the performance for parental varieties for some yield components and the mean performance of interspecific crosses involving G.hirsutum and G.barbadense that G.hirsutum L. parent should be selected mainly for lint index. Ramey (1963) reported dominance in the expression of lint index. Al-Rawi and Kohel (1969) observed that weight of lint per seed met all the assumptions required for the diallel analysis and this character was polygenically inherited and exhibited partial dominance. Additive genetic effects predominated for lint index (Gururaja Rao et al., 1977).
Medium x low, medium x medium types showed high heterosis. Due to genetic diversity of the parental material in the present study both additive and dominance effects were seen operating for lint index.

Yield per plant (Tables 23 and 27; Figs. 11 and 12)

In the Wr, Vr graph, the slope of the regression line differed significantly from one. The \( t^2 \) test was not significant. In Wr', Wr graph the slope was also significantly different from 0.5, indicating some partial failure of the assumptions (the presence of epistasis). The regression line cut the Wr axis below the origin showing overdominance. Parental arrays 8, 5, 7 which were in the 4th quadrant have shifted their position to second quadrant in Wr', Wr graph indicating the overdominance effects of these parents. The correlation coefficient of Yr and Wr + Vr were found to be significantly negative suggesting that most of the dominant genes had positive effects towards higher yield. Order of dominance was 8, 5, 9, 10, 6, 4, 3, 7, 1, 2, and the parental performance was 2, 1, 7, 6, 10, 4, 9, 3, 8, 5. Thus, parents Paymaster and Reba B 50 contained more dominant genes.

Dominance effects of \( H_1 \), \( H_2 \) and \( h^2 \) were positively significant indicating the operation of dominance effects more than the additive effects. KD/KR was 1.23 indicating the predominance of dominant genes. Additive effects were positive but not significant, indicating that some additive effects were also operating.
Overdominance effects were seen operating for yield and four major groups of genes control this character. \( \frac{1}{2} (D - H_1) \) was significant. Heritability was 27.2 per cent.

High x medium, MCU 1 x Acala 4-42 (143.0%), low x medium, Laxmi x Acala 4-42 (128.6%), medium x low, Albar 49 x Laxmi (118.6%), Acala 4-42 x Laxmi (97.9%) had shown high heterosis for yield.

Since gca, sca effects and reciprocal differences were significant, additive, dominance and other interaction effects governed this polygenically inherited character. Negative and positive gca effects of Laxmi x Acala 4-42, MCU 5 x Reba B 50 and Gujarat 67 x Paymaster, positive x positive, MCU 1 x Acala 4-42 and negative x negative, Laxmi x C 1998, gca effects had given higher sca effects in respective combinations.

Marani (1961) in *G. barbadense* observed that the yield showed distinct overdominance. Miller and Marani (1963) reported an appreciable amount of additive genetic variance for all the traits they studied. There were indications in the F₂ of epistasis for lint yield. White and Kohel (1964) in a diallel analysis of 5 widely diverse parents and their F₁s detected significant additive variation for lint yield. The degree of dominance for lint yield was in the partial dominance range (0.91) and most of the dominant genes had positive effects (towards higher yield effects). White (1966) in the same diallel but including F₂s as well as parents and F₁s obtained an estimate of 1.32 for degree of
dominance for yield which indicated overdominance, Lee, Miller and Rawlings (1967) detected both additive and non-additive gene action. Al-Rawi and Kohel (1969-70) reported multiple allelism and possibly correlated gene distribution for yield. Verhalen et al. (1971) observed that lint yield was controlled by overdominance gene action. Meredith, Bridge and Chism (1970) identified significant epistasis for lint yield. Pathak and Singh (1970) reported from studies of parents, F$_1$, F$_2$ and back-cross populations that in the short branch strain PRS 72 and normal branch type that dominance variance and dominant gene effects were higher than additive variance, and additive gene effects for yield and boll number, while additive gene effects were more important for other than yield components. Tabrah (1970) investigated back-cross populations of Acala 44 x OK 86 showed that most of the traits were influenced to a large extent by additive effects than by dominance effects.

Dominant gene action in addition to additive genes has been reported for yield in upland cotton by several workers. Turner (1953), Muramato (1958), Miller and Marani (1963), Miller and Lee (1964), White and Richmond (1963), Hawkins, Peacock and Ballard (1965) and White (1966) through diallel and top cross studies. Meredith and Bridge (1972) reported both additive and dominance effects were involved for lint yield. Baker and Verhalen (1973) identified overdominance for lint yield.
In the present study, dominance effects were more than additive effects confirming earlier findings. Average degree of dominance at each locus showed overdominance. Combining ability analysis showed additive, dominance and other interaction effects governed this character.

**Mean halo length (mm)** (Tables 23 and 27; Figs. 13 and 14)

The regression coefficient in Wr, Vr graph did not deviate significantly from unity, 't' test was not significant, thus satisfying some of the inherent assumptions. In the Wr', Wr graph the slope was significantly different from 0.5. In Wr, Vr graph the regression line lie close to the limiting parabola and close to unit regression line. The array points were far away from the origin, indicated both additive and dominance effects were important for this character. Similar trend was seen in Wr', Wr graph also.

The correlation coefficient of Yr and Wr + Vr was not significant indicating that operation of dominant genes was in the negative direction towards lowering the length. Parents Laxmi and Reba B 50 contained intermediate effects of dominant genes for length.

Additive effects (D) were positively significant and dominance components ($H_1$ and $H_2$) were negatively significant. Thus, for mean halo length additive effects governed more than the dominance effects. Heritability was very high 72.0 per cent. Partial dominance was seen operating for this character. $\frac{1}{2} (D - H_1)$
was significant indicating that additive effects were different from dominance effects.

The most dominant parents had the value of 8.34 to 6.38 and the most recessive parents had the values 2.55 to 0.60. The completely dominant parent had the value of 35.19 mm and completely recessive parent had the value of 22.1 mm.

Low x medium, 108 F x Reba B 50 (17.4%), low x high C 1998 x MCU 5 (9.1%) and low x low, Paymaster x 108 F (9.1%) and C 1998 x 108 F (8.5%) were the high heterosis values obtained for mean halo length.

Significant gca and sca effects indicated that mean halo length was mainly governed by additive and dominance effects. gca effects of positive x positive (Gujarat 67 x MCU 5), positive x negative (Gujarat 67 x C 1998) and negative x negative (Laxmi x Paymaster) and (Paymaster x 108 F) had given high positive sca effects in the respective combinations.

Ware, Jinks and Harrell (1943) reported that long lint length was partially dominant over short. Their data have been analysed by Kadapa (1969) who noticed that additive (d), dominance (h) genes effects were of equal magnitude in their material and dominance x dominance type of gene interaction effects were of higher magnitude than the two types of gene interactions. Ramey (1960) studied the cross between short linted variety and relatively long linted variety and found that both allelic (dominance effects)
and non-allelic interactions (epistatic effects) were responsible for the development of lint length. Verhalen and Murray (1967, 1969) observed that long fibres were partially dominant over short fibre. Miller and Rawlings (1967) from their studies on correlated response in cotton found that dominance effects were either lacking or were of little importance while additive genetic effects were predominant. Marani (1968) detected from the intra-hirsutum and intra-barbadense crosses, a small effect of dominance for fibre length with additive effects being larger with minor epistatic interactions.

In the present study, low x medium, low x high and low x low types showed high heterosis. Average degree of dominance at each locus showed partial dominance. Genetic and combining ability analysis showed that mean halo length was mainly governed by additive effects.

Ginning per cent (Tables 23 and 27; Figs. 15 and 16)

The regression coefficient in Wr, Vr graph did not deviate significantly from unity, 't²' test was not significant. In Wr', Wr graph the slope of the line did not differ significantly from 0.5, thus, confirming the validity of the assumptions. The regression line cut the ordinate above its origin indicating partial dominance. Space between the regression line and the limiting parabola was very close and the array points, clustered around the regression line, indicating little dominance in the parental arrays. The
correlation coefficient of Yr and Wr + Vr were negatively significant indicating that operation of dominant genes towards higher ginning per cent. The Wr', Wr graph confirms both the validity of the assumptions as well as the array points clustering around the regression line away from the origin, indicating little dominance.

The order of dominance was 4, 8, 7, 9, 3, 10, 1, 5, 6, 2 and that of parental performance was 2, 1, 4, 5, 3, 6, 7, 9, 10, 8. Thus, parents Paymaster and Acala 4-42 contained dominant genes for their higher performance. Parent Laxmi contained most recessive genes for low performance.

Significant positive D indicated that the character was mainly governed by additive effects. \( h^2 \) was significant but \( H_1 \) and \( H_2 \) were not significant, suggesting considerable amount of cancelling of dominant gene effects in the parental material. Two dominant genes for every one recessive gene was suggested by KD/KR value (1.578). \( \frac{1}{2} (D - H_1) \) was significant indicating higher additive effects. Heritability was very high 77%.

The most dominant parents had the value of 7.50 to 6.26 and the most recessive parent had the value of 1.50 to 2.5. The completely dominant parent had the value of 40.39, while that of recessive 30.98 for ginning per cent.

Medium x low, Reba B 50 x Laxmi (12.02%), low x medium, Laxmi x Reba B 50 (11.6%), high x low Paymaster x Laxmi (9.4%) were the high values observed for heterosis.
Significant gca and sca effects indicated that both additive and dominance effects were important for ginning per cent. Negative x negative, gca effects of Laxmi x Reba B 50 and negative x positive effects of gca for MCU 1 x Acala 4-42, Laxmi x Paymaster and MCU 1 x C 1998 had given higher positive sca effects.

In a cross between Acala and Hopi, Stith (1956) demonstrated partial dominance for higher lint per cent. Limaye (1957) found that low lint per cent was partially dominant. Verhalen et al. (1971) reported the fulfilment of the diallel assumptions for lint per cent. Pathak and Kumar (1975) observed that mainly additive gene action was found for ginning per cent. Quisenberry et al. (1975) observed that lint percentage is a function of seed index and lint index and will increase if either lint index increases or seed index decreases. Vallejo et al. (1976) showed that additive genetic variance was only important for lint per cent.

In the present study, medium x low, low x medium, and high x low showed maximum heterosis. Additive effects alone governed this character. Combining ability analysis indicated both additive and dominance effects were important. High heritability (77.6%) with high additive variance suggested that this character is fixable.
PART B

LINE x TESTER ANALYSIS

In formulating a programme of recombination or heterosis breeding for the genetic improvement of yield and other traits, the chief problem, is that of selecting appropriate parental lines. Selection of parents for hybridization is based on the general principle that the parents themselves should have the desirable characteristics in high order of expression (Gilbert, 1958). It is also important to estimate the relative potential of the different genotypes to transmit the desired traits in a specific cross combination. Knowledge on the nature of inheritance of the traits under study is also highly desirable.

The present study was taken up to evaluate three non-cultivated races of *G. hirsutum* like *palmeri* with high boll production and lacinated leaves, *morrilli* with good plant type and *richmondii* with boll weight, peduncle length and other desirable characters for ascertaining their genetic potential and understanding the nature of gene action involved, so as to utilize them in hybridization programme, for exploitation of heterosis as well as for subsequent selection for crop improvement.

All the three races were photosensitive and had a number of useful characters, resistance to disease and insects (Kappleman *et al.*, 1979). Earlier studies by Haley and Stephen (1975); Schuster (1976), Wilson and Wilson (1975, 1976, 1978)
and Wilson and George (1979, 1980) had shown that there were no major yield depressing genes in the crosses with these lines and the fibre properties of these advanced lines compared well with that of commercial cultivars (Kappleman et al., 1979).

Non-significant effects of lines, testers and lines x testers for plant height, number of monopodia and number of sympodia (Table 32), and the significance of parents vs. crosses indicated that all the crosses behaved alike and the nature of inheritance of these characters approached the mid-parental value and the combinations behaved like lines with certain non-significant type of modifications. In the case of mean maturity date (Table 32), the significant effects of testers and parents vs. crosses indicated that the effect of testers was more pronounced in imparting this character in the crosses.

Significance of testers in motes number and lines in ovule number and lines and testers in seeds per boll (Table 33), indicated that testers influence more towards motes, and lines towards ovules and both towards the inheritance of number of seeds per boll.

Significance of lines and testers for bolls per plant, boll weight, seed index, lint index, yield per plant and ginning per cent (Table 34), indicated that lines and testers contribute towards the differences.
Analysis indicated that the lines, testers and lines x testers for 2.5% span length and uniformity ratio (Table 35) indicated that the characters were governed by additive, dominance and interaction effects.

The combining ability analysis showed that the plant height, number of monopodia, number of sympodia and mean maturity date (Tables 36 and 40) were governed mainly by the dominance and interaction effects with little additivity. Low additive and higher negative dominance effects for motes and seeds per boll were observed. High positive dominance effects were seen for ovule number (Table 40).

Additive and dominance effects played an important role for boll number. Additive, dominance and interaction effects were noticed for yield. Higher dominance effects were observed for ginning per cent and seed index. Non-allelic interaction for lint index and higher additive effects and negative dominance effects for boll weight were operating towards the inheritance of these characters (Table 40).

For 2.5% span length, lower additive and higher dominance effects and for uniformity ratio, dominant effects of lines and other interaction effects were operating (Table 40).

**Heterosis and combining ability**

Positive heterosis over the mid-parent and better parental values (Figs. 17 to 20), for these characters viz., plant height,
number of monopodia and number of sympodia showed that these three characters could be improved by heterosis breeding. In the case of mean maturity date, heterosis was positive over the mid-parental value i.e., late duration and in all the combinations it was negative over the better parent. This indicated that in certain crosses mean maturity date could be brought down considerably.

**Plant height (Tables 36 and 40)**

Combining ability studies indicated that for plant height, *richmondii* showed positive gca effect. In the four cross combinations it showed negative sca effects with positive gca effect of lines. *Palmeri* and *morrilli* which showed negative gca effects for plant height showed negative sca effects in the respective combinations.

Negative x negative gca effects of C 1998 x *Palmeri*, SRT 1 x *morrilli* and C 1998 x *richmondii* showed correspondingly high negative sca effects towards lowering the height to 109.7, 110.0, 113.0 respectively. This was confirmed by the higher negative dominance with little additivity effects. Contribution of lines x testers was maximum thereby suggesting the interaction effects were operating for this character.

**Number of monopodia (Tables 36 and 40)**

Positive x positive gca effects of Reba B 50 x *palmeri*, and positive x negative gca effects of Acala 4-42 x *morrilli*
and C 1998 x morrilli had given higher negative sca effects. Negative x positive gca effects of Bikaneri Nerma x palmeri had given higher negative sca effects towards lowering the number of monopodia. Here the tester effects were more pronounced in the cross combinations. Dominance effect and the contribution of lines x testers was maximum, thereby suggesting that dominance and interaction effects were more in the inheritance of this character.

Number of sympodia (Tables 36 and 40)

Negative x positive gca effects of ROIL 3 x morrilli, C 1998 x morrilli and positive x negative gca effects of Albar 49 x richmondii had given higher positive sca effects towards increasing the number of sympodia. Mean performance of the testers showed that though the tester parent palmeri had higher number of sympodial branches, it was not fully exhibited in the cross combinations. Dominance effects were more than the additive effects. Contribution of lines x testers was maximum indicating that the interaction effects were important for this character. Covariance of Half Sibs of testers and contribution of lines suggested that the dominance effects were operating in the inheritance of this character.

Mean maturity date (Tables 36 and 40)

gca effects of negative x negative of crosses i.e., MCU 5 x palmeri, MCU 7 x palmeri, Paymaster x morrilli and C 1998 x morrilli
had given higher negative $sca$ effects towards lowering the number of mean maturity days. Tester parent morrilli was negatively significant and palmeri with negative values contributed towards reducing the number of days for maturity. The dominance effect was more than the additive effects, and the contribution of lines x testers was also maximum. It was evident that lateness was dominant to earliness due to the contribution of non-cultivated perennial races involved in the crosses.

Mean maturity date had the highest heritability and was considered the most reliable one for use in genetic studies (Ray and Richmond, 1966). Thomson (1971) observed that variation due to $gca$ predominated height. Singh et al. (1971) observed that substantial non-additive gene action was noted for number of sympodia. Baker and Verhalen (1975) identified dominance effects were important for earliness.

Anwar Mirza (1974) reported that the additive effects were more important for plant height. In diploid cotton ($G. arboreum$ L.) Waldia et al. (1980) reported predominantly non-additive type of gene action for plant height.

Combining ability analysis showed that plant height, number of monopodia, number of sympodia and mean maturity date were influenced by the contribution of non-cultivated perennial races involved in the crosses. Thus, the morphological characters i.e., plant height, number of monopodia and number of sympodia and mean
maturity date were governed by dominance and interaction effects with little additivity. Through heterosis breeding and recurrent back-cross methods, these characters could be kept at the desired levels.

Heterosis over the mid-parent and over the better parent values are represented graphically for number of ovules, number of motes and seeds per boll from Figs. 21 to 23.

F₁ combinations, MCU 5 x richmondii (15.8%) and SRT 1 x palmeri (6.8%), were highly heterotic over the mid-parent for ovules per boll. Heterosis over the mid-parent was maximum for the following combinations viz., Albar 49 x richmondii (47.8%) and Reba B 50 x palmeri (29.4%) for motes per cent. For seeds per boll, the hybrids Albar 49 x morrilli (8.4%) and Bikaneri Nerma x morrilli (7.9%) showed high values over the mid-parent.

Number of ovules (Tables 37 and 40)

All the commercial cultivars (lines) contained maximum number of ovules and the testers contained fewer number than the cultivars. Thus, in this study, lines have contributed towards increasing the ovules in a number of combinations.

Positive x negative gca effects of C 1998 x richmondii, and Reba B 50 x richmondii had given higher gca effects. Negative x positive gca effects of ROIL 3 x morrilli and negative x negative gca effects of MCU 5 x richmondii had given
higher **sca** effects, towards increasing the number of ovules.

Combining ability analysis showed that the dominance effects were higher than the additive effects and covariances of Half Sibs of lines was higher and the contribution of lines was maximum, indicating that this character was governed by dominance effects of lines.

**Number of motes** (Tables 37 and 40)

There was a wide variation in the heterotic effects of motes and due to higher mote content in tester parents. **Palmeri** contributed higher motes percentage in the combinations. On the average all the combinations showed lower mean per cent motes to their corresponding lines. Higher negative heterosis also indicated that motes per cent could be reduced. **gca** effects of positive x negative of Albar 49 x palmeri, Albar 49 x morrilli and positive x positive **gca** effects of 108 F x richmondii had given higher negative **sca** effects. Combining ability analysis indicated that dominance effects were negative for motes and additive effects were very low. Covariances of Half Sibs of testers was more than lines and the contribution of lines x testers was higher, indicating that the interaction effects were more for this character.

**Seeds per boll** (Tables 37 and 40)

Since both the lines and testers equally contributed towards increasing the number of seeds per boll, due to lower
seeds per boll in testers, heterosis was highly negative, and positive effects were seen over the mid-parental values in combinations involving tester parent morrilli. \textit{gca} effects of positive x positive Reba B 50 x richmondii, negative x positive, \textit{gca} effects of Bikaneri Nerma x richmondii, MCU 5 x richmondii, SRT 1 x richmondii and positive x negative \textit{gca} effects of Paymaster x palmeri had given higher positive \textit{sca} effects towards the increase of seeds per boll.

Combining ability analysis indicated that the dominance effects were negative and higher than the additive effects. The covariance of Half Sibs due to lines was higher and the contribution of lines was the highest. This indicated that though dominance was negative, improvement in this character was possible only through the lines.

Turner et al. (1977) reported that the cultivars influenced ovules per ovary and seeds per boll.

Combining ability analysis suggested that ovule number was influenced by the dominance effects of lines. Interaction effects were predominant in the influence of motes per cent. Inheritance of seeds per boll was mainly governed by the contribution of lines.

Heterosis over the mid-parent and better parent values are represented graphically in Figs. 24 to 29.
Bolls per plant (Tables 38 and 40)

Highest heterosis was observed in richmondii combinations. Cross combinations involving C 1998 x richmondii (161.9%), Albar 49 x richmondii (137.4%), ROIL 3 x richmondii (158.8%) and Acala 4-42 x richmondii (116.6%) showed maximum heterosis over the mid-parental values. Over the better parent, combinations involving ROIL 3 x richmondii (144.4%), C 1998 x richmondii (130.7%) and Albar 49 x richmondii (109.6%) had given maximum heterosis respectively. High heterosis was observed in Albar 49 x palmeri (67.7%) and Acala 4-42 x palmeri (39.0%) over the mid-parental value and over the better parent Albar 49 x palmeri (9.2%). F₁ combinations ROIL 3 x morrilli (105.9%) and Albar 49 x morrilli (72.9%) showed high heterosis over the mid-parental values and over the better parent values the same combinations showed 45.6% and 28.0% heterosis respectively for number of bolls per plant.

gca effects of positive x positive Albar 49 x palmeri, ROIL 3 x morrilli and negative x negative gca effects of C 1998 x richmondii had given higher positive sca effects. Combining ability analysis showed that this character was governed by both dominance and additive effects. Covariance of Half Sibs due to lines and testers were of the same order. Contribution of lines was more than that of testers. This character was mainly governed by the dominance effects of lines.
White and Richmond (1963) and White and Kohel (1964) observed significant dominance effects for bolls per plant. Thomson (1971) observed that variation due to $gca$ predominated for number of bolls. Lint yield in $F_1$ population was strongly genetically correlated with number of bolls.

In the present study, dominance effects of lines were seen controlling this character and confirmed the earlier findings.

**Boll weight** (Tables 38 and 40)

All the testers have equally contributed towards positive heterosis. Maximum heterosis observed over the mid-parental value was 19.5% for Bikaneri Nerma x morrilli and MCU 5 x morrilli 18.8%. Over the better parent, most of them were significantly negative due to the higher boll weight of all lines.

$gca$ effects of positive x positive, ROIL 3 x richmondii, positive x negative $gca$ effects of Acala 4-42 x palmeri, negative x positive $gca$ effects of SRT 1 x richmondii and negative x negative $gca$ effects of MCU 7 x palmeri had given high positive $sca$ effects. Combining ability analysis indicated that the dominance effects were negative and higher than additive effects. Covariance of Half Sibs due to lines was higher and contribution of lines was highest, indicating that the dominance effects of lines were important for the inheritance of boll weight.
Earlier studies on the inheritance of boll weight, in the intra-hirsutum hybrids led to the conclusion that it was highly additive (Harland, 1939, Stith, 1956) and therefore highly heritable. Miller and Marani (1963) observed that the magnitude of the average heterotic effects was medium for boll weight. Kumar et al. (1974) observed additive gene action for boll weight. Quisenberry and Kohel (1979) observed that boll weight showed both additive and dominance components with sufficient additive variance to support directional selection.

In the present study on interracial hybrids, dominance effects of lines were operating in the inheritance of boll weight.

**Seed index** (Tables 38 and 40)

Significant effects of heterosis of all the crosses for the mid-parental value, positive significant effects in most of the combinations over the better parental value indicated that the contribution of lines was more.

*ca* effects of positive x positive, ROIL 3 x *richmondii*, Albar 49 x *richmondii*, positive x negative *ca* effects of Acala 4-42 x *palmeri* and negative x positive, *ca* effects of C 1998 x *morrilli* had given higher positive *ca* effects. Combining ability analysis showed that the dominance effects were more than the additive effects. Covariance of Half Sibs due to lines was more than the testers and the contribution of lines was the
highest, indicating that both dominance and additive effects of lines were important in the inheritance of seed index to the desired levels.

Gupta and Singh (1970) observed that both additive and dominance were found to be highly significant for seed index. Rana and Singh (1974) reported that seed index was generally negatively correlated with all the characters. Thus, selection based on the seed index would adversely affect the improvement in economic traits. Gururaja Rao et al. (1977) observed partial dominance for seed index.

In the present study on inter-racial hybrids dominance and additive effects of lines were operating.

Lint index (Tables 38 and 40)

Because of the low value observed for the testers, the heterosis over the mid-parental values alone were positively significant, in 18 combinations. Heterosis over the better parent was significantly negative in all except one.

gca effect of positive x positive, ROIL 3 x richmondii, positive x negative, gca effects of MCU 5 x palmeri, Acala 4-42 x palmeri and 108 F x morrillii had given higher sca effects.
Combining ability analysis showed that both additive and dominance effects were low. Covariance of Half Sibs due to testers was higher, and equal contribution of lines and testers, suggested
that this character was governed by the additive effects of both lines and testers.

Marani (1963) observed that *G. hirsutum* L. parent should be selected mainly for lint index. Al-rawi and Kobel (1969) observed that weight of lint per seed showed a low but significant heterotic effect and a low level of dominance. Gupta and Singh (1970) observed that both additive and dominance variances were highly significant for lint index. Singh et al. (1971) observed that substantial non-additive gene action was noted for lint index. Vallejo et al. (1976) observed that additive genetic variance was important for lint index.

In the present study, additive effects of lines and testers influenced the lint index suggesting that this character could be fixable.

**Yield per plant** (Tables 38 and 40)

All the values over the mid-parental and over better parent except one, were significantly positive indicating that both lines and testers contributed towards the maximum value of heterosis.

**F₁** combinations Albar 49 x *palmeri* (188.8%), Acala 4-42 x *palmeri* (153.4%), Albar 49 x *morrilli* (182.0%), MCU 7 x *morrilli* (155.6%), Reba B 50 x *morrilli* (155.0%), C 1998 x *richmondii* (180.2%), and Paymaster x *richmondii* (138.9%) were the highest values observed for the mid-parental values. Albar 49 x *palmeri* (171.6%), Acala 4-42 x *palmeri* (130.8%), Albar 49 x *morrilli*(130.6%),
Reba B 50 x \textit{morrilli} (122.7\%), C 1998 x \textit{richmondii} (135.9\%) and Paymaster x \textit{richmondii} (134.7\%) were the high values observed over the better parent.

\textit{gca} effects of positive x positive, Albar 49 x \textit{palmeri}, negative x positive, \textit{gca} effects of Acala 4-42 x \textit{palmeri}, and 108 F x \textit{morrilli} and negative x negative, \textit{gca} effects of C 1998 x \textit{richmondii} and 108 F x \textit{richmondii} had given higher \textit{sca} effects. Both additive and dominance effects were higher. Covariance of Half Sibs due to lines and testers were higher, and contribution of lines was highest indicating that the yield was governed by the additive, dominance and interaction effects.

White and Richmond (1963) observed number of bolls per plant as conditioned by aerial vegetative mass and possibly boll size apparently were the components of yield contributing to heterosis. White and Kohel (1964) detected significant additive variation for lint yield. In addition dominance was operative for lint yield. White (1966) observed overdominance for lint yield. Lee, Miller and Rawlings (1967) observed both additive and non-additive gene action for lint yield. Al-rawi and Kohel (1969-70) identified partial dominance for lint yield. Meredith, Bridge and Chism (1970) observed, yield and its components had considerable dominance effects. Thomson (1971) observed that variation due to \textit{gca} predominated in all traits, particularly for lint yield. Baker and Verhalen (1973) identified overdominance for lint yield. Kumar \textit{et al.} (1974) reported that the non-additive gene action \textit{sca} was preponderant for yield and its components.
In the present studies on inter-racial hybrids, the range of heterosis was 9.2 to 188.8% for yield per plant over the mid-parental value. Yield was governed by the additive, dominance and interaction effects. Thus, heterosis breeding would help in realising the potential yield of these hybrids.

**Ginning per cent (Tables 38 and 40)**

The range of heterosis was limited, its positive effects were seen only in *richmondii* combinations and over the better parental values all of them were negative.

*gca* effects of positive x positive, C 1998 x *richmondii*, 108 F x *palmeri*, positive x negative *gca* effects of 108 F x *morrilli* and negative x negative *gca* effects of Reba B 50 x *morrilli* had given higher positive *sca* effects. Dominance effects were higher than the additive effects. Covariance of Half Sibs due to testers was more than that of lines and the contribution of testers was highest indicating that the tester parents effects were more pronounced.

Douglas and Adamson (1966) observed significant *gca* effects for lint per cent. Baker and Verhalen (1973) observed overdominance governing lint per cent. Baker and Verhalen (1975) observed that *gca/sca* ratio of variance components indicated that additive genetic variance was important for lint per cent. Gururaja Rao *et al.* (1977) reported partial dominance for ginning per cent.
In the present inter-racial hybrids dominance effects were higher than the additive effects and the tester parent effects were more pronounced in the inheritance of ginning per cent. Heterosis for the fibre characters are represented graphically from Figs. 30 to 33.

2.5% span length (Tables 39 and 40)

Significant positive heterosis over mid-parent and as well as better parental values were observed.

$gca$ effects of positive x positive, Reba B 50 x richmondii, positive x negative, Acala 4-42 x morrilli and negative x negative, MCU 7 x morrilli and C 1998 x palmeri had given high positive $sca$ effects. Dominance effects were more than the additive effects. Covariance of Half Sibs due to lines were more than the testers and the contribution of lines was highest. Hence this character was mainly inherited through the dominance effects of lines.

Miller and Marani (1963) reported an appreciable amount of additive genetic variance for fibre length. Verhalen and Murray (1967) observed that long fibre was on the average partially dominant over short fibre. Al-rawi and Kohel (1970) observed that fibre length was within the range of partial dominance. Baker and Verhalen (1973) observed complete dominance for 2.5% span length. Quisenberry (1975) observed additive genetic variance for fibre length.
In the present inter-racial hybrids also, dominance effects governed the inheritance of fibre length, confirming the earlier findings. The utilization of races compared favourably with those of the improved commercial cultivars.

**Uniformity ratio** (Tables 39 and 40)

Most of the combinations showed positive heterosis for mid-parental values and eleven combinations only showed positive heterosis over the better parental values indicating contribution of lines, testers and their interaction effects for these characters.

**gca** effects of negative x negative, Acala 4-42 x palmeri, Reba B 50 x richmondii, negative x positive, MCU 5 x morrilli and positive x negative, 108 F x palmeri had given high positive **sca** effects. Combining ability analysis indicated that the dominance effects were higher than additive effects. Covariance of Half Sibs due to lines was higher and the contribution of lines, and line x tester were also higher; indicating the dominance effects of lines and other interaction effects governing this character.


Thus, in the present inter-racial hybrids dominance effects were more than the additive effects in the inheritance of uniformity ratio.
**Micronaire (Table 39)**

In the micronaire value tester parent *richmondii* was very fine in having 3.0 as the micronaire value whereas, *palmeri* was fine (3.9) and *morrilli* was average (4.0).

In the hybrid combinations based on the effect of lines 14 combinations showed fine values from 3.0 to 3.9, 18 combinations showed average values from 4.0 to 4.9 and one combination namely, C 1998 x *morrilli* (5.20) in the 5.0 to 5.9 high category. $F_1$ combinations SRT 1 x *morrilli*, MCU 5 x *morrilli*, 108 F x *richmondii*, MCU 5 x *richmondii* had shown values of fine category.

Range of heterosis was from -11.25 (MCU 5 x *morrilli*) to 22.35 (C 1998 x *morrilli*) over the mid-parent and it was from -18.09 (MCU 7 x *palmeri*) to 15.56 (C 1998 x *morrilli*) over the better parental value.

**Bundle strength (Table 39)**

The bundle strength value indicated that 5 combinations in very good range 9.0 and above, 21 combinations as good 8.0 to 8.9 and seven combinations showed average values 7.0 to 7.9. All the tester parents belonged to the good category.

Good and average lines with good category testers have imparted better strength values viz., MCU 5 x *morrilli*, MCU 7 x *morrilli*, ROIL 3 x *morrilli*, Reba B 50 x *morrilli* and SRT 1 x *palmeri* gave the high values.
Range of heterosis was from -12.20 (Paymaster x richmondii) to 16.98 (SRT 1 x palmeri); over the mid-parent and it was from -13.25 (Paymaster x richmondii) to 8.33 (MCU 5 x morrilli) over the better parental values.

Ware and Harrell (1944) reported that fibre strength was inherited partially in a dominant fashion and controlled by numerous genes. Verhalen and Murray (1967) observed additive gene action for fibre strength and micronaire showed partial failure of the basic assumptions. Al-rawi and Kohel (1970) showed that fibre strength was within the range of partial dominance and the fibre fineness was controlled by overdominant gene action. Baker and Verhalen (1973) observed that complete dominance was seen for fibre strength and partial dominance was noticed for fibre fineness.

Both fibre strength and fineness would improve the commercial cultivars in the subsequent selection programme. Particularly the tester parent palmeri which had a strength of 8.9, imparted a strength of 9.3 in the cross combination SRT 1 x palmeri.

In the present study, an attempt has been made to understand the genetics of various quantitative characters in G. hirsutum. A representative sample of genotypes of this species was chosen and the genetic studies was confined to non-segregating generation (F1). The nature of material chosen restricted the choice of methods used for genetic analysis. The primitive
non-cultivated races of *hirsutum* with their potential perennial habit made them impossible to be included in the set of diallel. They were necessarily used as testers using early maturing lines to avoid errors due to wide differences in maturity, which in turn would affect the yield and its components.

It is well known that the corresponding interpretations are valid if a simple additive-dominance model of gene action is adequate to account for the behaviour of the diallel (Mather and Jinks, 1977). In the presence of non-allelic interactions, the most useful information to be gained is about the existence of such interactions, since the graph itself being sensitive to interactions, often permits their detection (Jana, 1975). The estimates of $D$, $H_1$, $H_2$ besides graphical analysis of the regression of $W_r$ on $V_r$ using $V_r-W_r$ limiting parabola will provide a complete genetic interpretation of results of an actual experiment. Based upon these limitations, graphic analysis provides the relative proposition of dominant and recessive genes present in the experimental materials and their genetic diversity.

In genetic analysis additive effects, the mean degree of dominance, the proportion of genes with positive and negative effects in the parents, the proportion of dominant and recessive genes in the parents and heritability estimates in a narrow sense are estimated. Combining ability analysis provides the nature of general, and specific combining ability, corresponding to the parents and the hybrids. It also gives the nature of additive and dominance effects.
Table 41. Gene action for the 8 characters estimated through diallel analysis for intra-hirsutum crosses and by line x tester analysis for inter-racial hybrids

<table>
<thead>
<tr>
<th>Characters</th>
<th>Diallel analysis</th>
<th>Line x tester analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bolls per plant</td>
<td>Additive effects were significantly negative, dominance effect was negative. Partial dominance. Abnormal value for the groups of genes that control this character. Combining ability analysis showed significant gca, sca and reciprocal effects. Additive effects were less than dominance effects. Bolls per plant was governed by additive, dominance and interaction effects.</td>
<td>gca effects of Albar 49, ROIL 3 and palmeri were positively significant. 108 F, Paymaster and richmondii were negatively significant. Dominance and additive effects were operating. Mainly governed by dominance effects of lines.</td>
</tr>
<tr>
<td>Seeds per boll</td>
<td>Partial dominance, and additive effects were positively significant and dominance effects were negatively significant. gca effects alone were significant; additive effects were higher than dominance effects. Seeds per boll was mainly governed by additive effects.</td>
<td>gca effects of paymaster was positively significant and MCU 7 and Bikaneri Nerma were negatively significant. Dominance effects were negative and higher than additive effects. Improvement in this character is possible only through the lines.</td>
</tr>
</tbody>
</table>

Contd...
Table 41 (Continued)

<table>
<thead>
<tr>
<th>Character</th>
<th>Diallel analysis</th>
<th>Line x tester analysis</th>
</tr>
</thead>
</table>
| Boll weight  | Partial dominance, additive effects were significantly positive and dominance effects were negative.  
               | *gca* and *sca* effects were significant, additive effects were higher than dominance effects.  
               | This character was mainly controlled by additive and interaction effects.                  | *gca* effects of Reba B 50 and *richmondii* were positively significant.  
               |                                                                  | MCU 7, Bikaneri Nerma and *palmeri* were negatively significant.  
               |                                                                  | Negative dominance effects were higher than additive effects.  
               |                                                                  | Dominance effects of lines are important for this character.  
               |                                                                  | *gca* effects of Albar 49 and MCU 5 were positively significant.  
               |                                                                  | MCU 7, Bikaneri Nerma and *palmeri* were negatively significant.  
               |                                                                  | Dominance effects were higher than additive effects.  
               |                                                                  | Both dominance and additive effects of lines are important to keep the seed index at the desired levels.  |
| Seed index   | Overdominance, both additive and dominance effects were negatively significant.  
               | Direction of dominance was towards lowering seed index.  
               | *gca* and *sca* effects were significant.  
               | Both additive and dominance effects were operating.                                     |                                                                                             |

Contd...
<table>
<thead>
<tr>
<th>Character</th>
<th>Diallel analysis</th>
<th>Line x tester analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lint index</td>
<td>Complete dominance, additive and dominance effects were positively significant. \textit{gca} and \textit{sca} effects were significant, additive effects were higher than dominance effects. Mainly governed by additive and dominance effects.</td>
<td>\textit{gca} effects of ROIL J and \textit{richmondii} were positively significant. MCU 7, Bikaneri Nerma and \textit{morrilli} were negatively significant. Low dominance and additive effects. Additive effects of lines and testers are operating.</td>
</tr>
<tr>
<td>Yield per plant</td>
<td>Overdominance, dominance effects were positively significant and additive effects were lower. \textit{gca}, \textit{sca} and reciprocal effects were significant. Additive, dominance and other interaction effects were operating.</td>
<td>\textit{gca} effects of Albar 49 and \textit{palmeri} were positively significant. 108 F, Paymaster and \textit{richmondii} were negatively significant. Both additive and dominance effects were higher. Additive, dominance and interaction effects are operating.</td>
</tr>
<tr>
<td>Mean halo length</td>
<td>Partial dominance; additive effects were positively significant; dominance effects were negatively significant, additive effects were higher than dominance effects.</td>
<td>\textit{gca} effects of Albar 49, MCU 5, Acala 4-42, Reba B 50 and \textit{richmondii} were positively significant. MCU 7, 108 F, Bikaneri Nerma, C 1998 and \textit{palmeri} were negatively significant. Contd...</td>
</tr>
<tr>
<td>Character</td>
<td>Diallel analysis</td>
<td>Line x tester analysis</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------------------------------------------------------------------------------</td>
<td>----------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Ginning per cent</td>
<td>$gca$ and $sca$ effects were significant. Additive effects were higher than</td>
<td>Dominance effects were more than the additive. Mainly inherited</td>
</tr>
<tr>
<td></td>
<td>dominance effects. Mainly governed by</td>
<td>through dominance effects of lines.</td>
</tr>
<tr>
<td></td>
<td>additive effects with lower dominance effects.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Partial dominance. Additive effects were positively significant and higher</td>
<td>ROIL 3, C 1998 and <em>richmondii</em> were positively significant. MCU 5 and</td>
</tr>
<tr>
<td></td>
<td>than dominance effects. $gca$ and $sca$ effects were significant, additive</td>
<td><em>morrilli</em> were negatively significant for $gca$ effects. Dominance effects were</td>
</tr>
<tr>
<td></td>
<td>effects were higher than dominance effects. Mainly governed by</td>
<td>higher than additive effects. Tester parent effects were</td>
</tr>
<tr>
<td></td>
<td>additive effects and lower types of dominance effects.</td>
<td>more pronounced.</td>
</tr>
</tbody>
</table>
In the line x tester analysis general and specific combining ability of the corresponding lines and testers, the nature of additive and dominance effects are estimated. Further, the contribution of lines, testers and lines x testers are obtained.

It is inferred from the diallel analysis that MCU 1, Albar 49 and MCU 5 for boll number, MCU 1, Acala 4-42, Paymaster for locules per boll, Paymaster, MCU 1, 108 F and Acala 4-42 for seeds per boll, Acala 4-42, Paymaster, 108 F and MCU 1 for boll weight, Paymaster, Laxmi and 108 F for seed index, Acala 4-42, Paymaster and 108 F for lint index, MCU 1, Albar 49 and Paymaster for seed cotton yield per plant, MCU 5, Gujarat 67, Acala 4-42 and Albar 49 for mean halo length, Paymaster, Acala 4-42 and C 1998 for ginning per cent have greater potential for the inheritance of respective characters.

Line x tester analysis shows that C 1998 and SRT 1, with palmeri and morrilli for plant height, Bikaneri Nerma, Reba B 50 with palmeri and richmondii for number of monopodia, MCU 5, Acala 4-42 and Reba B 50 with palmeri and morrilli for number of sympodia and MCU 5, MCU 7, Bikaneri Nerma and C 1998 with palmeri and morrilli for mean maturity date are identified as useful combinations in keeping these characters at the desired levels.

Paymaster and 108 F with palmeri and morrilli for number of ovules, Bikaneri Nerma and Acala 4-42 with palmeri and morrilli for motes content, Paymaster, Reba B 50 and 108 F with morrilli
and *richmondii* for seeds per boll are considered as useful in increasing the ovules and seeds per boll and in decreasing the motes content.

Albar 49, ROIL 3, MCU 5, Acala 4-42 with *palmeri* for boll number, ROIL 3, Reba B 50, 108 F with *richmondii* for boll weight, Paymaster, SRT 1, 108 F with *richmondii* for seed index, ROIL 3, 108 F, Albar 49, Reba B 50 with *richmondii* for lint index are considered as promising ones in the inheritance of these characters towards the desired direction.

Albar 49, MCU 5, SRT 1, Reba B 50 with palmeri for yield per plant; 108 F and ROIL 3 with *palmeri*, C 1998 and Paymaster with *richmondii* for ginning per cent are considered promising for these two characters.

MCU 5, Albar 49 with *palmeri*, Albar 49, Reba B 50 with *richmondii* for 2.5% span length, 108 F, C 1998, Paymaster with *morrilli* and *richmondii* for uniformity ratio are considered as promising for these two characters.

Studies on the intra and inter-racial hybrids of *G. hirsutum*

1. Plant height

The increased plant height in *F₁* is a desirable trait to realise high seed cotton yield. Marani (1961, 1968) felt that heterosis involved dominance nature of gene action for plant height in intra-*hirsutum* crosses. Galal *et al.* (1966) reported,
that heterosis was found for plant height, earliness and other vegetative characters.

In the present study, plant height in inter-racial hybrids was mainly governed by higher negative dominance effects. C 1998 and SRT 1 in palmeri and morrilli crosses kept the plant height at the desired levels.

2. Number of sympodia

Singh, Murty and Butany (1971), reported that the nature of gene action was predominantly non-additive for number of sympodia. In inter-racial crosses similar conditions existed. Thus, ROIL 3 and C 1998 with negative gca effects and Reba B 50 and Albar 49 with positive gca effects could be utilised with positive effects of morrilli and palmeri, and negative effects of richmondii respectively for the inheritance of this character.

3. Mean maturity date

Christidis and Harrison (1955), Ray and Richmond (1966) reported that mean maturity date had the highest heritability and was considered the most reliable one for use in genetic studies of both commercial cultivars and as well as non-cultivated races. MCU 5, MCU 7, Paymaster and C 1998 along with palmeri and morrilli could be used in obtaining desired earliness. The commercial cultivars were early to late duration varieties. The non-cultivated races were perennials. Due to high negative gca
effects of testers it is possible to reduce the duration through the recurrent back-cross method.

4. Bolls per plant

In commercial cultivars the level of bolling potential had already reached a saturating point and this was indicated by negative additive effects. Proportion of dominant to recessive alleles (F) was negative and dominance component $H_1$ was greater than $H_2$, bolls per plant could be mainly improved through the non-additive effects. In the inter-racial crosses both additive and dominance effects were operating. Covariance of Half Sibs due to lines and testers were of the same order and contribution of lines was greater than testers.

The positive additive effects of testers, which were fixable along with the dominance effects of lines could be useful in improving this character. This had been confirmed by high heterosis observed in the crosses belonging to richmondii and palmeri. Among the lines Albar 49, ROIL 3 and C 1998 had shown promising results. Further, MCU 1, MCU 5, Laxmi and Reba B 50 had shown high positive effects in the inheritance of this character.

5. Seeds per boll

Due to higher seeds per boll in intra-hirsutum crosses, there was a predominance of negative effects towards lowering
number of seeds per boll. In the inter-racial hybrids, though the tester parents contained lower seeds per boll, similar negative effects existed. But due to high significant additive effects in diallel crosses and low significant additive effects in the line x tester analysis, indicated effective nature of additive gene action in intra-hirsutum hybrids. This was further confirmed by high covariance of Half Sibs due to lines and high contribution of lines in the line x tester analysis.

Parents Reba B 50, Paymaster and MCU 5 varieties which had shown dominance effects in intra-hirsutum hybrids, had given positive $sca$ effects in the line x tester analysis with palmeri and richmondii.

6. Boll weight

The commercial cultivars used in the diallel had more boll weight than the testers used in the line x tester analysis. In intra-hirsutum crosses additive component D was positively significant. In the line x tester analysis additive effects were less than dominance effects and were in the negative direction, suggesting that this character was mainly governed by the dominance effects in the inter-racial crosses.

Increase in boll weight was possible only through the additive effects of ROIL 3, Acala 4-42, Paymaster, 108 F and the tester parent richmondii.
7. Seed index

Seed index was generally negatively correlated with all the characters. Thus, selection based on the seed index would adversely affect the improvement in economic traits (Rana and Singh, 1974). In intra-hirsutum crosses, genetic parameters were negatively significant and heritability was very low. In line x tester analysis positive dominance effects were more than the additive effects. The dominance effects of the testers were more important in obtaining the desired levels of seed index. Along with the three testers, Albar 49 and Acala 4-42 could be more useful in these aspects.

8. Lint index

In intra-hirsutum hybrids, both additive and dominance effects were significant and the direction of dominance was towards positive direction. In the line x tester analysis though dominance and additive effects were low, the contribution of lines and testers was of the same order, indicating that testers played an important role in the inheritance of lint index.

Among the testers richmondii contributed more than the other two testers and in the lines, ROIL 3, MCU 5, Paymaster and Acala 4-42 contributed more towards the inheritance of this character.
9. **Yield per plant**

In intra-hirsutum hybrids dominance effects were positively significant and additive effects were comparatively low, and the direction of dominance was towards the improvement of yield; in inter-racial hybrids both dominance and additive effects were higher, covariance of Half Sibs of lines and contribution of lines was also highest, indicated that commercial cultivars due to acclimatization had greater potential in the inheritance of this character.

Among the testers, **gca** effects of *palmeri* was positively significant and that of *richmondii* was negatively significant. Due to the high additive effects of testers *palmeri* and *richmondii* coupled with dominance would help in achieving the desired levels of inheritance in yield. In the lines Paymaster, Reba B 50, Acala 4-42, Albar 49 and testers *richmondii* and *palmeri* could be considered as promising ones for the hybridization programme.

10. **Ginning per cent**

In the intra-hirsutum hybrids, there were significant higher additive effects and the dominance effects were also positive. This was further confirmed by the high heritability per cent.

Additive effects contributed towards the inheritance of ginning per cent in the commercial cultivars. In inter-racial
hybrids dominance effects were higher than the additive effects. Covariance of Half Sibs due to testers as well as contribution of testers was also higher. Thus, dominance effects of testers was more important in the inter-racial hybrids. Combinations involving parental lines Acala 4-42, Paymaster, C 1998, 108 F and Reba B 50 along with tester parents richmondii and palmeri could be considered for the inheritance of ginning per cent.

11. 2.5% span length and uniformity ratio

Baker and Verhalen (1973) observed complete dominance for 2.5% span length and over-dominance for uniformity in the inheritance of several agronomic and fibre properties among selected lines of upland cotton.

In the present inter-racial hybrids dominance effects were higher than the additive effects for 2.5% span length and uniformity ratio. Thus, for 2.5% span length, lines Reba B 50 and Acala 4-42 with tester parents richmondii and morrilli would help in achieving the desired level. Parental lines Acala 4-42, MCU 5, C 1998 with morrilli and richmondii testers could be utilized for keeping the uniformity ratio at the optimum level.

Role of different races in heterosis

The exploitation of hybrid vigour in cotton has been engaging the attention of research workers for many years and the earlier results have been reviewed by Rao (1968), Meredith
and Bridge (1972). An intra-specific (inter-hirsutum) hybrid, Hybrid-4 was released in 1968 in India for commercial cultivation followed by an interspecific hybrid involving G.hirsutum and G.barbadense i.e., Varalaxmi in 1972. The two hybrids are the most successful commercial cotton hybrids under cultivation.

Genetic improvement of polygenic characters through selection becomes effective, if the characters under study are governed by additive gene system associated with high genotypic coefficient of variability and high heritability (Jhonson et al., 1955). Wilson and Wilson (1975, 1976, 1978) using non-cultivated races observed heterosis for yield ranging from 75 to 87 per cent and established the breeding potential of the races. Kappleman et al. (1979) using non-cultivated races of cotton, observed that there were no major yield depressing genes in the crosses and the advanced generations compared favourably with those of the commercial cultivars in yield and fibre traits.

In the present study wide variability was seen in both morphological and other yield components. In the cultivar crosses, heritability was very high for ginning per cent, mean halo length, locules per boll, boll weight and lint index and medium for yield and lower values for boll number and seed index and negative for seeds per boll.

The non-cultivated races have imparted wide variability and medium to high heterosis for all the characters compared to
the cultivar crosses. The races *palmeri*, *morrilli* and *richmondii* had 127, 80 and 29 bolls per plant respectively. Parental lines, Albar 49, SRT 1, Acala 4-42, MCU 5 and ROIL 3 had 38, 46, 23, 35 and 33 bolls per plant respectively. F₁ combinations, *palmeri* x Albar 49, SRT 1, Acala 4-42 and MCU 5 had 138, 108, 104 and 101 bolls per plant respectively. *Morrilli* x ROIL 3, Albar 49 and SRT 1 had given high number of bolls per plant in the corresponding crosses, 116, 102 and 90 respectively. Similarly *richmondii* with Albar 49, ROIL 3 and SRT 1 had given high number of bolls per plant in the corresponding crosses, 80, 81 and 75 respectively. However, heterosis over the mid-parent was high for boll number in *richmondii* crosses and this was due to the low value of the parent (*richmondii*). Range of heterosis over the better parent was also high (40.9 to 144 per cent) in *richmondii* crosses.

Non-cultivated races had lower boll weight, i.e., *palmeri*, *morrilli* and *richmondii*, 2.06, 2.22 and 2.67 (g) respectively. Parental lines ROIL 3, Reba B 50, Albar 49, MCU 5 had 5.65, 5.49, 4.87 and 4.87 (g) boll weight respectively. *Richmondii* x ROIL 3 and Reba B 50 had given comparatively promising boll weight of 4.56 and 4.57 (g) in the corresponding crosses. *Palmeri* x Albar 49 and MCU 5 had given good boll weight of 4.07 (g) for both. *Morrilli* x Albar 49 and MCU 5 showed similar trend. Low degree of heterosis (-3.2 to 20%) over the mid-parental values were observed for boll weight.
The seed cotton yield per plant of non-cultivated races compared favourably with that of commercial cultivars i.e., 145.0 (g) for palmeri, 104.0 (g) for morrilli and 60.0 (g) for richmondii. Parental lines Albar 49, Acala 4-42, SRT 1, Reba B 50, MCU 7, ROIL 3, C 1998 and Paymaster had given 164.0, 119.0, 177.0, 140.0, 79.0, 171.0, 95.0 and 63.0 (g) yield per plant respectively. Palmeri x Albar 49, Acala 4-42, SRT 1 and Reba B 50 had given 446.3, 334.0, 332.0 and 320.0 g respectively in the corresponding cross combinations. Morrilli x Albar 49, MCU 7, Reba B 50 and ROIL 3 had given 379.0, 234.4, 311.2 and 326.1 (g) respectively in the corresponding combinations. Richmondii x Paymaster, C 1998, SRT 1 and Albar 49 had given 152.6, 224.3, 247.3 and 271.4 (g) yield per plant respectively in the corresponding crosses.

The non-cultivated races palmeri, morrilli and richmondii had lower fibre length values of 22.8, 24.8, 25.4 mm respectively. Parental lines, Albar 49, Acala 4-42, Reba B 50, SRT 1, ROIL 3, MCU 7, Paymaster and C 1998 had given 29.3, 28.8, 28.7, 28.0, 24.6, 23.8 and 22.5 mm 2.5% span length respectively. Palmeri x Albar 49, Acala 4-42, Paymaster and C 1998 had given high 2.5% span length in the corresponding combinations 29.8, 28.7, 26.4 and 25.6 mm respectively. Morrilli x Acala 4-42, Reba B 50, ROIL 3 and MCU 7 had given high values of 30.3, 29.3, 28.2 and 28.1 mm respectively. Similarly richmondii x C 1998, Paymaster, SRT 1 and Albar 49 had given high values of 26.1, 27.0, 29.0 and 31.2 mm respectively.
Non-cultivated races palmeri, morrilli and richmondii in general showed good uniformity ratio viz., 45.7, 47.0 and 47.7 respectively. Morrilli with the lines gave good to excellent progeny. Palmeri and richmondii with 8 lines gave good to excellent progeny for uniformity ratio.

The testers palmeri (8.9), morrilli (8.4) and richmondii (8.3) had good bundle strength. Parental lines Reba B 50, Paymaster, Albar 49, Acala 4-42, ROIL 3, MCU 7, C 1998 and SRT 1 had given 8.1, 8.1, 7.9, 7.9, 7.3, 7.2, 7.1 and 7.0 (PSI lb/mg) bundle strength respectively. Palmeri crosses with SRT 1, Albar 49, Reba B 50 and Acala 4-42 had given good bundle strength viz., 9.3, 8.9, 8.5 and 7.9 (PSI lb/mg). Morrilli x Albar 49, Reba B 50, ROIL 3 and MCU 7 had given good to very good bundle strength of 8.8, 9.0, 9.0 and 9.1 (PSI lb/mg) respectively in the corresponding crosses. Richmondii x Paymaster, C 1998, Albar 49 and SRT 1 had given average bundle strength of 7.2, 7.6, 7.9 and 7.9 (PSI lb/mg) respectively.

Non-cultivated races, had shown divergent type of 'fineness' as indicated by micronaire values viz., palmeri (3.9) fine, morrilli (4.0) average and richmondii (3.0) very fine. Parental lines ROIL 3, Albar 49, Acala 4-42 and Reba B 50 showed average values of 4.8, 4.7, 4.2 and 4.0 respectively, whereas MCU 7 and SRT 1 showed fine category of 3.8 each. Palmeri x Acala 4-42 and Reba B 50 had shown fine category lint of 3.8 and 3.9 respectively.
From the data obtained in the present study, there is considerable evidence to show that the utilization of primitive races of *G.* *hirsutum* with a view to exploit heterosis will be a profitable proposition. Even though these races are potentially perennial in habit, and late in flowering and maturity due to their photosensitive nature, the hybrids involving these races are sufficiently early maturing in these experiments which were conducted at a low latitude ($11^\circ N$).

The success of intra-*hirsutum* and *hirsutum-barbadense* hybrids as commercial crops in India has brought up many problems to be solved in heterosis breeding. In general, the magnitude of heterosis in inter-*hirsutum* crosses is low and not as high as in inter-specific hybrids, the exception being Hybrid-4, which has high yield potential and inspite of its late maturity has spread to a large area in the Central and Western India. It combines high yield with good fibre characters. In contrast, almost all *hirsutum-barbadense* hybrids exhibit high degree of heterosis and combine good fibre quality. But the major drawbacks of species hybrids are the poor fibre maturity and the presence of nep in the yarn which adversely affect the fabric (Sundaram, 1977).
Data so far available and presented here indicate, that by using primitive races on one hand and using modern photo-insensitive *hirsutum* cultivars on the other, we can get highly heterotic combinations with high yield and good fibre characters without the presence of motes in the lint. The highest per plant yield of seed cotton in a hybrid involving race *palmeri* with Albar 49 is 446.3 g compared to Hybrid-4 (123.2 g) and Varalaxmi (271.8 g). Similarly, number of bolls per plant in the experimental hybrid Albar 49 x *palmeri* (138.3) compared favourably with that of Hybrid-4 (26.4) and Varalaxmi (77.7). However, in case of boll weight none of the hybrids were superior to Hybrid-4 (5.3) but Reba B 50 x *richmondii* (4.57) was slightly better than Varalaxmi (4.46). The race *palmeri* with its small bolls depressed the boll weight in the hybrids. Hybrids also compared favourably with Hybrid-4 in fibre length (2.5% span length). Combinations like MCU 5 x *palmeri* (31.2), MCU 5 x *morrilli* (31.4), MCU 5 x *richmondii* (31.8), and Albar 49 x *richmondii* (31.2) were superior to Hybrid-4 (30.2), but were inferior to Varalaxmi (33.4 mm).

Since Varalaxmi has *G. barbadense* as one of its parents, it is expected to have better fibre length. However, in case of fibre strength five $F_1$ combinations had PSI value of 9.0 and above compared to 6.8 of Hybrid-4 and 7.8 of Varalaxmi, thereby indicating the superiority of the inter-racial hybrids. Since high fibre strength is very important in high quality cotton, these hybrids definitely will be more attractive to textile industry.