HETEROSES AND RETENTION OF HYBRID VIGOUR:

Heterosis had been of frequent occurrence in most hybrids for different characters and had been discussed individually.

1. In the present study, heterosis was observed for plant height in 16 out of 36 crosses. The combinations CO × NL, CO × 40 and SS × CO were especially good. Crosses 40 × CO, NL × CO and CO × SS surpassed plant height of their taller parents. Unrau (1947), Kinman and Earle (1964) and Rutt (1966) reported hybrid vigour in plant height. Zdanov (1964) reported 5 percent increase in height, Kloczowski (1971) reported hybrids to be 10.4 percent taller. The negative heterosis is also not unusual and in the present case, out of 36 crosses studied 20 crosses showed negative heterosis over the mid parent, which for any crop would be desirable as tallness lead to more problems than dwarfness, especially when higher fertilization and irrigation is important part of the cultural
practices. Kloczowski (1967), Vulpe (1966, 1971), and Kovacik (1967) reported reduction in height also, and the findings in the present investigation collaborate these reports. Out of 36 crosses studied nearly 50 percent retained this vigour in F2 generation. Combinations 13 × 14, 13 × 40, SS × N2 and SS × 13 not only maintained hybrid vigour but had expressed its increase in F2 generation. This phenomenon could easily be due to the transgressive segregation of some dominant genes.

2. A crop like sunflower which usually bears one capitulum per plant needs a strong solid stem to support the increasing weight of the head upon maturity and thickness of stem is of advantage. Twenty-four and eleven crosses expressed hybrid vigour over mid-parental values and superior parents respectively. Crosses AR × NL, CO × AR, CO × N1 and 13 × AR were outstanding. Negative heterosis was also seen in about one third cases. Vulpe (1966) was the only one to report that the hybrids had thicker stem. The loss of hybrid vigour in F2 generation was observed in about half of the cases, nevertheless in crosses AR × 40, AR × 14, 15 × 14 and CO × N1 this vigour was not only retained but enhanced upto nearly 25.30 percent, which offered sufficient opportunity to select progenies, and especially 15 and CO seemed to possess adequate genes for this purpose.
3. Head diameter is an important component of yield. Out of 36 hybrids compared, 25 and 10 were found to surpass their mid and superior parental values. Thus the expression was largely towards bigger head size. These findings are in confirmation with Unrau (1947), Kovacik (1960), Putt (1966b) and Clement and Diskl (1968) who reported hybrid vigour in this character in F₁ and as well as in F₂. The combinations CO × AR, CO × N₁, AR × N₁ and SS × 40 were noteworthy. More than 50 percent of 36 total hybrids showed enhanced vigour in F₂. Crosses 13 × 40 and SS × N₂ were very good in this respect. Parents CO, N₁, AR, SS, 40 and N₂ seemed to offer ample opportunity for enhancing size of capitulum and thereby that of yield provided sufficient filling can be obtained.

4. Besides the size of head, its proper filling is important in achieving desired yield level in sunflower and the latter aspect can be indirectly assessed through weight of head when it was completely dry. The extent of hybrid vigour noticed in the present study ranged from 1.34 to 143.63 percent and from 0.21 to 123.45 percent over mid- and superior parental values respectively. Crosses CO × AR, AR × N₁, 40 × N₁ and SS × 40 were especially noteworthy in this respect and selection from their derivatives offered excellent opportunity to enhance yield level. It was very satisfactory to notice that out of 36 combinations, 24 did not show any loss of vigour but rather its enhancement in F₂ generation.
5. It was observed that out of 36 hybrids, 21 were superior to their mid-parental values and 14 to superior parents, for dry weight of the plant. Hybrid vigour ranged from 0.72 to 147.54 percent over the mid-parent and 3.26 to 95.30 percent over superior parent. Hybrids AR × N1, Co × AR, 13 × AR and SS × 40 were especially good. The increase in total plant weight would be important in the varieties useful from forage point of view.

6. In the present study lessening of the periods for flowering, maturity and flowering to maturity showing negative heterosis are of interest rather than when heterosis increases these durations. In major cases it has been reported that the hybrids tended towards earliness in flowering and total maturity as well (Unrau, 1947; Kovacik, 1959 and 1961; Shchori and Pinthus, 1969 and Vulpe, 1971). Out of 36 crosses studied, 23 and 9 crosses flowered earlier than their biparents and earlier flowering parents respectively, where the combinations AR × 15, SS × N2 and 14 × 15 and 15 × N1 were much earlier to flower compared to their parents. Cross 15 × N1 besides retaining this earliness in subsequent generation flowered even earlier, than the earliest parent. Similarly, 22 hybrids matured earlier than earlier parents. Twenty four hybrids in F2 generation showed earlier maturity than their F1s. It was worth noticing that in all crosses in which parents 14 and 15 were used as pollen parents were earlier in maturity. Crosses SS × 14, 13 × 14, AR × 14, AR × 15 and 14 × 15 offered considerable opportunity of further selection in
this direction. Gumenjuk (1967) found hybrids to tend more towards early maturing parents and suggested mid-season high yielding varieties as female parents in breeding programme on this crop. So far as period of flowering to maturity was concerned, parent 14 used as male gave earlier offsprings. Crosses N2 × 14 and 13 × 14 were very outstanding besides 40 × 14 and 40 × N1, as their progenies in F2 on the whole were even earlier.

7. Apart from the size and weight of a capitulum it is the filling that is significant contributor towards seed yield in sunflower. This character was indirectly measured in the present study as threshing percentage. It was observed that 20 and 13 hybrids out of 36 studied gave better threshing percentage than their mid-parental and superior parent values, respectively. However, in some cases, negative heterosis resulting in lesser threshing values was also observed. The heterosis ranged from 0.49 to 32.36 percent and from 1.69 to 26.49 percent over mid- and superior parent values. Crosses SS × N2, SS × 40, SS × N1, CO × 15 and 15 × N2 were outstanding. In crosses CO × N1, 13 × N1, N2 × N1, there was enhancement in threshing percentage in F2 around 25 percent over F1 and it offered considerable opportunity for selection in this important yield contributing character.
8. In the present study, 27 and 20 hybrids gave more number of seeds per plant over mid- and superior parent respectively, and 23 and 13 hybrids showed greater weight of seeds per plant over their mid- and superior parent values. In F₂, out of 36 hybrids, 26 hybrids did not show depression in weight of seeds per plant but gave enhanced yield of seed per plant ranging up to about 80 percent. Parents 13 and N₁ when used as pollen parents gave progenies having more seeds per plant, and also more weight of seed thus obtained. The extent of hybrid vigour ranged from 2.50 to 81.80 percent and from 4.45 to 54.39 percent for number of seeds per plant over mid- and higher parental values respectively. In case of weight of seeds per plant, this vigour ranged from 1.19 to 219.94 percent and from 3.30 to 115.36 percent over mid- and superior parents respectively. Crosses 40 × N₁, CO × 13, SS × 13, AR × N₁, 15 × N₁ and 13 × N₁ and 40 × N₁, were high in number of seeds per plant, whereas CO × AR, AR × N₁, SS × 40, SS × N₂, 40 × N₁, SS × N₁ were highly yielding combinations giving high seed weight per plant.

9. Besides number of seeds and their weight per plant, seed size is a valuable character that needs to be kept in view while breeding for higher yield in this crop. The size of seed was indirectly assessed in the present study as weight of 100 seeds. This value is indicator of size and filling also. Out of 36 combinations studied, 23 and 14 showed greater 100 seeds weight over their mid- and superior parental values respectively, the heterosis
ranged from 3.55 to 63.00 percent and from 0.99 to 24.80 percent over average and higher parents respectively. Vulpe (1966) found 1000 grain weight to be greater in some hybrids. Also Shchorni, and Pinthus (1969), and Kovacik (1972) reported heterosis for seed size, and these results are in confirmation of the above reports. As usual some negative heterosis was also noticed, which ranged from - 0.69 to - 25.87 percent from mid to superior parents respectively. Hybrids CO × AR, AR × N1, 40 × N1, CO × 40, 13 × AR and CO × N1 were especially outstanding in heterosis for this character.

10. In the present study, 19 hybrids showed heterosis in oil percentage over mid-parental values and 10 hybrids showed increased vigour over superior parents, the heterosis ranged from 0.59 to 19.23 percent and 0.13 to 12.46 percent over average and superior parents respectively. A number of workers have reported heterotic effects in oil percentage (Habura, 1958; Merfert, 1965; Vulpe, 1966; Vicentini, 1971; Gundaev, 1965 and 1968; Kloczowski, 1971; Elagin, 1954; Zdanov, 1964; Shuravina, 1972). The heterosis for oil yield per plant ranged from 13.68 to 293.17 percent over mid-parental values and from 3.86 to 166.70 percent over superior parents. Among the 36 crosses studied, crosses CO × AR, SS × 40, AR × N1, SS × N2, 40 × N1, CO × 40, N2 × 40, CO × N1, 13 × N2 and 15 × N1 seemed to offer very good opportunity in advancement.
through selection in this ultimate commercial product of this crop. The first 3 combinations were especially outstanding.

**GENE ACTION:**

Information on gene action was obtained through diallel analysis for different characters. Parameters $D$, $F$, $H$ and $H_2$ are useful in obtaining information of gene action, whereas estimators $(\hat{H_1}/\hat{D})^{1/2}$, $\hat{H}_2/\hat{H}_1$, ratio of $KD/ KR$ and $F_1-\bar{F}$ are informative for the extent of dominance, proportion of dominant and recessive genes, and direction of dominance so that the breeding programme can be followed in a purposeful manner. Part of the above information is also given by Wr, Vr graph. It is for the first time that such information is being obtained for sunflower through the diallel cross analysis.

1. The plant height was found to be due largely to slight over dominance as was seen from the regression line of variance covariance passing a little below the origin. Epistasis was not indicated as the regression value was not significantly different from unity. The estimator $(\hat{H_1}/\hat{D})^{1/2}$ was very close to unity. The proportion of genes with positive and negative effects was unequal. This was also confirmed by $KD/ KR$ and $F_1-\bar{F}$ values which tended to verify that this character was controlled by more dominant genes and therefore greater amount of heterosis was also recorded as well as
reported in almost all cases in literature, and hybrids tended
towards tallness.

2. Partial dominance was obtained for stem diameter as
revealed from Wr, Vr graph where regression line was cutting Wr
axis above origin and estimated value of \( \left( \frac{H_1}{D} \right)^{1/2} \) was 0.68, and
\[ b_{yx} = 0.81. \] The \( \hat{D} \) and \( \hat{F} \) values were significant, but \( \hat{D} \) was larger.
The large value of estimator \( KD/KR \) and very small \( H_2/4H_1 \) component
showed unequal proportion of dominant and recessive genes. As
thicker stem is a desirable character for sunflower, and parents
40, CO, 13 and N2 would offer considerable opportunity for selecting
progenies having thicker stem as these parents were associated with
more dominant genes.

3. Head diameter did not show any epistatic gene effects but
was largely additive action of genes as seen from large and
significant \( \hat{D} \). The interesting regression line well above origin
in Wr, Vr graph, and low estimate of \( \left( \frac{H_2}{D} \right)^{1/2} \) showed in-complete
dominance. The frequencies of dominant and recessive genes were
almost equal as was seen from KD/KR ratio nearer to unity, and
small and non significant variance of \( \hat{F} \). Parents CO, N2, 13 and 40
indicated greater diameter of head associated with dominant genes,
and parent CO was particularly desirable as it possessed maximum
number of these genes. As for this character, largely additive gene
action was indicated, it would be comparatively easy to select for
large headed progenies.
4. Value of only $\hat{D}$ was significant and large, suggesting largely additive action of genes for weight of dry head. The low and non significant $\hat{F}$ and low estimated value of $(\hat{H}_1/\hat{D})^{1/2}$ also supported this finding. Whereas $b_{yx} = 0.94$ which was not significantly different from unity indicated the absence of epistatic effects. The $W_r, V_r$ graph indicated incomplete dominance as the regression line intersected $W_r$ axis well above origin. The dominant and recessive genes were not in equal frequency as shown by $KD/kr$ ratio and value of $\hat{H}_2/\hat{H}_1$. However, larger value of $\bar{F}_1 - \bar{P}$ indicated direction towards some dominance. Parents CO and 40 were large headed having more dominant genes, and would form good parental stock for breeding large headed genotypes which would be easy through selection in view of additive gene action.

5. The regression line in $W_r, V_r$ graph intersected $W_r$ axis well above origin indicating incomplete dominance and the value $b_{yx} = 1.29$, not significantly different from unity, eliminated possibility of presence of any epistatic gene action for total weight of the dry plant. Only $\hat{D}$ was large and significant indicating largely presence of additive gene action. Estimator $(\hat{H}_1/\hat{D})^{1/2}$ was also quite small suggesting incomplete dominance. Though $\hat{H}_2/\hat{H}_1$ was less than $1/4$ suggesting unequal frequency of positive and negative gene effects, comparatively larger value of $\bar{F}_1 - \bar{P}$ and ratio $KD/kr$ indicated
gene action towards dominance in positive direction. It would be possible to utilize recessive genes with greater plant weight present in parents N2, 14 and 15 in a breeding programme when such progenies can be easily screened in segregating generation.

6. The presence of non-allelic interaction for days to flower, days to mature and period from flowering to maturity was not indicated as the byx values of 1.09, 1.26 and 1.01 were significant but not significantly different from unity. The D was large and significant for days to flower and equal to F for days to mature, whereas F was slightly larger than D for period from flowering to maturity. These estimates indicated slight over dominance in days to flower and near complete dominance in flowering to maturity, while in days to maturity it is partial dominance. The regression line in Wt, Vr graphs for days to flower, intersected Wt axis slightly below origin, above the origin for days to maturity and close to origin for days from flowering to maturity. Thus the question of earliness largely depended on direction of genic effects, i.e., towards negative direction. The less than 1.0 values of $\left(\frac{H_1}{D}\right)^{1/2}$ for flowering and flowering to maturity confirmed slight over dominance and near complete dominance and partial dominance for maturity and values of less than 1/4 for $\frac{H_2}{D_{H_1}}$ for flowering, maturity and from flowering to maturity periods revealed very much unequal distribution of positive and negative genes.
The ratio KD/KR for days to flower was near unity and positive indicating near equal proportion of dominant and recessive genes, whereas this ratio increased for days to maturity and from flowering to maturity indicating preponderance of dominant genes leading towards lateness. The negative $F_1 - F$ values for days to flower, indicated dominance towards earliness.

Parents N2, 40, S5, C0 and 13 were associated with dominance and earliness and would prove valuable breeding stock for evolving earlier maturing genotypes. Out of these, particularly parents S5, 40 and C0 would be more desirable as their combinations are likely to be much earlier than parents 13 and N2.

7. Near complete dominance would be possible in case of threshing percentage as seen from regression line cutting Wr axis well close to zero and the regression value though significant not significantly different from unity besides estimator $(\hat{h}_1/D)^{1/2}$ close to 1.0 of the parameters tested, $\hat{D}$, $\hat{h}_1$ and $h^2$ were significant and positive, which indicated additive and dominance gene actions, however the proportion of genes with positive and negative effects was not equal as shown by estimator $\hat{h}_2/d\hat{h}_1$ that had value much below $1/4$. The larger value of 3.3 for $F_1 - F$ also confirmed in general dominance of greater threshing percentage.
8. No indication of any non-allelic interaction was given for number of seeds per plant as the $b_{yx}$ values were significant but not significantly different from unity, but near complete dominance seemed to prevail as resolved by the regression line intersecting Wr axis close to zero. The estimator $(\hat{H}_1/\hat{D})^{1/2}$ indicated complete dominance, $\hat{D}$ was less than $\hat{H}_1$, thus revealing that, the number of seeds would give misleading information in selecting genotypes having higher yield. The estimator $\hat{H}_2/\hat{H}_1$ revealed that the genes with positive and negative effects were in unequal proportions. Mostly dominant genes governed greater number of seeds as shown by ratios $KD/KR$ which were greater than unity, also very large value of $\hat{F}_1-P$ suggested strong dominance.

Parents 13, N2, 14 and 15 were associated with dominant genes having greater number of seeds. Thus in attempting for higher number of seeds per plant parents 13 and N2 are likely to prove ideal breeding parents.

9. The regression line in Wr, Vr graph intersected Wr axis well above origin indicating incomplete dominance, for weight of seeds and after removal of the array CO the $b_{yx}$ values were significant but not significantly different from unity. The epistasis was present, and it was removed by removing one array.
The estimator \((\hat{H}_1/D)^{1/2}\) indicated incomplete dominance and \(\hat{D}\) was more than 2 times than \(\hat{H}_1\). The estimator \(\hat{H}_2/\hat{H}_1\) revealed that the genes with positive and negative effects were in equal proportions. Mostly dominant genes governed higher weight of seeds per plant as shown by ratios KD/KR which were greater than unity, also, large value of \(\overline{F}_1-P\) suggested dominance to some extent for weight of seeds per plant. Parent 13 and N2 were associated with dominance for higher seed weight per plant. Thus, in attempting for higher yields of seed per plant, parents 13 and N2 are likely to prove ideal breeding parents.

10. No indication of any non-allelic interaction was given for 100 seed weight and the slope \(h_{yx}\) had value of 0.72 ± 0.22. The \(\hat{D}\) only was significant and very large, also the estimator \((\hat{H}_1/D)^{1/2}\) had very small value indicating only partial dominance and largely additive gene action for this character. The regression line intercepted well above origin. As the degree of dominance was only partial, the proportion of genes with positive and negative effects was not at all equal, but the dominant and recessive genes controlling this character were in equal frequency as revealed from KD/KR value near to unity. Though small, but, positive \(\overline{F}_1-P\) value suggested possibility of increasing 100 seed weight through proper combination.
11. Partial dominance was indicated in case of oil percentage and there was no epistasis as Wr, Vr regression line intercepts Wr axis above the origin in Wr, Vr graph and regression index b_{yx} = 1.220 is not significantly different from unity. \( \hat{D} \) was twice the value of \( \hat{H}_1 \) and the estimator \( (\hat{H}_1/\hat{D})^{1/2} \) was much less than 1.00, which indicated more additive action of genes rather than dominant action. However, genes with positive and negative effects were almost in equal proportion (\( \hat{H}_2/\hat{H}_1 = 0.22 \), i.e., nearer to 0.25). Nevertheless ratio KD/KR was a little more than 1.00 signifying more dominant genes. The overall dominance was not great as was seen from \( \bar{F}_1 - \bar{P} \) value of 0.75.

All the above estimates suggested that parents 13, 14, 15, N2, SS and 40 contain more oil due to greater frequency of recessive genes and they can be advantageously utilized in any breeding programme aimed at evolving genotypes with higher oil content. As largely additive gene action was suggested, it would be easy to achieve considerable progress within one or two selection cycles.

The yield of oil per plant resulting as an interaction between oil content and seed yield per plant, had \( b_{yx} = 0.59 \) which was significant but not significantly different from unity after removal of the array CO. The epistasis was present, and it was removed by removing one array. Comparatively greater \( \hat{D} \) and lower value of \( (\hat{H}_1/\hat{D})^{1/2} \) indicated more additive action of genes. Also the
regression line intersected wr axis well above zero ruling out complete or overdominance.

The genes with positive and negative effects and dominance and recessive seemed to be existing in equal frequencies \( KD/H_n = 1.06 \), also from value of estimator \( H_2/4H_1 \) very close to 0.25.

Considering oil content and oil yield together, it was noticed that both had almost similar values of different parameters and estimators and selection based on either character would not give misleading information, and parent 14 be extensively used for this purpose. As these characters seemed to be comparatively simply inherited, perhaps lines with high oil content could be isolated by Russian workers through selection procedures (Rodenhiser et al., 1959; Alexander, 1963; Panchenko, 1966).

**Heritability:**

Heritability was comparatively low for threshing percentage, yield of seeds, oil yield and 100 seed weight due to smaller contribution of additive component in expression of these characters. The head diameter, weight of dry head, weight of dry plant and number of seeds per plant indicated medium heritability. The high heritability was expressed by plant height, oil percentage, stem diameter, days to flower and days to maturity as well as duration
of flowering to maturity. The high estimate indicated comparatively
greater contribution of additive gene effect. Habura (1958) reported
21 percent heritability for oil content and the result of present study
differ from his finding and in confirmation to those reported by
Nikolic et al. (1971).

**GENETIC ADVANCE:**

It was not enough to know the heritability estimates and start
selection in a population because it is a mere tool to help the breeder,
with appropriate biometrical formula a breeder can predict the amount
of advance that he can achieved through a selection cycle in the next
generation from the existing population. Genetic advance was
comparatively low for threshing percentage, days to flower, days to
maturity, duration from flowering to maturity, 100 seed weight and head
diameter, whereas considerable improvement would be possible in
improving weight of dry head, weight of dry plant and number of seeds
per plant by affecting one or two selection cycles. No work is available
on this aspect in literature on sunflower.

**COMBINING ABILITY:**

The general combining ability (g.c.a.), specific combining
ability (s.c.a.) and reciprocal effects were estimated in F₁ and F₂
populations raised during rabi, 1972 and late rabi, 1973 seasons
respectively. The g.c.a. estimates in general give an idea of additive
gene action which is comparatively highly heritable, whereas s.c.a. is
resultant of interaction of genic effects and usually not carried
further in subsequent generations.
1. The g.c.a., s.c.a. and reciprocal effects were significant for plant height, however, g.c.a. estimates were by far greater than s.c.a. and reciprocals revealed that this character was governed largely through additive action of genes. Putt (1966b) reported g.c.a. and s.c.a. for plant height to be highly significant, but observed greater value of s.c.a. than g.c.a. and the results of present study differ from his findings and are in confirmation with those reported by Kovacik and Skolowed (1972). In F₂ progeny, though the mean squares for g.c.a., s.c.a. and reciprocal effects were significant, the estimates did not differ much. In general, parents CO, N2, 13 and SS showed greater g.c.a. effects, whereas crosses CO × 40, CO × N1, 13 × 15 and AR × N2 expressed high s.c.a. However, negative values are more desirable for plant height. Parents AR and N1 tended to give shorter progenies and crosses SS × AR and AR × 15 in particular gave dwarfer progenies.

2. Stem diameter did not seem to change much and neither g.c.a., s.c.a. nor reciprocal effects were significant for F₂ populations. However, the F₁ population gave highly significant g.c.a. estimates only. None of the parents indicated significant differences in g.c.a. except CO and 13 in F₁ population, and combinations CO × 13, SS × CO and SS × 13 seemed to combine to produce thicker stemmed progenies, otherwise, the resultant offsprings were largely thin stemmed compared to parents. No work has been
reported on this aspect for stem diameter and hence it was not possible to confirm these findings.

3. The g.c.a., s.c.a. and reciprocal effects were significant for F₂, but only g.c.a. was significant in F₁ indicating that the head diameter was largely governed by additive gene effects. However, the g.c.a. and s.c.a. mean squares were almost equal and this finding was in confirmation to that reported by Putt (1966). Parents 13 and CO showed comparatively high and significant g.c.a. effects, whereas crosses SS × CO, SS × AR, SS × 15, CO × 14, and 13 × N2 seemed to combine very well in giving progenies having greater head diameter.

4. In F₂ population, the g.c.a., s.c.a. and reciprocal estimates were significant for weight of dry head, whereas F₁ progeny indicated only g.c.a. to be significant. The mean squares for g.c.a. and s.c.a. were almost equal in F₂ but the g.c.a. variance was nearly 9 times more than s.c.a. in non-segregating population. Parents N₂ and 13 had high and significant g.c.a. in F₂ but in F₁, the latter seemed to have lost this effect. Parent CO was particularly good general combiner. Crosses SS × CO, 13 × N2 were very outstanding showing high s.c.a. and so also were CO × AR, SS × 13, SS × 40 and 15 × N1.
5. For the weight of dry plant, studied in $F_1$, only the g.c.a. effects were significant and nearly 10 times greater than s.c.a. Parents CO and N2 seemed to combine well in general and with AR, 40 and 13 in particular as was noticed from high significant values of g.c.a. and s.c.a. No work is available in literature for these aspects of weight of dry head or dry plant.

6. As has been mentioned earlier in this manuscript, negative values for days to flower, to maturity and period from flowering to maturity are more desirable in sunflower, since a breeder attempts to evolve short duration high yielding varieties. The g.c.a., s.c.a. and reciprocal effect was significant for days to flower. However, the g.c.a. variance was nearly 10 times more than s.c.a. in the non-segregating $F_1$ population, but these two variances were nearly equal in $F_2$. Considering the negative values, none of the parents showed significant g.c.a. in $F_2$ but in $F_1$ population, parents AR and N1 gave significant and high negative g.c.a. indicating, that by and large these parents tended to produce early flowering progenies. Combinations SS × 40, CO × 15, 13 × N2, 13 × 40 and AR × 15 had highly significant negative s.c.a.

The days to maturity gave similar picture, except for $F_1$ where s.c.a. effects were also significant, the g.c.a. variance was nearly 10 times more than s.c.a. variance. Parents SS and AR gave significant g.c.a. values that were negative, whereas 14, CO and 13 gave significant positive g.c.a. values. So far as early maturity is concerned, combinations SS × 40, CO × 15, AR × 15, AR × 40 and
15 × 40 need a special mention where their s.c.a. effects were significant and negative.

The period from flowering to maturity indicated significant g.c.a. and s.c.a. effect in F2 only, and all effects were non-significant in non-segregating F1 population, where the mean squares of g.c.a. was 50 percent more than that of s.c.a. Putt (1966b) while investigating these aspects in sunflower reported variances of g.c.a. and s.c.a. to be significant for days to bloom and days to mature and greater g.c.a. component than s.c.a. for days to mature, but essentially same for days to bloom. The present findings are in agreement with those of Putt (1966b).

7. Only g.c.a. variance was significant for threshing percentage, and was 2 to 4 times more than s.c.a. mean squares, in F1 and F2 populations. Only parent AR gave significant and positive g.c.a. component, whereas N1 and CO gave significant but negative g.c.a. values. Combinations CO × N2, 15 × N1, 15 × 40 and 13 × 14 gave high and significant s.c.a. effects, in F2 population whereas, SS × N2, CO × 13 and CO × AR gave highly significant positive values in F1. No earlier investigations have been made on this aspect.

8. The aspect of combining ability effects on number of seeds per plant could be studied in F1 generation only, where the g.c.a., s.c.a. and reciprocals were found to be highly significant. However, g.c.a. component was nearly 5 times greater than the s.c.a. and
reciprocal components. Parents 13, 15 and N2 were particularly good combiners in general as shown by their high g.c.a. values. Some of the outstanding combinations were: \(CO \times AR, 15 \times N1, SS \times 40, SS \times N2\) and \(CO \times 13\) as was revealed by their high and significant s.c.a. values.

9. Along with the number of seeds, the weight of seeds per plant should also be considered. The g.c.a., s.c.a. and reciprocal effects were significant for this character and s.c.a. component was a little greater than g.c.a. in \(F_1\) but in \(F_2\) population g.c.a. was nearly 5 times greater than s.c.a. which was identical to number of seeds per plant. Parents CO and 13 gave higher g.c.a. effects that were significant in \(F_2\) generation only. The s.c.a. effects of combinations \(SS \times CO, 13 \times N2\) and \(40 \times N1\) were high and significant in \(F_1\) and in \(F_2\), \(SS \times 13, CO \times AR, SS \times N2, SS \times 40\) and \(15 \times N1\) gave high and significant s.c.a. values.

10. The significant and almost equal g.c.a. and s.c.a. variances for seed size measured in terms of 100 seed weight was noticed in \(F_2\) population, whereas in \(F_1\) only g.c.a. variance was significant and about 10 times greater than s.c.a. Putt (1966b) observed estimates of g.c.a. and s.c.a. to be essentially the same and both were significant for 100 seed weight. The \(F_2\) data presented here are in confirmation of findings reported by Putt (1966b). Parent CO was the only one to show significant and positive general combining ability.
for this character and its combinations with AR recorded highest significant s.c.a. Also crosses $13 \times N2$, $AR \times 14$, $AR \times N1$, $N2 \times N1$ and $SS \times CO$ gave significant s.c.a. estimates.

11. The oil content in seeds could not be assessed for combining ability in $F_2$ population for want of insufficient facilities, and time. In $F_1$, the g.c.a., s.c.a. and reciprocal variances for oil content was nearly 10 times greater than s.c.a. indicating largely additive gene effects. Pitt (1966 b) also reported mean squares for g.c.a. and s.c.a. to be significant for oil content and g.c.a. component to be greater than s.c.a. Kovacik and Skaloud (1972) found certain combinations from cross Ruzyne 9 × Scovenskasiva which showed high s.c.a. for oil content. The results from present study are in agreement with the above reports. Parents 13, N2 and 15 showed significant and high g.c.a. effect for oil content and crosses $13 \times 14$, $13 \times N2$, $13 \times AR$, $N2 \times 14$, $15 \times N1$ and $CO \times AR$ were particularly high in s.c.a. effects.

In the present study, the g.c.a., s.c.a. and reciprocal variances for oil yield were significant. However, the g.c.a. mean square was nearly 5 times more than s.c.a. variance. Out of 9 parents, studied, only one viz., N2 had significant g.c.a. value. Parent AR had significant but negative g.c.a. effect for oil yield. Among the specific combinations, $CO \times AR$, $SS \times N2$, $SS \times 40$, $13 \times N2$ and $15 \times N1$ need special mention for their high and significant s.c.a.
SUITABILITY OF THE VARIETIES FOR FURTHER BREEDING:

Parent AR has best performance for threshing percentage though it has medium number of dominant genes for this character, for most of the character it has lowest value with recessive genes. It is also good for breeding programme of earliness, as it has dominant genes for days to maturity and days from flowering to maturity. It is a favourable aspect that dominant genes determine shorter maturity duration. This parent is a good general combiner for threshing percentage for late rabi season. It possess superior s.c.a. with N2 and 40 for days to flower, with N2 and 15 for days from flowering to maturity in rabi season, with 15 for days to maturity in late rabi season. In F1 it gave high heterosis with N1 for stem diameter, head diameter, weight of the dry head, weight of the dry plant, number of seeds per plant, yield of the seeds per plant and oil yield per plant, with 15 and 14 for earliness. It gave highest inbreeding depression with 40. In both the season the performance of this parent is identical except for height and stem diameter.

Parent CO has got epistatic genes for yield of the seeds per plant and oil yield per plant. This parent is specially good for incorporating into programmes where thicker stem diameter, greater head diameter and higher 100 seed weight and lesser days for maturity
are required, since it possesses maximum dominant genes for these characters. CO has also maximum dominant genes for oil percentage, though has got lowest oil percentage. It is good general combiner for plant height, stem diameter, head diameter, weight of the dry head, weight of the dry plant, earliness, 100 seed weight and yield of the seeds per plant in rabi season. It possess superior s.c.a. with 13 for stem diameter, with AR for head diameter, weight of the dry head, days to flower, threshing percentage, number of seeds per plant, 100 seed weight, yield of the seeds per plant, oil percentage and oil yield, with 40 for plant height, weight of the dry plant, days to flower, with N2 for days to flower and threshing percentage, with N1 and 14 for days to flower in rabi season with 13 for stem diameter, with 40 for days to flower with N2 for threshing percentage in late rabi season. In F1 it gave high heterosis with N1 for plant height, head diameter, weight of the dry head, weight of the dry plant, 100 seed weight, yield of the seeds per plant and oil yield per plant, with 40 for plant height, oil percentage and oil yield per plant, with AR for head diameter, weight of the dry head, weight of the dry plant, 100 seed weight, yield of the seeds per plant, oil percentage and oil yield per plant, with 15 for threshing percentage, with 13 for number of seeds per plant and oil percentage. In F2 it gave high heterosis with N1 for threshing percentage. The parent gave highest inbreeding
depression with 15 for head diameter, with AR for weight of the dry head, with N2 for threshing percentage, with AR for yield of the seeds per plant. In rabi season it gave higher performance than late rabi season for all the characters except for 100 seed weight.

Parent N1 has got few dominant genes for oil percentage though has got medium oil percentage. This parent is good for incorporating in a programme where higher threshing percentage is required since it possess dominant genes for this character. In both the seasons, the performance of this parent is identical except for days from flowering to maturity and 100 seed weight.

Parent SS is good for breeding programme for earliness, as it has dominant genes for days to flower and maturity and dominant genes are generally associated with earliness. It possess superior s.c.a. with 13 for stem diameter, days to flower, days to maturity, with 14 for flowering to maturity in rabi season, with C0 for plant height and weight of the dry head in late rabi season. In F1 it gave high heterosis with 40 for head diameter, weight of the dry plant, threshing percentage, yield of the seeds per plant and oil yield per plant, with C0 for plant height, with 14 for days to maturity, with N2 and N1 for threshing percentage, yield of the seeds per plant and oil yield per plant, with 13 for number of seeds per plant and yield of the seeds per plant. In F2 it gave high heterosis with N2
for head diameter and high inbreeding depression with CO for plant height, with AR for stem diameter. In rabi season it gave higher performance as compared to late rabi season for all the characters except threshing percentage.

Parent N2 has more number of dominant genes and taller height, and since dominant genes are effective towards higher phenotypic performance the parent may be used for increasing plant height. This parent is also good for incorporating into programmes where thicker stem diameter, greater head diameter, earliness, more number of seeds per plant, higher yield per plant and higher oil yield per plant are required, since it possesses dominant genes for these characters. It is good general combiner for plant height, weight of the dry head, weight of the dry plant, number of seeds per plant, oil percentage and oil yield in rabi season and with head diameter, weight of the dry head, flowering to maturity in late rabi season. It possess superior s.c.a. with 14 for days to flower and flowering to maturity, with 40 for days to flower in late rabi season. In F₁ it gave high heterosis with 40 for oil percentage and oil yield per plant. It gave higher performance in rabi season for all the characters except stem diameter.
Parent 13 is good for breeding programme where thicker stem diameter, higher head diameter, higher threshing percentage, more number of seeds per plant, higher yield per plant and higher oil yield are required since it possesses dominant genes for these characters. It is good general combiner for plant height, stem diameter, days to maturity, yield per plant, oil percentage, oil yield per plant in rabi season, for head diameter, weight of dry head and flowering to maturity in late rabi season. It possess superior s.c.a. with AR and N1 for days to flower in rabi season, with N2 for head diameter, flowering to maturity and 100 seed weight in late rabi season. In F1 it also gave high heterosis with AR for weight of the dry head, weight of the dry plant, 100 seed weight and yield of the seeds per plant, with 14 for days to maturity, with N1 for number of seeds per plant and yield of the seeds per plant, with N2 yield of the seeds per plant and oil yield per plant. In F2 population it gave heterosis with 40 for weight of dry head, 100 seed weight, yield of the seeds per plant, with N2 for flowering to maturity with 14 for yield per plant and gave high inbreeding depression with 15 for days to flower, with N1 for 100 seed weight. In rabi season it gave higher performance for all characters except stem and head diameter.

Parent 14 is good for breeding programme of number of seeds per plant, as it has dominant genes with higher parental performance for
this character. 14 has higher oil percentage though has got recessive genes. It is good general combiner for plant height in rabi season and for days to maturity in late rabi season. In F₂ it gave highest heterosis with N₁ for days to flower. In both the season the performance of this parent is nearly identical except for higher yield of the seeds per plant in rabi season.

Parent 15 is good for breeding programme of oil yield per plant, as it has few dominant genes with higher parental performance for this character. This parent has higher oil percentage though has got recessive genes. This parent is also good for breeding programme of higher number of seeds per plant as it has dominant genes for this character. It is good general combiner for plant height, days to flower, number of seeds per plant and oil percentage in rabi season and for 100 seed weight for late rabi season. In F₁ it gave high heterosis with N₁ for number of seeds per plant, yield of the seeds per plant and oil yield per plant, with 14 for earliness and with N₂ for threshing percentage. In F₂ it gave highest heterosis with N₁ for days to flower. In both the seasons the performance of this parent is identical.