DISCUSSION

India, with about two million hectares under linseed cultivation, accounts for 25 percent of the total world area, ranking first in area, fourth in production and eighth in productivity. Linseed is an important oilseed crop in our country but compared with its statistics from the world over productivity of this crop in India is surprisingly poor. Among various vital factors limited genetic manipulation and improvement in this country is an important cause of poor productivity.

The genetic make up of the existing cultivars does not respond intensive management with high fertility. Also some of the biotypes evolved from land races fell prey to different diseases and pests during the course of their cultivation over a period of time. It is the high time for plant geneticists and breeders to identify and evolve moderate to high fertility responsive ideal genotypes for enabling a possible increase in productivity. Thus efforts need to be intensified for a systemic and effective genetic amelioration of this important oil seed crop.

Grain yield is the most important agronomic parameter which a plant breeder would like to improve. Inheritance of grain yield is quite complex and this trait is reported to be controlled by a series of genes and oftenly affected by a set of modifying factors. Breeding for
grain yield is, therefore, accomplished through improving some of the yield contributing traits. This, however, is possible only if sufficient basic information on the inheritance of these traits is available for formulating a breeding programme based on sound principles of biometrics. Among various biometrical tools available to the plant scientists, dialled cross technique given by Jinks and Hayman (1953), Jinks (1954, 1955) and Hayman (1954), has been extensively applied in many self pollinated crop. This design provides useful information on the nature and magnitude of gene action for different component characters and offers useful information about the breeding value of the Parents and specific cross combinations. Considering the spectrum of genetic information offered by this procedure with a reasonable precision, diallel cross analysis was used in linseed which offers the much needed basic information.

Diallel cross technique is based on seven assumptions, namely, homozygous parent, diploid segregation, no reciprocal differences, no multiple allelism, no linkage, absence of epistasis and uncorrelated gene distribution (Hayman, 1954). In the light of the material used in the present study an attempt has also been made to evaluate the validity of the procedure, adopted.

The parental material exhibited homozygosity as the linseed is a self pollinated crop and the parents used were maintained as pure and homozygous lines for a number of
generations and were rated to be homozygous.

The validity of diploid segregation was assumed in linseed by Richharia and Kalankar (1939), Richharia and Roy (1957), Rai (1969) and Rai and Das (1982). They observed 15 bivalents at diakinesis and metaphase I and 30 diploid somatic chromosomes. Joshi et. al. (1961) Postulated that though Linum usitatissimum L. is a basic diploid, the absence of quadrivalent formation at the metaphase I stage of meiosis, taken together with the fact that tetrasomic genetic ratios have so for been not reported in the material, suggests that if at all, it is a polyploid, it must be an ancient one, which has undergone extensive differentiation and is behaving genetically like a diploid.

The absence of reciprocal differences was not tested in the present study. However, no reciprocal differences in linseed have been reported (Rai, 1973). The assumption of absence of multiple allelism has not been considered of enough importance as to the validity of other assumptions as reported by Kempthorne (1956). He also upheld that the assumption with regard to independent distribution of the genes is most difficult to establish.

In the present study 10 x 10 diallel analysis was undertaken. The base material for this study was chosen to represent a wide spectrum of variability for different quantitative traits mostly of agronomic value.
Different biometrical models, namely variance component analysis (Hayman, 1954a), combining ability (Griffing, 1956b) and heritability (Crumpacker and allard, 1962) have been used for different genetic analysis. The results have been presented in the previous chapter and these are discussed below under the following heads:-

1. To estimate components of genetic variance
2. To estimate variances of general and specific combining ability
3. To estimate general and specific combining ability effects
4. To estimate economic heterosis in $F_1$, a hybrids and inbreeding depreciation incurred in $F_2$
5. To estimate the heritability and excepted genetic gain in respect of attributes under study
6. To work out association among the characters under study at genotypic level.

1. **Estimation of components of genetic variance**: Before the estimation of different genetic parameter we calculated analysis of variances for different characters which have been summarised in table 4. The variances for treatment were partitioned into its orthogonal components namely Parents, $F_1$S, Parent Vs $F_1$S, $F_2$S and parent Vs $F_2$S.

The variances among parents were found highly significant for all the characters studied except No. of
Primary branches and No. of seeds per capsule.

The results obviously suggest a significant spectrum of variability in the base material as well as in $F_1$ hybrids significant differences were observed among parent Vs $F_1$S for all the characters except No. of seeds per capsule while parent Vs $F_2$S exhibited significant differences for all the characters except days to flower, Plant height, No. of Primary branches and No. of seeds per capsule. The study indicated considerable heterosis for these characters and indicating considerable in beeding depression.

The estimated values of all the additive components of variation ($\hat{\theta}$, $\hat{H}_1$, $\hat{H}_2$, $\hat{F}$, $\hat{h}^2$ and $\hat{E}$) alongwith their standard error and presented in table 5.

The estimates of additive component ($\hat{D}$) were found highly significant for Days to flower, Days to maturity, Days for reproductive Period, Plant height, No. of secondary branches, No. of capsules per plant, oil content, fibre field per plant, Harvest index and grain yield per plant in both the generations.

The estimated values of dominance components ($\hat{H}_1$) were found highly significant for days to flower, Days to maturity, Days for reproductive Period, plant height, No. of secondary branches, No. of capsules per plant, Harvest index and grain yield per plant in both the generations.
The estimated values of dominance ($\hat{h}_2$) were recorded significant for Days to flower, Days to maturity, Days for reproductive Period, Plant height, No. of secondary branches, No. of Capsules per Plant, 1000-seeds weight, oil content, fibre yield per Plant, Harvest Index and grain yield per Plant in both the generations.

The estimates of $\hat{h}_1$ were found higher than that of ($\hat{h}_2$) for days to flower, days to maturity, Days for reproductive period, Plant height, No. of primary branches, No. of secondary branches, No. of Capsules per Plant, No. of Seeds per Capsule, 1000 - Seed weight, oil content, fibre yield per plant, harvest index and grain yield per Plant in both the generations.

The magnitude of $\hat{h}_1$ and $\hat{h}_2$ was higher than $\hat{d}$ for Days to flower, Days to maturity, Days for reproductive Period, Plant height, No. of secondary branches, No. of capsules per Plant, No. of primary branches, No. of seed per Capsule, 1000 seeds weight, fibre yield per plant, Harvest Index and grain yield per plant in both the generations. This indicated that these characters are largely governed by dominant gene action. Therefore, it would be difficult to improve these characters through selection breeding.

The genetic component, $\hat{h}^2$ was found significant for days to flower, Days to maturity, Days for reproductive
period, No. of secondary branches, No. of capsule per plant, 1000-seed weight, oil content, fibre yield per plant, Harvest Index and grain yield per plant in both the generations. The plant height were also found significant in $F_1$ generation. This suggests the presence of dominant gene.

Genetic component, $\hat{F}$ was found positive for Days to flower, Days to maturity, Plant height, No. of Primary branches, No. of secondary branches, oil content, fibre yield per plant, Harvest index and grain yield per plant in both the generations, and Days for reproductive period, No. of capsules per plant, No. of seeds per capsules, 1000-seeds weight in $F_2$ generation. Contrary to this negative values of $\hat{F}$ for Days for reproductive period, No. of capsules per plant, No. of seeds per capsule and 1000-seeds weight in $F_1$ generation. This indicated the preponderance of dominant alleles in the former and recessive alleles in the latter. The genetic component $\hat{F}$ was found positively significant for Days to maturity, Plant height, No. of secondary branches, oil content and Harvest index in both the generations, and Days to Flower, Days for reproductive period, No. of capsules per plant, fibre yield per plant and grain yield per plant in $F_2$ generation. Indicating thereby that the dominant genes are more frequently distributed than the recessive genes in the parents for these characters.
The values of mean degree of dominance \((\hat{H}_1/\hat{D})^{1/2}\), indicated overdominance for the characters; Days to flower, Days to maturity, Days for reproductive period, Plant height, No. of primary branches, No. of secondary branches, No. of capsules per plant, 1000-seeds weight, oil content, fibre yield per plant, Harvest index and grain yield per plant in both the generations and No. of seeds per capsules in \(F_2\) generation. The value of mean degree of dominance being less than one for the characters mentioned above suggested partial dominance.

The proportion of genes with positive and negative effects \((\hat{H}_2/4\hat{H}_1)\) were found less than the theoretical value (0.21) in both the generations for all characters except Days to maturity, Plant height, No. of Primary branches, No. of capsules per plant, fibre yield per plant in \(F_1\) generation. This indicated that the positive and negative alleles were distributed in considerable symmetrical manner over all the arrays. Mather and Jinks (1971) pastulated that unless \(u=v=0.5\), the ratio \((\hat{H}_1/\hat{D})^{1/2}\) in not true measure of degree of dominance, \(u=v=0.5\) may be tested by \(\hat{H}_2/4\hat{H}_1\), which should be equal to 0.21 when \(u=v=0.5\).

The ratio of \([((4\hat{D}_1) + \hat{F})/4\hat{D}_1]^{0.5} - \hat{F}\) denotes the relative value of dominant and recessive genes among the parents and determines the extent of genetic advance that can be made in a particular direction. If the alleles
present in the population are recessive in nature, the expression towards selection will be determined by dominant gene action. This ratio was more than unity for Days to maturity, Days for reproductive period, plant height, oil content in both the generations. This indicated that the dominant genes were more frequently distributed than the recessive genes.

The ratio of $\frac{\hat{h}^2}{\hat{H}_2}$ was found significantly less than unity for Days to maturity, No. of primary branches, No. of secondary branches, No. of capsules per plant, 1000-seeds weight, fibre field per plant, Harvest index, grain yield per Plant in both the generations. The value for this ratio were found significant in $F_2$ for days to flower, Days for reproductive period, Plant height, No. of seeds per capsule, oil content, suggesting thereby that one major gene group is possibly controlling inheritance of these character. This was however, not true for characters like days to flower, days for reproductive period, plant height, No. of seeds per capsule and oil content in $F_1$ for which more than one major gene group was responsible for the expression.

2. Estimation of combining ability variances:

Combining ability variances were calculated according to model 1 and method II of Griffing (1956 b). A perusal of the contents of table 6 shows that variances for combining ability mean squares for general combining ability (g.c.a.) and spe-
cific combining ability (s.c.a.) were observed highly significant for all the characters under study in both the generations. However, the g.c.a. of No. of Primary branches and s.c.a. of No. of primary branches, No. of seeds per capsule and 1000-seeds weight were found non-significant. This means that both additive and non-additive gene effects were involved in the expression of these traits and the parents, and progenies differed for their combining ability effects. Magnitude of g.c.a. variances was much higher than s.c.a. variance in both the generations for all the characters. This suggests preponderance of additive gene action operating in the expression of this trait. The g.c.a. is primarily a function of additive gene action and additive X additive interaction, whereas s.c.a. is due to non allelic interactions and over dominance. The ratio between g.c.a./s.c.a. (which is presented in table 6) was found generally more than one for all the characters.

In the present study the variances due to s.c.a. decreased from $F_1$ to $F_2$ generation for all the characters. paroda and Joshi (1970) in wheat and Zubri and Ahmad (1973) in Brassica compestris also observed lesser s.c.a. variance in $F_2$ may be attributed to the dissipation of the heterozygosity by 50 percent and breaking of coupling phase linkage any.
Murty and Anand (1966) reported major role of s.c.a. for branch number, capsule Number and seeds per five capsules and g.c.a. for flowering time and plant height. Singh and Joshi (1966) reported primarily non-additive gene action for seed yield, flowering date, capsule number per plant and seeds per capsule and additive gene action for tillar number and 200-seed weight. Anand and Murty (1969) found additive gene action predominated in most of the characters with non-additive gene action for number of fruit bearing branches and capsules per plant. Badwal and Gupta (1970a) recorded s.c.a. to be more important for seed yield and capsule number, and g.c.a. for tillar number and days to flower. Shehata and Comstock (1971) observed higher g.c.a. effects than s.c.a. for capsules per unit area, seed size, seed per capsule and oil content. Anand et al. (1972) observed additive gene action predominant for flowering time, height at branching and non-additive gene action for the plant height, tillar number and seeds per five capsules. Singh (1976) observed non-additive gene action for plant height, branch number, capsule number, seeds per capsule and yield per plant; additive gene action for days to flower and 1000-seed weight and equal importance of both the gene action for oil content.

3. **Estimation of General and Specific Combining ability effects:**

Combining ability studies have successfully been used for selecting suitable parents and also for isolating the
promising cultures from germ plasm. In the present study, when the general combining ability effects of the parents were compared in both the generations in respect of all the characters (Table 7) the parents Neelam, Mukta, T-397, Garima and LCK 8605 offered high values. Negative values were, however observed for days to flower. Since earliness is a desirable character, Neelam, Mukta, T-397, Garima and LCK 8605 for days to maturity (for earliness); Shubhra and Garima for days for reproductive period; Gaurav, LCK 8605 and Neelam for tallness; Mukta and LCK 8605 for No. of Primary branches; Laxmi-27 for No. of secondary branches; LCK 8605 for No. of capsules per plant; Shubhra for No. of seeds per capsule; LCK 8605 for 1000-seeds weight; Mukta, Shubhra and Laxmi-27 for oil content; Gaurav, Neelam and LCK 8605 for fibre yield per plant; Laxmi-27 Shubhra, Garima, T-397 and Neelam for Harvest index and LCK 8605 for grain yield per plant were found good general combiners in both ($F_1$ and $F_2$) the generations. In general, most of the parents maintained their performance in both the generations indicating that the best general combiners and also stable in their performance over generations. Some of these parents like Shubhra, Mukta, Laxmi-27, T-397, Neelam, Hira, Garima and LCK 8605 are good combiners for some or the other yield contributing characters in both the generations. However, for grain yield per plant none of these parents was the best
combining parent in $F_1$ and $F_2$. This may be attributed to mutual cancellation of the contribution by other characters towards the total sum of grain yield. Singh and Joshi (1966) also reported that the lines possessing higher g.c.a. effects for yield did not necessarily have higher g.c.a. effects for yield components. The parents, NP Hyb. 42 and EC41583 were observed good combiners for five out of 10 characters studied.

The estimates of specific combining ability effects of 45 $F_1$S and an equal number of $F_2$S were computed for all the 13 characters under study and the results are summarized in Table 8. It is interesting to observe that none of the crosses expressed consistently high s.c.a. effect for all the traits in both the generations. Out of 45 crosses 1 for days to flower, 7 for days to maturity, 4 for days for reproductive period, 9 for plant height, 20 for No. of Primary branches, 10 for No. of secondary branches, 13 for No. of capsules per plant, 13 for No. of seeds per capsule, 14 for 1000-seeds weight, 1 for oil content, 10 for fibre yield per plant 3 for harvest index and 18 for grain yield per plant were found to be consistent in exhibiting significant and desirable s.c.a. effects in both $F_1$ and $F_2$ generations. For grain yield per plant 22 crosses in $F_1$ and 20 in $F_2$ generation had significant and desirable s.c.a. effects these crosses involved all three possible
combinations between the parents of high and low g.c.a. effects i.e., high X-high, high X low and low X low. Several crosses involving parents with low x low g.c.a. effects proved better than those which involved the parents with high x high and high x low g.c.a. effects. It is not necessary that a good cross combination is always between high x high or high x low combiners. Low x low combiners may also give rise to excellent cross combinations. Similar observations were also reported by Chaudhary (1974), Singh (1976), Mishra (1977) and Dubey (1978).

The cross combinations Gaurav X Neelam, Gaurav XT-397, Gaurav X Laxmi-27 and Shubhra X Laxmi 27 in F₁ generation could be placed in first category, where both the parents had highly significant and desirable g.c.a. effects for grain yield per plant. Out of these cross combinations Gaurav x LCK 8605 showed positive s.c.a. effects in F₂ generation, indicating the presence of dominance and epistasis type of gene effects. The crosses Gaurav X Neelam, Gaurav XT-397, Gaurav X Laxmi-27 and Shubhra X Laxmi-27 showed highly significant and desirable s.c.a. effects in F₁ and Gaurav XLCK 8605 showed highly significant s.c.a effects in F₂ indicating the presence of additive X additive interaction. It is, therefore, desirable that where additive X additive interaction is present, biparental mating programme on the model of design III presented by comstock
and Robinson (1948) may be followed in order to get transgressive segregants from crosses involving high X high and high X low combiners.

On the other hand nine different crosses in F₂ generation, which showed significant and desirable s.c.a. effects for grain yield per plant, involved atleast one parent exhibiting significant g.c.a. effect. The crosses can provide desirable segregates by developing new population as the additive genetic system present in combiners and complimentary epistatis fashion to maximise the desirable plant attributes, which could be exploited for breeding purpose. Singh and Gupta (1969) and Singh et al. (1974) observed similar results.

4. **Estimation of Heterosis and Inbreeding Depression:**

The degree of heterosis should preferably be measured as superiority of F₁ hybrids over the economic parent. Such estimates, in real sense, decide whether the hybrid is worth exploiting or not. Accordingly, in the present study heterosis was measured as deviation of the performance of hybrid from the economic parent. Bailey et al. (1980) have pointed out that F₂ performance was a good indication of predicting F₁ hybrid in self pollinated crops. The use of parents, F₂ and three way crosses would provide the performance of F₁ hybrids with increased precision and
without field testing of $F_1$ hybrids. With this aim, in
breeding depression in $F_2$ generation has also been
studied.

In the present investigation, the percentage increase
in $F_1$ over economic parent for grain yield per plant ranged
from - 61.91 to 62.89 percent. 10 crosses were found to
exhibit significantly positive heterosis for grain yield per
plant. Arranged in a descending order some of the cross
combinations showing heterosis for this attribute included
Shubhra X Neelam, Gaurav X Neelam, Shubhra X Laxmi-27,
Laxmi-27 X T-397 and Gaurav X Laxmi-27 (Table 9). A
considerable extent of heterosis for grain yield was
reported by Singh(1983).

The cross combinations, Shubhra X Neelam, Gaurav X
Neelam, Shubhra X Laxmi-27 showed significant heterosis,
significant specific combining ability and low percentage of
inbreeding depression for grain yield per plant. The female
parents involved in these crosses were the best general
combiners and produced positive additive effects. It was the
only situation, where heterosis may be expected in $F_2$
generation. Barley et.al. (1980) supported the view that
additive gene effects were the major causes of heterotic
response in the diallel and triallel crosses as well as in
$F_2$ population. Generally, it was found that most of the
crosses producing high and significant heterosis were
involved with good general combiner female parent, having desirable positive additive effects. Since, cytoplasm is a lipoid fluid rich in RNA and mitochondria, which is usually transmitted through the female parent to the offspring, interactions of nuclear and cytoplasmic factors also seem to be involved in the heterotic expression (Chaudhary, 1982). Mitochondria are the chemical power houses of the cell. The progenies of the above mentioned crosses may be handed through pedigree method of breeding.

5. **Estimation of Heritability and genic gain:**

heritability denotes a statistical concept and it widely used in estimating expected progress in determining the degree to which the character may be transmitted from parent to offspring. It also indicates the relative importance of heredity and environment on character variations. For denoting the effective improvement in the character/characters for which the selection is practised, the heritability is like a measuring rule when expressed in terms of genetic advance. The population expressing large proportion of genetic variability for character/characters can give the desired plant type more frequently, if selection is practised. On the other hand, when the character is largely influenced by environment agencies, one has to raise a large population for realizing the desired effect of selection. Therefore, genetic advance, through not
an independent identity, has an added advantage over heritability as a guiding factor to the plant breeder where the character is to be improved through series of segregating generations. Johnson et al. (1955) pointed out that without genetic advance, the estimates of heritability will not be of much value. They further suggested that genetic gain should be considered along with heritability estimates in formulating coherent selection breeding programme.

High heritability estimates were observed for days to maturity, plant height, No. of primary branches, No. of secondary branches, No. of seeds per capsule, oil content, fibre yield per plant, Harvest index and grain yield per plant in both the generations (Table 10). The results are compatible with those of genetic analysis which indicated higher proportion of the additive genetic component in controlling the inheritance of these traits.

The high genetic advance (in percent) was observed for No. of secondary branches, No. of capsule per plant, Fibre yield per plant, Harvest index and grain yield per plant in both the generations. It indicated that manifestation of these traits was primarily governed by additive genetic effects which are of fixable type, and that the desired selection gain could be achieved in early generations.
Medium heritability estimates were observed for 1000-seeds weight, No. of Capsules per plant and days to flower in $F_1$ and 1000-seeds weight, No. of capsules per plant, Days for reproductive period and days to flower in $F_2$ generation. These results are in agreement with genetic analysis which indicated the greater role of non-fixable genetic effects.

Medium genetic advance was recorded for days to flower, days for reproductive period, plant height, No. of primary branches, No. of seeds per capsule and 1000-seeds weight in both the generations.

The heritability estimates in $F_2$ generation were comparatively higher than $F_1$ for Days to flower, Days for reproductive period, No. of capsules per plant and 1000-seeds weight. Similar was the trend for genetic advance except days to flower, days for reproductive period, No. of secondary branches, No. of capsules per plant, No. of seeds per capsule, 1000-seed weight, oil content, fibre yield per plant, Harvest index and grain yield per plant. Selfing of $F_1$s could improve the above yield contributing characters and further improvement may be expected in advanced generations by suitable selection procedure.

Low genetic advance in percent over mean was observed for Days to maturity and oil content in both the
generations. The selection in this set of material would not be much effective for these traits in early generations.

**Correlation Study:**

To enhance the yielding ability of the crop is the main target of a plant breeder. It is true that there are so many characters which contribute and have their relationship with yield. In the present investigations their were twelve characters which had been kept for correlation study with yield.

The genotypic and phenotypic corelation study revealed that Plant height, No. of secondary branches, No. of Capsules per plant, 1000-seeds weight and fibre yield per plant have their true relationship with yield because of having positive and significant correlation with yield.

Among the above characters only two namely No. of capsules per plant and 1000-seeds weight had the strongest associationhip with yield because these two characters had shown positive and significant correlation with yield at all the three levels Viz., which parental, $F_1$ and $F_2$ levels.

Badwal *et al.* (1971) Yadav and Dalal (1971) Kumar and Vasudeva (1974) found that number of capsules per plant was highly correlated with yield.

Kumar and Chauhan (1979) found number of branches highly correlated with yield.
Kumar and Chauhan (1979) reported association in the regregrating populations of lin seed they observed that seed yield has significant and positive association with plant height, tiller per plant, branches per plant and capsules per plant at phenotypic level. High positive correlation of 1000 seed weight with seed yield has also been recorded at genotypic level. Seeds per capsule was negatively correlated with seed yield at phenotypic level. Path analysis indicated that branches per plant, capsules per plant and 1000 seed weight are the most important yield contributing characters.

Gupta et.al. (1984) analysis of data on seed yield per plant and 7 yield related traits from 8 parents and their 56 $F_1$S and 28 $F_2$S revealed that (1) seed yield per plant was significantly and positively correlated with seed number per capsule, 200 seed weight and plant height and (2) 200 seed weight, capsule number per plant and seed number per capsule had the greatest positive direct effects on seed yield per plant.

Li et.al. (1985) in the study of 11 agronomic characters fibre content had the highest heritability value, genetic coefficient of variation to lodging resistance and fibre yield were 72% fibre content, stem yield seedling survival late and number of days from sowing to flowering correlated with fibre yield.
In the present investigation, only two characters namely, No. of capsules per plant and 1000 seeds weight showed positively and high significantly correlated with yield per plant, which indicated that the selection can be utilized for the next hybridization breeding programme.

It is, therefore, suggested that the plant height, No. of secondary branches and fibre yield per plant must be considered for the selection breeding programme.

It is, therefore, suggested that the following parents must considered for better performance in hybridization programme they are as follows: Neelam

LCK 8605
Laxmi-27
Gaurav.

Followings are the cross combinations which must be considered for the development of yield in this crop. The cross combination are:- Gaurav X Neelam

Gaurav X T-397
Gaurav X Laxmi-27
Shubhra X Laxmi-27
Gaurav X LCK 8605
Mukta X Swlta