EVALUATION OF SUNFLOWER INBREDS FOR THEIR COMBINING ABILITY BY LINE X TESTER ANALYSIS

A. C. SHANKARA

DEPARTMENT OF AGRICULTURAL BOTANY
UNIVERSITY OF AGRICULTURAL SCIENCES
BANGALORE

1981

EVALUATION OF SUNFLOWER INBREDS FOR THEIR COMBINING ABILITY BY LINE X TESTER ANALYSIS

A. C. SHANKARA

Thesis submitted to the
University of Agricultural Sciences, Bangalore
in partial fulfilment of the requirements for
the degree of
MASTER OF SCIENCE (AGRICULTURE)
in
AGRICULTURAL BOTANY

Bangalore   July, 1981

Dedicated to

Late Dr. K. M. D. Nayar

Department of Agricultural Botany
University of Agricultural Sciences
Bangalore

CERTIFICATE

This is to certify that the thesis entitled "EVALUATION OF SUNFLOWER INBREDS FOR THEIR COMBINING ABILITY BY LINE X TESTER ANALYSIS" submitted in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE(AGRICULTURE) in AGRICULTURAL BOTANY to the University of Agricultural Sciences, Bangalore, is a record of research work carried out by Mr.A.C.Shankara, under my guidance and supervision and that no part of the thesis has been submitted for the award of any other degree, diploma, associateship, fellowship or other similar titles.

A Seetharam
(A.Seetharam)
Associate Co-ordinator
(Minor Millets and Germplasm Mobilization)

July , 1981

APPROVED BY:

Chairman: A Seetharam
(A.Seetharam)

Members : 1. ________
(G.Shivashankar)

2. S.S. Sindagi
(S.S.Sindagi)

3. M.N. Venkataramu
(M.N.Venkataramu)

ACKNOWLEDGEMENT

It is my privilege to express my deep sense of gratitude and sincere thanks to Dr.A.Seetharam, M.Sc(Agri), Ph.D(IARI), Associate Co-ordinator(Minor Millets and Germplasm Mobilization), ICAR and Chairman of my Advisory Committee for suggesting the interesting problem, his able guidance and constant encouragement throughout the course of this study.

I am grateful to Dr.G.Shivashankar, Professor of Agricultural Botany; Sri.S.S.Sindagi, Project Co-ordinator (Sunflower) and Sri.M.N.Venkataramu, Junior Statistician(Sunflower and members of my Advisory Committee for their constructive criticisms and review of the manuscript.

My thanks are also due to Dr.K.Giriraj, Senior Sunflower Breeder, Sri.B.T.Shankare Gowda, Plant Scientist(Ragi) and Sri.D.Sudhakar, Research Assistant(Dryland Agriculture), for their co-operation in my study and reviewing the manuscript critically.

I thank Dr.K.G.Shambulingappa, Geneticist(Sunflower) and Mrs.P.Kusuma Kumari, Research Assistant(Sunflower) and other staff members of Sunflower Scheme, for their co-operation rendered during my study.

I am thankful to Mr.H.Dayakara Reddy, Mr.A.Vittala Raya Kini and other P.G.Students and staff of the Department of Agricultural Botany, for their co-operation. I thank Mr.Kenchaiah and Mr.Chickegowda for their help during my study. My sincere thanks are also due to Mr.N.V.Srinivasa, for neatly typing this thesis.

I am also grateful to the authorities of Indian Council of Agricultural Research, for the financial assistance during the course of my study.

I am very much indebted to Sri.M.Aswathaiah, Sri.P.K. Subramany Swamy, Sri.N.Nandappa, my parents, uncles and sisters for their lively company and encouragement during my study.

A.C. Shankara

Bangalore
July 27th, 1981

(A.C.Shankara)

C O N T E N T S

LIST OF TABLES

INTRODUCTION

I. INTRODUCTION

Sunflower (Helianthus annuus L.), a member of the family Compositae (Asteraceae) is an important oil seed crop, ranking second in the world production of edible oil. It is believed to have originated in Mexico and Central America, but undoubtedly its domestication as an oil seed crop was first started in USSR in early part of nineteenth century. However, with the development of varieties in Russia with high seed yield and oil potential in 1960's, its cultivation has spread to other continents. In the year 1980, sunflower was grown over 11.81 million hectares in various parts of the world and USSR alone accounted for 39 per cent of total world production (Anon., 1980). The development of sunflower hybrids in early 1970's in France, Romania, and USA has further increased its scope and importance in the world edible oil trade.

Large scale cultivation of sunflower in India as a source of edible oil was started in 1972 with the introduction of high yielding Russian varieties. The cultivars EC.68414 (Peredovik) and EC.68415 (Armavirskij-3497) were found suitable for our country and is grown presently in many states.

Being essentially a cross pollinated crop, it exhibits heterogeneity within the varietal population. Prior to the discovery of cytoplasmic male sterility by Leclercq (1966), the breeding was mainly to develop superior populations following the methods of population breeding. Nevertheless, in recent years there is shift in breeding technique from population improvement to heterosis breeding by way of developing single cross hybrids. Hybrid sunflower is preferred over presently grown open pollinated varieties in view of their homogenity, uniformity and imparting stability to the production. Besides, hybrid sunflowers are more self fertile, thus showing enhanced seed set and seed filling (Seetharam, 1980, 1981). The value of hybrids in sunflower production was recognised long back in many countries particularly in France, Romania, USA and Canada and the first commercial hybrid was released in France as early as 1969.

In heterosis breeding programmes, the knowledge of relative role of general combining ability (gca) and specific combining ability (sca) for quantitative characters influencing yield and its components is very necessary in selecting the inbreds as parents for the production of superior hybrids. Sprague and Tatum (1942) defined 'gca' as average performance of a line in several hybrid combinations and 'sca' as the effects in certain specific combinations which significantly deviated from 'gca' on the basis of average performance of the line involve The line x tester analysis is one of the simplest and efficient methods of assessing combining ability of large number of inbred lines. This method has been followed in sunflower and in many other crop plants (Miller and Lee, 1964; Murthy *et al.*, 1967; Shankare Gowda, 1970; Sindagi, 1972; Setty and Basudeo Singh, 1977).

The present study is an attempt to assess the utility of 22 promising inbred lines as parents in the heterosis breeding programme by line x tester analysis. Sixty six hybrids, produced by crossing 22 inbreds with 3 testers, were studied for their combining ability and extent of heterosis for important yield and yield attributes. The objectives of this study were:

1. To assess the general and specific combining ability of inbreds and to estimate the extent of heterosis in respect of yield and yield attributes.

2. To identify superior inbreds for further utilisation in the production of hybrids and synthetics.

3. To understand the gene action for various quantitative characters.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

As sunflower is an highly cross pollinated crop, it is ideally suited for exploitation of hybrid vigour. In the past 3-4 decades the improvement in this crop was mainly through mass selection and recurrent selection procedures which resulted in the development of populations. Since 1970 more emphasis is being given to the development of hybrids and this has been possible due to the discovery of cytoplasmic-genetic-male sterility in this crop. The first step in the development of hybrids is the selection of parents (inbreds) with good nicking ability. Of the several methods available to assess the combining ability of inbreds; line x tester analysis is one which is simple and efficient. In literature, there are not many reports on the utility of line x tester analysis in the study of combining ability and heterosis of sunflower inbreds. The following review is an attempt made to compile all the pertinent literature available in this area.

A. Combining ability

In the study of large number of inbreds and their top crosses with the variety Sunrise at Manitoba (Canada) by Russel (1953), it was revealed that correlation coefficients between days to flowering, plant height and head diameter of inbreds and same characters in the top crosses were positive and highly significant. But there was no relationship between the 10 plant characters viz., yield of inbred, leaf area, plant height, days to flowering, days to maturity, stalk diameter, head diameter, rust rating, vigour rating and per cent lodged plants of the inbreds and combining ability for yield in top crosses.

In the study of top crosses with I_4 and I_5 inbreds, Schulze (1960) observed in the progenies, a few with good and others with poor combining ability in respect of seed yield, 1000 seed weight and oil content. As some progenies gave higher yield than that of the test variety, he concluded that the top cross method should be used for the production of hybrids.

Putt (1966) observed significant general combining ability and specific combining ability effects for several characters. Estimates of GCA variance were greater than SCA variance for days to maturity, bushel weight and oil content.

Kovacik and Skaloud (1972) in a 4-parent diallel cross observed the significant differences in gca for plant height and seed yield per head. A high sca for seed yield per head and oil content was shown by combinations of lines derived from

Rusyne-9 and Slovenskasiva. The ratio of variability components of gca and sca was 1:9.64 for seed weight per head indicating that suitable hybrids rather than parental lines should be selected. But it was opposite in the case of earliness where corresponding ratio was 1:1. In another study Klocsovskii (1972) obtained positive correlation between gca and yield. This was considered valuable in developing high yielding synthetic varieties.

Klimov (1972) studied 30 Soviet varieties by poly-cross, top cross and diallel cross methods. Good gca was found in Voronesh-151, Chakinskii-269, Chernyanka-66 and Enisei and medium gca in the more common varieties including Peredovik (Vanguard), Armavirskij-3497, VNIIMK-6540 and VNIIMK-1646, while VNIIMK-8883, VNIIMK-8931, Vostok (East), Vympel (Pennant), Smena (Change) and Luch (Ray) all had poor gca.

Anashchenko and Roshkova (1974) made a study on combining ability for seed yield in sunflower. Out of 39 lines evaluated, the highest gca was shown by K.2140 of Australia. Good sca was shown by the Russian varieties Sputnik, Zarya (Dawn), Voskhod (Ascent), Saratov-2114 and K.2080 from Iraq and K.2171 from Romania.

High GCA for seed yield in such varieties as Armavir-1813, Chernyanka and Sputnik was observed by Anashchenko et al. (1975).

Iyalyushkin and Sharova (1975) at Moldavian Experimental Station, observed that lines setting less than 50 per cent of seeds on selfing, generally had a higher gca than more autogamous forms. An evaluation was made on 150 lines for gca; 33 per cent of the F_1 hybrids obtained, exceeded VNIIMK-1646 in seed yield by 3-9 q/ha.

Kostyuchenko (1976) crossed eleven lines with six testers and established a direct correlation between the yield of lines and their respective top-cross hybrids. High yielding lines had high gca for yield.

Setty and Basudeo Singh (1977), in a line x tester analysis involving 10 inbreds and 2 open pollinated sunflower varieties studied various economic characters and found that gene action for flowering, head diameter, seed filling, hull content and seed yield was predominantly non-additive but it was additive for days to 75 per cent maturity and plant height.

Burlov and Buntovskii (1978) in their study with 8 lines observed that gca for seed yield and oil yield per hectare depend more on environmental conditions. While it was not so for oil content. The lines Od.2586 and K.395 had high gca for most characters and were promising.

Kovacik and Skaloud (1978) established differences in combining ability for plant height and achene yield from the data recorded on a wide range of characters in parental lines and hybrids.

Manjunath (1978) studied the genetics of some quantitative characters in sunflower. Analysis of data from F_1, F_2, BC_1, BC_2 from a 10x10 diallel cross study has revealed that dominant x dominant gene action was more important than dominant gene action for days to flowering, leaf number, length and breadth, stem girth, ratio of head weight to seed yield, 100 seed weight and seed number per head. But, the reverse was true for plant height, head diameter, head weight and seed yield. Dominant x dominant was more important than additive x dominant gene action for days to maturity, but both were equally important for petiole length. Epistasis was important for ray and bract number and oil content. In general, over dominance was prevalent and dominant genes had positive effects.

Studies made by Rozhkova (1978), in the sunflower collections revealed that 19 per cent of the lines had high gca. Three testers proved significant to determine the sca of the lines studied.

Rozhkova (1978a) in her another study determined gca of 64 varieties and various inbred lines by means of top crosses using 4 testers. A line from variety Sputnik showed high gca, as did 18 other forms, including Peredovik uluchshennyi (Improved Vanguard) and a line from the variety G-22. Some reciprocal differences in gca were found and the line Zhs-17 gave more heterotic progeny when used as female rather than male.

Sudhakar (1978) observed significant sca effects only in seven out of 27 top cross hybrids for some of the characters studied like seedling height, days taken to flowering, stem girth and plant height. Among females Krasnodorates, RM.62, HS.53 had good gca effects. Non-additive gene action was predominant for seedling height, plant height, days to flowering, stem girth, head diameter, days to 75 per cent maturity, number of filled seeds, volume weight and test weight, whereas gene action was additive for number of leaves, plant yield, hull content and oil content.

Alekseev et al. (1979) determined the gca of short stemmed inbreds by top crosses with the tall Majak and Zenit and the short Donskoi niskoroslyi.47 and Chernyanka-66. High gca for seed yield was shown by such hybrids as 3/95, 3/102, 4/13, 3/11 and also by Chernyanka-66.

Sindagi et al. (1979), observed that the nature of gene action was predominantly additive for the characters studied in a line x tester analysis involving 11 inbred lines and 3 open pollinated sunflower varieties. Among females S_2-RR-234 and S_3-69874-91 were good combiners for yield and yield components, while S_2-161 proved to be the best combiner for oil content, hull content and test weight. Crosses S_2-145-1/64 x Morden, S_3-69874-91 x Romson Record and S_2-415-2/151 x EC.68415 gave high sca effects for the number of filled seeds, yield, head diameter, oil content and test weight.

B. Heterosis

Heterosis is increased vigour of the F_1 of a cross over the mean of the parents or better parent. Various hypotheses have been advanced to explain the phenomenon of heterosis. According to the most accepted hypothesis, dominance, over dominance and epistasis (inter-alellic interaction) all acting together produce heterotic effect.

Habura (1958), studied heterosis for yield and yield attributes in 100 crosses of sunflower and found heterosis in 25 hybrids only, with respect to growth and oil content.

Kovacik (1959 and 1960) made several inter-varietal crosses and observed that seed yield in F_1 obtained was higher than that of both the parents and the extent of increase ranged from 1 to 20 per cent. Differences were also observed with respect to oil content, but only a few hybrids exceeded the parents. The F_1s were more vigorous and flowered earlier than the parents.

Kurnik and Zelles (1962) while comparing the progenies from selfed and crossed seeds, observed that plants from crossed seeds flowered 3 days later and they were 18.7 per cent taller, 4.2 per cent higher yielding and 10.8 per cent higher in 1000 grain weight.

Popov and Lazarov (1963) developed inbred lines from high yielding varieties and reported that single cross and top cross hybrids exceeded their parents in oil content and seed yields. Some inter-varietal hybrids exceeding their parents in seed yields were also obtained.

Neagu and Catrina (1965) effected direct and reciprocal crosses between Timisara lines characterised by high seed production. Out of 18 F_1s studied 4 showed heterosis for seed weight per plant 10 for seed yield per hectare, and 6 for oil content. Most of the hybrids matured 1-2 days earlier than their respective early parents and 1-5 days earlier than the standard variety VNIIMK-8931.

Schuster (1964) made studies on heterosis and inbreeding depression in sunflower hybrids and observed that, more than 50 per cent of the hybrids in their study exhibited heterosis upto 47 per cent over the best population. Heterosis for seed yield was upto 70 per cent in 32.8 per cent of the hybrids and 18 per cent of the hybrids showed heterosis for kernel percentage and oil content respectively.

Heterosis for plant height and seed yield was observed in a study of 8 sunflower hybrids by Putt (1966). Scerbak (1966) obtained inter-varietal hybrids with low husk content.

Grebenjuk (1967) in a study of ways of using inbred lines of sunflower in breeding for heterosis, observed heterosis in interline hybrids for yield upto 54 per cent over standard variety VNIIMK-1646.

Kloczowskii (1967) compared inter-varietal hybrids with interline hybrids for various qualitative and quantitative characters. He observed higher heterotic effects in inter-line hybrids than inter-varietal hybrids.

Kloczowskii and Kolodziejczak (1967) compared interline and line x variety hybrids with 4 checks. None of the hybrids were earlier than standard variety Borowskii. Interline hybrids yielded better than checks. A few hybrids equalled the check varieties, Peredovik and Smena in oil and kernel percentage.

Vranceanu (1967) effected 125 and reciprocal single crosses by artificial hybridisation between S_3-S_4 inbred lines. 27 hybrids gave heterosis for seed yield ranging from 9 to 28.8 per cent over the best check variety VNIIMK-8931. The best hybrid had oil content upto 63.5 per cent which was 3.2 per cent more than check variety.

Vulpe (1967) obtained 118 single cross hybrids using male sterility and fertility restoration systems, of which 53 gave higher seed yields than VNIIMK-8931. Out of these, 2 hybrids gave maximum increase 30 to 35 per cent for seed yield; 81 per cent gave higher oil yields and 101 had higher oil content than VNIIMK-8931. Maximum increase was upto 8 per cent in 3 hybrids for oil content. Hectolitre and 1000 grain weight were greater than the control in 58 and 76 hybrids respectively. In general, the hybrids were dwarf with thick stems and matured 8 days earlier than their parents.

Gundaev (1968, 1968a) reported an increase of 20 to 30 per cent seed yield; upto 40 per cent oil yield more than the control VNIIMK-8931 in the interline hybrids. By the use of male sterile lines, Vranceanu and Stoenescu (1969) in a diallel cross observed 7 promising hybrids showing heterosis for seed yield and oil content to an extent of 78 per cent and 13 per cent respectively. These hybrids out yielded the standard variety Record by 24 per cent in seed yield and 31 per cent in oil content. In another study, Vranceanu and Stoenescu (1976) observed an increase of 14 per cent more oil in one of the hybrids than the standard variety Record.

Shuravina (1969) compared the line x variety hybrids with the parents for sugar, oil, protein, and phosphorus contents in the seeds. The oil content in the cross I_9 x Majak was 49.4 g per 1000 kernals while the parents had 29.0 and 41.7 g oil per 1000 kernals respectively. Inter-varietal hybrids between cultivars with high oil contents were intermediate

Vol'F (1969) reported that interline and top-cross hybrids showed marked heterosis for high oil content. Velkov (1970) concluded from his studies on the F_1 and F_2 generations that the character plant height was controlled by dominant gene action and had marked heterotic effect in all the hybrids.

Neagu (1970) while studying the performance of some F_1 hybrids between mutant sunflower lines, observed that the hybrids had faster growth rate and 23 hybrids were earlier by 1 to 12 days than their earlier parents. In 28 hybrids, yields were between 118 to 245 per cent of the control value. Of the quantitative characters studied, the plant height showed high heterosis.

Heterosis for plant height, achene yield, and oil content in the hybrids derived from the lines of Russian, Polish and Canadian origin was observed by Kloczowskii (1971). Heterosis was upto 10.4 per cent and 13 per cent for plant height and oil content respectively. The hybrids yielded almost double as compared to parents.

Leclercq (1971) observed an yield increase of 12 to 40 per cent over standard Peredovik by a hybrid developed on the basis of genetic male sterility.

Stoyanova et al. (1971) in a study involving 192 stabilised inbred lines and 140 F_1 hybrids showed that Mid-parent heterosis occurred in respect of plant height and oil content upto 29 per cent and 5 per cent respectively.

Vicentini (1971) reported, that the hybrid produced by crossing an inbred line of high performance with genetic male sterile line, surpassed the check variety Record by 24 per cent in seed yield. Heterosis for this character was as high as 78 per cent.

Kovacik and Skaloud (1972) have also reported heterosis for yield, size of seeds, head diameter and plant height. Pogorletskii (1972) observed low hull percentage in one of the hybrids derived by crossing 4 cytoplasmic sterile lines with lines heterozygous for sterility (Helianthus annuus x H. tuberosus).

Kleczowskii (1972) obtained achene yields of over 30 quintals per hectare and oil yields greater than 10 quintals per hectare in the F_1s from experimental crosses, representing heterotic effects of 90 to 100 per cent for seed yield. In F_2 achene yield and oil content were dropped by 20 and 4 per cent respectively.

Shuravina (1972) crossed 7 cultivars with high and 10 with low oil content with two testers having high oil content. Half the hybrids exceeded the parents in seed weight upto 25 per cent, those with the greatest increase exceeded the parents by 46 per cent in the seed yield, some hybrids also showed reduction in husk content, three hybrids exceeded the higher parent in oil content by 2.4 to 2.6 per cent and the standard by upto 3.7 per cent in protein content. In another study with 21 hybrids, 16 displayed heterosis for seed weight upto 39 per cent and for seed yield upto 20 per cent over the tester. But all the hybrids had high hull content and low oil content. In another study with 18 hybrids obtained by crossing inbred lines, 14 showed heterosis in seed weight upto 90 per cent and yield increases upto 34 per cent. Ten hybrids had a reduced husk content and 3 excelled both parents in oil content upto 4.8 per cent.

In a study of interline and variety x line hybrids by Vol'F and Dumacheva (1972), it was observed that 10 to 20 per cent of combinations were promising in heterosis for yield. Heterosis for seed yield was more strongly expressed than heterosis for oil content.

In a study of F_1 hybrids obtained from a full diallel cross involving 8 inbred lines, Pogorletskii (1973) observed heterosis for stem height, head diameter, 100 seed weight, number of seeds per head, oil content and yield. Different degrees of dominence was showed for tallness, large head, high oil content and high yield.

Vranceanu (1973) and Vranceanu et al. (1973) in the trials of hybrids based on lines observed 13 to 21 per cent higher yield and 1 to 2 per cent higher oil content than the check variety Record. In another study a total of 12 hybrids were assessed of which HS-12, 16 and 17 were 16 to 19 days earlier than Record. HS-52, 53, 55 and 73 were slightly earlier than this variety and gave higher yields. The hybrids HS.53, 52, 12 and 33 had high oil content than the check variety. Hybrids were highly uniform with respect to their height.

Changes in the fatty acid content in the oil during hybridisation was observed by Ermakova and Popova (1974). They compared 4 hybrids showing heterosis for yield with their parental forms. The seed oil of Peredovik I_2 x Chernyanka-66 and Smena x SL Armavir-1813 contained more linoleic acid than that of both the parents and the oil of Armavir 1813-081 x Chernyanka-66 contained slightly more oleic acid than that of both its parents.

Fick and Zimmer (1974) in a study involving four restorers viz., RHA.271, RHA.273, RHA.274 reported that hybrids have higher oil content and also yield 2 to 31 per cent more seed than Peredovik. In another study (1974a), they effected cross between 4 male-sterile lines viz., HA.285, HA.286, HA.287, HA.289 with 2 testers viz., RHA.280 and RHA.282. Five of the hybrids which were tested gave an average increased yield of 77 per cent above the variety Sundak.

Semienchuk et al. (1974) developed an hybrid Debalk G 104 in Argentina, which exceeded in oil yield per hectare by 30 per cent, besides maturing 4 to 7 days earlier.

Turchi (1974) made crosses between introduced varieties and local in Kenya and observed an increase in seed yield over the local parent and reduction in oil percentage compared to introduced parent.

Harinarayana et al. (1976) observed that in a spontaneous self-compatible mutant the percentage of filled seeds after selfing ranged from 25 to 56 per cent as against, 0 to 8.5 per cent in self compatible lines. In hybrids from crosses between self incompatible and self-compatible plants, the filled achenes after selfing ranged from 0 to 83 per cent with a mean of 48 per cent compared with means of 40 per cent and 6 per cent in the self-compatible and self-incompatible lines respectively.

In the study of some characters in oil sunflower Kloczowskii (1975), observed heterosis for various components of yield. Mean heterosis for achene yield was 43 per cent in inter line hybrids and 18 per cent in line x variety hybrids.

Stoyanova and Ivanov (1975) observed heterosis for oil content in the F_1 from interline crosses. The hybrids exceeded the mid-parental value by 1.2 to 6.7 per cent in oil content. But no heterosis occured for protein content.

Stoyanova et al. (1975) observed that out of 2500 interline hybrids studied in Bulgaria, some 90 per cent had marked heterosis, but only 3 per cent exceeded the standard Peredovik in oil yield per hectare. For protein content many of the hybrids were close to the low protein parent.

Several promising hybrids have been bred recently by Voskoboinik and Soldatov (1975) in USSR, notably MS.257, MS.353 and MS.127, which exceeded the standard VNIIMK-8931 by 18 to 30 per cent in seed yield. Also promising was MML-41 obtained by crossing mutant lines which exceeded VNIIMK-8931 in oil yield by 13 per cent.

Vranceanu (1975) while discussing the theoretical and practical problems on the use of heterosis in sunflower, suggested that consideration be given to the inheritance of oil content and it was suggested that in breeding for high oil content, varieties of VNIIMK type should be used although they do not give high degree of heterosis when intercrossed.

Gorbachenko (1977) produced 520 F_1 interline, variety-line and inter-varietal hybrids by diallel crosses between short and tall varieties. He observed that the highest yielders were observed by crossing short lines, families and varieties with the variety Chernyanka-66. The best hybrid 3/102 yielded upto 30.7 quintals per hectare. The best F_1 hybrids which had Donskoi-niskoroslyi-47 as the short parent gave 15 to 24 per cent higher seed yield than the better parent.

Top cross hybrids were produced between 30 Russian varieties with 3 testers by Klimov and Ermoshin (1977). Of the hybrids studied, 28.3 per cent showed, 10 to 23 per cent heterosis, 50.1 per cent showed 1 to 9 per cent heterosis and rest showed no heterosis for seed yield.

Kovacik and Skaloud (1978) in a study of combining ability observed considerable amount of heterosis for achene yield, achene size, capitulum diameter and plant height. Heterosis was not observed with respect to earliness and oil yield.

Pasucci and Alba (1977) while evaluating the hybrids and commercial varieties of sunflower as a main crop and as a catch crop in Italy, observed that some hybrids gave higher yields than the best variety.

Seetharam et al. (1977) obtained 8 hybrids by crossing 4 cytoplasmic male sterile lines and 2 restorers. The hybrids showed significant positive heterosis for days to flower, plant height, head size, test weight, oil content and seed yield. Heterosis was non-significant for stem girth and number of leaves. The best hybrids BSH-1 and BSH-2 surpassed the check variety EC.68415 (Armaviriskij 3497) by 30 per cent in seed yield

Skoric (1977) observed that 4 single cross hybrid varieties derived from NS-RM yielded 25 to 30 per cent more grain yield and were earlier, shorter and more resistant to disease than Peredovik and VNIIMK-8931. Two hybrids had approximately 3 per cent higher oil content.

Voskoboinik (1977) using the lines derived from Soviet varieties with high oil content and lines from USA, France, Romania, Argentina and Canada produced 320 inter-line hybrids. Some of them out yielded the standard Peredovik by 10.7 to 33.8 per cent. The single inter line hybrid 5 (485 x 1485) out yielded the standard by 14 to 15 per cent; and the hybrid OPS-1870 exceeded Peredovik by 15 to 20 per cent in seed yield.

Vulpe (1977) produced a series of single, double and three way hybrids in Romania utilizing male sterility and compared them with Record. All the hybrids were earlier and shorter and had larger flower heads, 1000 seed weight and yields.

Bunmit et al. (1978) found that the double and three way cross hybrids were similar to single cross hybrids in seed yield, oil content and oil yield. Heterosis for oil content was 5 to 10 times less than that for seed yield and oil yield.

Reshkova (1978) observed that eleven crosses out yielded the standard variety Peredovik by 12 to 23 per cent.

Singh et al. (1978) while studying the heterosis in intervarietal crosses observed that the variety EC.93611-1 produced good hybrid if used as male parent. P 21 MS x EC.93611-1, EC.27638 x EC.93611-1 and EC.27631 x EC.96311-1 were superior to the control variety for seed yield, number of filled seeds, 100 seed weight. The first two of these crosses were superior to the better parent in seed yield.

Sudhakar (1978) did not find heterosis over the best parent in top cross hybrids for any traits studied except for number of leaves in only one cross. Considerable heterosis was observed over mid-parental values for the characters studied. Magnitude of heterosis over mid-parental values were upto 41.31 and 31.92 per cent for plant yield and oil content respectively. Hybrids showing higher magnitude of desirable heterosis also had better mean performance in many of the characters.

Interline hybrid ML-3 (MA 234 x BK 66) was developed using cytoplasmic male sterility by Voskoboinik (1978). It matured in 97 days, 3 days earlier to Peredovik and recorded a height of 190 cm as against 203 cm in Peredovik. It yields 33.3 and 16.7 quintals per hectare of seed and oil respectively indicating 4.4 and 2.6 quintals per hectare more than Peredovik. Another early hybrid is GS-1 which ripens in 93 days and reaches an height of 159 cm and seed yield of 29.2 quintals per hectare.

In comparative trials of native and foreign sunflower hybrids Vrataric and Krismanic (1978) observed that out of

26 hybrids ten surpassed the two standard varieties in achene yield. Only one hybrid surpassed VNIIMK in seed oil content while 4 did so in oil yield. Dedio (1979) while studying the performance of sunflower hybrids in Canada, observed that the hybrids yielded 79 per cent more than Peredovik. In a trial of 4 hybrids at four sites the hybrids yielded 20 per cent more than the open pollinated controls. At Altona, in large scale field tests, they out yielded Saturn by about 15 per cent in 1977 and upto 60 per cent in 1978.

Electrophoretic analysis of proteins was used by Zasharskii (1978) as a method of selecting parental pairs in breeding for heterosis. Each variety has its own specific protein fractions. F_1 hybrids had all the protein fractions of the parental lines. The greater the number of specific fractions in the parental forms, the greater was the heterotic effect in the hybrids.

Alekseev <u>et al</u>. (1979) concluded that the intervarietal hybrids between the short and tall testers proved promising; the best for seed yield was Donskoi niskoroslyi-47 x Chernyanka-66 In respect of oil yield, the best hybrids were 4/8 x Majak, 4/13 x Chernyanka-66 and 3/95 x Chernyanka-66.

Frank (1979) observed that male sterile line HR-0 has good combining ability giving hybrids which exceeded the control

VNIIMK-6540 by 4 to 47 per cent in yield and 48 to 53.68 per cent in oil content.

Gorbashenko (1979) made all possible crosses between the tall Majak and Zenit and the short Donski-niskoroslyi-47, Chernyanka-66 and Karlik-68. The hybrids showed heterosis for seed yield and oil yield. The most promising were hybrids involving Donski niskoroslyi-47. In the best hybrids, seed yield was 15 to 22.4 per cent higher than in the better parent.

Rozoriteleva and Beletskii (1979) studied genome plastome interaction and the effect of mutant plastome in different genetic back grounds on heterosis in sunflower. They observed that the mutant plastom effected heterosis for oil content, husk content, plant height and 1000 seed weight.

Vranceanu and Steenescu (1979) in their study on heterosis in single, three-way and double cross sunflower hybrids found that all types of hybrids had similar values for seed yield, quality characters and days to flowering. Differences in height were apparent, the three way and in particular double cross hybrids were taller. Comparis-on with the parental lines showed that average levels of heterosis were similar in each type of hybrid.

MATERIAL AND METHODS

III. MATERIAL AND METHODS

The experimental material consisting of 91 entries - 66 top crosses and 22 female and 3 male parents - was sown at Gandhi Krishi Vignana Kendra, University of Agricultural Sciences, Bangalore during kharif 1980. The experimental block had red sandy soils with a pH around 6.0. The monthly rainfall average maximum and minimum temperature, relative humidity and sunshine hours that prevailed during the experimental period are presented in the Table 1.

A. Materials

22 Hungarian inbred lines were used as female parents and three varieties as testers. The female lines were 256, 260, 263, 263A, 266, 269, 270, 272, 275, 276, 277, 278, 284, 286, 288, 289, 290, 290A, 292, 294, 296 and 298. The three testers used in the study were Morden, EC.68415 (Armaviriskij-3499) and Canadian genepool.

B. Methods

Crossing technique: The seeds of inbred lines and testers were sown separately at Gandhi Krishi Vignana Kendra, Bangalore during June 1979. A solution of 100 ppm Gibberellic acid was used for inducing male sterility in the inbred lines. The

Table 1. Meteor-ological observations during the experimental period

Months	Total rainfall (mm)	Maximum temperature (oC)	Minimum temperature (oC)	Relative humidity (%) 07.30/14.30 hrs.	Sunshine hours during the day
August 1980	61.6	29.2	18.6	84/57	5.4
September 1980	106.0	29.4	18.9	85/52	6.6
October 1980	106.5	29.3	18.3	80/41	7.3
November 1980	32.9	27.6	16.1	85/52	7.4
December 1980	0.0	28.3	14.3	81/40	8.8

method suggested by Seetharam and Kusumakumari (1975) for inducing male sterility by the application of 0.5 ml GA_3 at the star bud stage consecutively for two days was followed. Pollination of the treated plants by the foreign pollen was avoided by covering the heads with cloth bags. Controlled hand pollination was done by collecting the pollen from the tester parents. In all 66 hybrids were produced by crossing 22 inbred lines with 3 testers.

C. Layout

The ninety one entries (66 hybrids, 22 lines and 3 testers) were sown in a randomised complete block design with 3 replications. Each entry was raised in 2 row plots with a row length of 3 meters. The spacing maintained was 50 cm between rows and 30 cm between plants. The hybrids and parents were randomised separately but grown in contiguous plots. As regards manuring 30, 90 and 60 kg of nitrogen, phosphorus and potash respectively per hectare as the basal dose was applied and another 30 kg nitrogen per hectare as top dressing was applied 35 days after sowing. The other package of practices recommended for irrigated sunflower were followed to raise the crop.

D. Sampling and observations

Six plants were tagged at random in each treatment in a replication for recording detailed observation on the following characters.

1. Number of days taken to 50 per cent flowering: Number of days taken for the opening of ray florets in 50 per cent of the total plants was recorded.

2. Plant height: Height was measured at maturity in cm from the base of the plant at ground level to the point of attachment of capitulum.

3. Stem girth: Diameter of the stem at the first basal node was measured in cm with vernier callipers.

4. Capitulum diameter: Diameter of the capitulum was measured at the maximum width of head in cm.

5. Plant yield: The filled seeds obtained after threshing were dried and the weight was recorded in grams.

6. Volume weight: Weight of a known volume of (200 ml) seeds was taken as criteria and this was recorded in grams.

7. Test weight: One hundred seeds were separated from each treatment and its weight was recorded in grams.

8. <u>Hull content</u>: Fifty seeds were dehusked in each treatment by hand and the weight of husk to the total seed weight (husk+kernal) was expressed in percentage.

9. <u>Oil content</u>: Oil content was determined with the help of 20Pi minispec NMR (Nuclear Magnetic Resonance) spectrometer that was available in the Sunflower Project, University of Agricultural Sciences, Bangalore. This instrument gives direct value of oil content in the seeds that were previously oven dried.

10. <u>Oil yield per plant</u>: Data on oil content obtained under item 9 above together with seed yield per plant (item 5) was used to work out the oil yield per plant and it was expressed in grams. While calculating oil yield, 10 per cent of the weight was deducted from the seed yield as moisture content and it was calculated as follows.

$$\text{Oil yield per plant (g)} = \text{90\% of seed yield/plant (g)} \times \text{Oil percentage in seeds}$$

E. <u>Analysis of variance for parents and hybrids</u>

The mean of each replication for the above said ten characters recorded for hybrids and parents were subjected to statistical analysis and the variances due to different sources were worked.

ANOVA Table for parents and hybrids

Source	Degrees of freedom	Mean sum of squares
Replication	(r-1)	
Treatments	(t-1)	
Parents	(p-1)	
Parents vs Crosses	1	
Crosses	(mf-1)	
Lines	(f-1)	M_1
Testers	(m-1)	M_2
Lines x Testers	(m-1)(f-1)	M_3
Error	(t-1)(r-1)	M_4
Total	(tr-1)	

where, r = number of replications

m = number of male parents (testers)

f = number of female parents (inbred lines)

F. <u>Combining ability analysis</u>

Expected mean sum of squares are not available for modified line x tester analysis. So the mean of each replication for the above said ten characters recorded for hybrids alone were subjected to line x tester analysis and the variance of general combining ability (GCA) of the parents and specific combining ability (SCA) of the hybrid combinations were worked out based on the procedure developed by Kempthorne (1957).

ANOVA Table for combining ability

Source	d.f.	MSS	Expected mean sum of squares
Replication	(r-1)		
Crosses	(mf-1)		
Lines	(f-1)	M_1	σ^2+r Cov(FS)-2 Cov(HS)+ mr Cov(HS)
Testers	(m-1)	M_2	σ^2+r Cov(FS)-2 Cov(HS)+ fr Cov(HS)
Lines x Testers	(m-1)(f-1)	M_3	σ^2+r Cov(FS)-2 Cov(HS)
Error	(r-1)(mf-1)	M_4	σ^2
Total	(mfr-1)		

where, r = number of replications

m = number of male parents (testers)

f = number of female parents (inbred lines)

Cov(FS) = covariance of full sibs

Cov(HS) = covariance of half sibs

From the expectations of mean sum of squares, covariance of full sibs (FS) and covariance of half sibs (HS) were estimated as follows:

$$\text{Covariance(HS)} = \frac{(M_1-M_3) + (M_2-M_3)}{r(m+f)}$$

$$\text{Covariance(FS)} = \frac{(M_1-M_4)+(M_2-M_4)+(M_3-M_4)}{3r} + \frac{6r\ \text{Cov(HS)}-r(f+m)\text{Cov(HS)}}{3r}$$

Variance due to GCA = Cov(HS)

Variance due to SCA = Cov(FS)-2 Cov(HS)

After estimating Cov(HS) and Cov(FS) the GCA variance of lines and testers and SCA variance for the hybrids were estimated as shown below:

$$\text{GCA variance for lines} = \frac{M_1-M_3}{rm}$$

$$\text{GCA variance for testers} = \frac{M_2-M_3}{rf}$$

$$\text{SCA variance for hybrids} = \frac{M_3-M_4}{r}$$

where, M_1 = Mean sum of squares due to females

M_2 = Mean sum of squares due to males

M_3 = Mean sum of squares due to females x males

M_4 = Mean sum of squares due to error.

Estimation of combining ability effects

The model used to estimate gca and sca effects of ijk observations was:

$$Xij = \mu + gi + gj + sij + eijk$$

where, μ = population mean

gi = gca effect of i^{th} female parent

gj = gca effect of j^{th} male parent

sij = sca effect of ij^{th} combination

i = number of female parents

j = number of male parents

k = number of replications.

The individual effects were estimated as indicated below:

a) Lines: $gi = \frac{Xi..}{mr} - \frac{X...}{mfr}$

where, $Xi..$ = total of i^{th} female parent over all male parents and replications.

b) Testers: $gj = \frac{X.j.}{fr} - \frac{X...}{mfr}$

where, $X.j.$ = total of j^{th} male parent over all female parents and replications

Specific combining ability effects

$$Sij = \frac{Xij.}{r} - \frac{Xi..}{mr} - \frac{X.j.}{fr} + \frac{X...}{mfr}$$

where, $Xij.$ = ij^{th} combination total over all replications.

The standard error (SE) pertaining to gca effect of male and females; and sca effects of different combinations were calculated as below:

SE GCA for females = $\sqrt{\frac{\text{Error variance}}{mr}}$

SE GCA for males = $\sqrt{\frac{\text{Error variance}}{fr}}$

SE SCA = $\sqrt{\frac{\text{Error variance}}{r}}$

G. Abbreviations used

gca = General combining ability effects.

sca = Specific combining ability effects.

GCA = Variance due to general combining ability.

SCA = Variance due to specific combining ability.

H. Estimation of Heterosis

The over all mean value for each parent or hybrid from all the three replications for each character was taken for the estimation of heterosis. Heterosis over mid-parent, higher parent, best parent were computed. Heterosis was calculated as the percentage increase or decrease of mean F_1 performance.

i) Above mid-parental value = $\frac{F_1 - MP}{MP} \times 100$

ii) Over that of higher parental value = $\frac{F_1 - HP}{HP} \times 100$

iii) Over that of best parental value = $\frac{F_1 - BP}{BP} \times 100$

MP = Mid-parental value: For each character studied the airthmatic mean value of two parents involved in the cross was taken.

HP = Higher parental value: For each character superior value of the two parents in each cross was taken.

BP = Best parental value: For each character studied the best value among 25 parents involved in the study was taken.

The following standard errors were used to test the significance of heterosis.

$$SE(MP) = \sqrt{\frac{3M_4}{2r}} \quad \text{and} \quad SE(BP) = \sqrt{\frac{2M_4}{r}}$$

where, M_4 = the error mean sum of square.

EXPERIMENTAL RESULTS

IV. EXPERIMENTAL RESULTS

The results of the present study on Heterosis and combining ability in sunflower involving 66 top crosses, 22 inbred lines and 3 testers are presented under four broad heads.

1. Analysis of variance for parents and crosses.
2. Heterosis.
3. Combining ability variances.
4. Combining ability effects.

1. Analysis of variance for parents and crosses

The ANOVA showing the mean sum of squares for the ten characters namely number of days taken to 50 per cent flowering, plant height, stem girth, capitulum diameter, plant yield, volume weight, test weight, hull content, oil content and oil yield per plant are presented in Table 2. The mean value recorded for the above characters of both crosses and parents are presented in Table 3.

Significant block effects were observed for all the characters except number of days taken to 50 per cent flowering and plant height. Mean sum of squares for treatments were highly significant for all the ten characters. Treatment mean

Table 2. Analysis of variance for ten characters in Sunflower

Source	Degrees of freedom	No.of days taken to 50% flowering	Plant height	Stem girth	Capitulum diameter	Plant yield	Volume weight	Test weight	Hull content	Oil content	Oil yield per plant
Replication	2	1.33	65.65	1.38**	11.38**	106.93**	47.30*	1.55**	96.88**	12.64*	21.74**
Treatments	90	28.34**	911.00**	0.08**	3.64**	117.27**	72.48**	0.94**	16.64**	28.85**	23.33**
Parents	24	20.57**	746.49**	0.12**	6.61**	226.41**	86.06**	1.79**	33.92**	41.27**	45.79**
Parents vs Crosses	1	17.87*	13644.80**	0.15*	5.51	153.26**	401.93**	6.62**	2.87	376.63**	77.44**
Crosses	65	31.37**	775.84**	0.06**	2.51*	76.42*	62.39**	0.53**	10.47**	18.91**	14.21**
Lines	21	31.10*	810.28**	0.08*	3.54*	83.85	120.66**	0.54	15.16**	33.19**	14.62
Testers	2	376.97**	9832.35**	0.38**	10.41**	361.20**	4.35	1.93*	53.02**	85.42**	80.53**
Lines x Testers	42	15.05**	327.35**	0.04	1.61	59.15**	36.02**	0.47**	6.10**	8.60**	10.84**
Error	180	2.94	121.08	0.03	1.77	17.93	10.99	0.18	2.67	4.18	3.40
Coefficient of variance %		2.84	7.36	9.16	8.58	13.64	4.60	9.69	6.33	4.87	15.57
SE (±)		1.40	8.98	0.14	1.09	3.46	2.70	0.35	1.33	1.67	1.50

*Significant at 5 per cent.
**Significant at 1 per cent.

Table 5. Mean values for different characters under study in respect of hybrids and parents

Crosses	No.of days taken to 50% flowering	Plant height (cm)	Stem girth (cm)	Capitulum diameter (cm)	Plant yield (g)	Volume weight (g)	Test weight (g)	Hull content (%)	Oil content (%)	Oil yield per plant (g)
256 x Morden	55.67	133.5	1.87	14.7	28.64	77.30	3.93	27.19	41.76	10.75
260 x Morden	56.00	136.0	1.73	15.8	26.34	68.83	4.33	28.46	40.83	9.68
263 x Morden	58.33	136.5	1.93	16.1	32.81	73.60	4.03	27.60	43.40	12.81
263Ax Morden	58.67	152.7	1.93	14.6	28.44	66.57	4.90	28.12	40.00	10.24
266 x Morden	55.33	129.9	1.83	15.0	26.05	66.23	3.97	28.42	38.83	9.17
269 x Morden	56.33	143.5	1.83	14.7	30.80	74.87	4.60	25.01	42.83	11.88
270 x Morden	55.67	121.4	1.73	14.7	25.70	71.10	4.00	28.34	39.30	9.12
272 x Morden	56.33	129.5	1.97	15.8	29.26	73.87	4.57	26.67	40.30	10.62
275 x Morden	60.33	168.8	1.97	16.0	28.44	66.73	4.23	29.08	42.73	10.99
276 x Morden	56.67	144.0	2.13	16.2	40.64	74.47	5.10	25.80	43.49	15.86
277 x Morden	55.67	128.2	1.67	14.9	21.44	71.33	4.47	28.58	40.56	7.85
278 x Morden	56.00	127.4	1.67	13.6	23.43	68.87	3.70	27.61	34.40	7.23
284 x Morden	55.00	134.4	2.07	16.1	31.80	79.73	4.80	23.35	43.80	12.62
286 x Morden	63.33	168.1	1.97	16.7	32.02	66.10	4.23	27.04	40.33	11.53
288 x Morden	57.00	147.7	1.93	14.9	32.40	73.93	4.30	27.82	40.40	11.79
289 x Morden	57.67	126.8	1.70	16.1	31.53	78.73	5.27	25.21	44.90	12.73
290 x Morden	55.33	135.0	1.80	16.3	36.75	77.20	4.53	24.47	44.46	14.72
290Ax Morden	56.33	145.5	1.93	15.2	27.14	75.40	4.50	25.56	41.86	10.22
292 x Morden	62.00	143.3	1.67	15.7	23.92	70.07	3.80	27.21	40.83	8.78
294 x Morden	63.00	163.0	2.00	15.3	32.39	80.00	4.33	26.14	41.67	13.50
296 x Morden	57.33	134.6	1.77	13.0	27.50	73.33	4.57	25.35	42.03	10.31
298 x Morden	57.33	133.7	1.97	16.5	33.55	67.73	4.80	24.97	42.53	12.86

Table 3 (Contd)

Crosses	No.of days taken to 50% flowering	Plant height (cm)	Stem girth (cm)	Capitulum diameter (cm)	Plant yield (g)	Volume weight (g)	Test weight (g)	Hull content (%)	Oil content (%)	Oil yield per plant (g)
256 x EC.68415	60.67	156.5	1.90	15.1	35.22	82.37	4.43	28.29	41.56	13.28
260 x EC.68415	63.33	161.7	1.90	15.7	34.12	75.03	4.63	24.10	47.10	14.51
263 x EC.68415	63.33	152.6	2.17	17.6	49.32	65.03	6.17	27.00	41.06	18.28
263Ax EC.68415	62.00	181.3	2.23	15.6	44.35	76.73	5.20	25.21	45.23	18.20
266 x EC.68415	61.67	164.5	2.23	16.6	33.87	68.20	4.23	27.76	40.43	12.42
269 x EC.68415	63.33	158.2	2.10	16.4	28.44	69.73	4.60	23.93	44.56	11.37
270 x EC.68415	64.00	159.7	1.87	15.0	24.77	65.73	4.23	28.79	39.93	8.95
272 x EC.68415	63.00	174.1	2.07	16.4	31.47	70.47	4.70	24.79	44.20	12.52
275 x EC.68415	60.67	149.3	1.93	16.2	33.43	71.33	4.63	23.88	45.13	13.59
276 x EC.68415	65.33	184.2	2.13	16.0	31.75	70.27	3.90	29.49	44.60	12.78
277 x EC.68415	59.67	153.4	2.00	14.7	27.11	82.03	4.67	25.88	44.73	10.90
278 x EC.68415	62.00	172.1	2.03	16.1	35.66	69.30	4.40	27.61	41.30	13.23
285 x EC.68415	64.67	165.5	2.07	15.9	34.14	77.13	5.00	22.70	49.56	15.25
286 x EC.68415	66.33	176.5	2.07	17.5	34.97	64.43	4.70	27.08	38.83	12.27
288 x EC.68415	61.00	157.9	1.97	16.6	32.70	72.90	4.17	25.88	42.33	12.47
289 x EC.68415	55.67	124.1	1.87	15.1	32.36	74.90	4.77	25.64	42.53	12.40
290 x EC.68415	58.67	167.9	1.93	15.7	32.60	85.47	5.03	24.74	47.03	13.84
290Ax EC.68415	61.33	161.7	2.13	16.4	37.90	75.33	5.40	23.62	39.76	13.54
292 x EC.68415	62.33	170.5	2.07	16.5	35.84	69.93	4.60	25.60	41.43	13.32
294 x EC.68415	58.67	172.2	1.87	16.1	32.41	74.40	5.13	24.12	45.36	13.23
296 x EC.68415	61.67	162.3	1.93	15.5	30.06	78.50	4.70	25.01	44.93	12.15
298 x EC.68415	67.33	[illegible]	[illegible]	[illegible]	[illegible]	67.63	5.00	22.34	43.60	15.04

Table 3 (Contd)

Crosses	No.of days taken to 50% flowering	Plant height (cm)	Stem girth (cm)	Capitulum diameter (cm)	Plant yield (g)	Volume weight (g)	Test weight (g)	Hull content (%)	Oil content (%)	Oil yield per plant (g)
256 x Genepool	62.33	145.5	1.90	15.6	24.83	71.63	4.33	26.41	40.50	9.05
260 x Genepool	57.00	150.8	1.83	14.8	28.08	77.60	4.60	24.18	46.53	11.65
263 x Genepool	60.33	161.7	1.93	15.5	32.80	70.37	4.63	77.46	40.43	11.98
263Ax Genepool	62.00	164.3	1.83	14.6	30.36	71.13	4.83	27.07	42.63	11.63
266 x Genepool	58.00	132.8	1.77	14.1	32.90	68.40	4.47	26.35	42.90	12.85
269 x Genepool	57.67	138.2	1.83	15.5	26.48	73.87	3.93	24.73	43.67	10.42
270 x Genepool	57.67	145.3	1.80	15.0	25.67	68.10	4.37	27.17	40.73	9.45
272 x Genepool	61.00	162.0	2.20	17.0	29.27	75.13	4.30	26.65	42.63	11.21
273 x Genepool	61.00	149.6	1.93	15.6	30.19	76.20	4.83	24.11	44.80	12.12
276 x Genepool	64.67	157.4	1.97	16.3	38.30	68.73	5.00	24.29	45.00	15.53
277 x Genepool	57.67	153.8	1.93	16.0	32.86	77.90	4.23	23.82	46.70	13.73
278 x Genepool	57.67	147.7	1.77	14.8	36.89	70.90	4.70	24.08	40.83	13.51
284 x Genepool	59.33	154.6	2.00	15.5	27.25	76.63	4.43	26.37	46.80	11.47
286 x Genepool	66.00	174.5	2.17	17.1	35.94	67.77	4.27	23.94	41.96	13.58
288 x Genepool	64.00	166.7	2.13	16.4	32.30	69.80	4.53	25.62	41.26	12.15
289 x Genepool	61.00	147.6	1.63	13.7	20.22	71.57	4.53	22.71	44.67	8.33
290 x Genepool	61.33	173.6	2.17	15.9	33.78	73.20	4.40	21.95	43.70	13.27
290Ax Genepool	59.67	162.8	2.03	15.3	33.80	75.17	5.03	25.59	42.23	12.90
292 x Genepool	64.67	153.8	2.07	16.8	33.50	75.20	4.73	23.86	44.00	13.27
294 x Genepool	63.33	167.4	2.07	14.8	26.58	74.00	4.13	24.13	41.83	10.08
296 x Genepool	61.33	170.6	2.10	16.4	36.16	78.63	4.80	26.35	44.10	14.18
298 x Genepool	63.00	178.5	2.03	14.3	29.08	73.00	4.00	21.80	45.86	12.01

Table 3 (Contd)

Parents	No.of days taken to 50% flowering	Plant height (cm)	Stem girth (cm)	Capitulum diameter (cm)	Plant yield (g)	Volume weight (g)	Test weight (g)	Hull content (%)	Oil content (%)	Oil yield per plant (g)
256	61.67	161.2	2.30	15.9	29.80	76.67	3.70	27.19	40.06	10.76
260	62.00	123.0	1.97	13.9	23.11	68.30	3.80	23.62	39.93	8.30
263	65.00	126.8	1.90	13.5	21.13	64.40	3.23	31.36	36.93	7.05
263A	61.00	144.1	1.83	15.2	29.47	69.67	4.60	25.45	41.86	11.07
266	61.00	127.6	1.83	13.6	19.86	63.73	3.43	30.99	34.13	6.11
269	61.67	127.4	1.97	15.5	21.69	68.30	3.67	24.01	40.23	7.86
270	59.33	137.4	1.97	15.2	26.99	65.90	3.93	28.83	35.96	8.72
272	57.67	117.8	2.23	15.1	17.11	65.73	3.47	22.34	32.36	4.96
275	60.33	161.1	2.47	17.3	45.60	79.86	4.93	21.22	46.43	19.08
276	60.67	123.0	2.03	15.8	33.80	69.23	4.57	23.10	44.10	13.40
277	63.77	124.7	1.93	13.9	25.62	79.20	3.30	22.41	42.43	7.50
278	58.67	126.2	1.77	13.7	25.72	63.53	4.17	30.46	34.00	7.98
284	61.67	141.6	2.23	17.1	36.98	78.50	4.33	21.58	47.60	15.84
286	55.33	116.8	1.67	15.7	31.36	67.26	4.00	30.29	42.16	11.90
288	61.00	145.2	2.07	16.5	35.16	62.80	4.23	27.88	38.93	12.30
289	60.33	133.9	2.03	16.3	34.83	72.43	4.97	24.79	40.16	12.57
290	61.00	143.8	1.90	14.7	26.91	70.40	4.00	25.81	38.00	9.75
290A	61.00	147.7	1.93	14.2	26.04	77.76	4.37	22.84	42.26	9.90
292	67.67	146.0	1.77	15.1	30.13	63.30	3.73	25.63	38.80	10.51
294	59.33	129.2	1.87	13.7	32.16	67.86	3.67	33.26	38.06	11.18
296	58.67	141.9	2.07	14.1	20.20	71.30	3.17	23.59	39.26	7.13
298	60.67	133.4	1.83	13.3	23.09	65.76	4.47	25.47	42.46	8.82
Morden	55.33	124.6	2.00	17.2	42.78	72.53	5.63	27.51	42.46	15.13
EC.68415	61.67	178.7	2.40	18.4	47.58	73.80	6.00	23.43	39.63	18.92
Genepool	62.67	163.9	2.07	17.8	44.44	74.53	5.70	26.48	44.20	17.67
CD at 5%	3.04	14.78	0.24	1.79	5.69	4.45	0.58	2.19	2.75	2.48
CD at 1%	3.26	20.89	0.34	2.53	8.04	6.29	0.82	3.10	3.89	3.50

sum of squares was further partitioned and the variances due to parents were found highly significant for all the characters. Mean sum of squares due to parents vs crosses were significant for number of days taken to 50 per cent flowering, plant height, stem girth, plant yield, volume weight, test weight, oil content and oil yield per plant. Variance due to crosses was significant for all the characters; while variance due to lines was significant in seven out of ten characters except in yield per plant, test weight and oil yield per plant. Differences between testers were highly significant for all characters except volume weight. Variance due to line x tester interaction was found to be highly significant for all the characters except stem girth and capitulum diameter.

The mean sum of squares due to testers was of higher magnitude compared to those due to lines or line x testers except in the case of volume weight and thereby indicating greater diversity among male parents compared to female parents.

2. <u>Heterosis</u>

Heterosis was studied for all the ten characters under study. The mean values of F_1s were compared with the value of mid-parent (MP), higher parent (HP) and the best parent (BP) and the differences were expressed as percentage heterosis and the data are presented in Table 4 to 13. The results obtained in respect of various characters are presented below.

2.1. <u>Number of days taken to 50 per cent flowering</u>

The line which flowered early among the lines included in the study was considered as the best parent. The inbred line 286 (55.33 days) among females and Morden (55.33 days) among males were the earliest (Table 3). The hybrid 284 x Morden was the first to flower among hybrids (55.00 days).

Thirty eight out of 66 hybrids exhibited negative heterosis over mid-parental value ranging from -0.28 to -8.74 per cent and in 26 hybrids it was significant. The extent of positive heterosis ranged from 0.26 to 14.46 per cent and in 18 hybrids it was significant. The hybrids, 263 x EC.68415 and 290A x EC.68415 did not show any heterosis over mid-parental value (Table 4).

Fourteen out of 66 hybrids showed negative heterosis ranging from -0.60 to -8.06 per cent over higher parent. But only in 8 of them it was significant. Fifty hybrids showed positive heterosis of which 26 hybrids exhibited significant differences. Extent of positive heterosis was from 0.50 to 19.88 per cent. Only 2 out of 66 hybrids did not show heterosis.

Table 4. Heterosis in respect of number of days taken to 50 per cent flowering

Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP
256 x Morden	-4.84**	0.60	0.60	256 x EC.68415	-1.62	-1.62	9.65**	256 x Genepool	0.26	1.07	12.65**
260 x Morden	-4.53**	1.21	1.21	260 x EC.68415	2.43*	2.69	14.46**	260 x Genepool	-0.55**	-8.06**	3.02
263 x Morden	-3.04**	5.42**	5.42**	263 x EC.68415	0.00	2.69	14.46**	263 x Genepool	-5.48**	-3.73**	9.03**
263Ax Morden	0.88	6.04**	6.04**	263Ax EC.68415	1.09	1.64	12.05**	263Ax Genepool	0.27	1.64	12.05**
266 x Morden	-4.87**	0.00	0.00	266 x EC.68415	0.55	1.09	11.45**	266 x Genepool	-6.19**	-4.92**	4.82**
269 x Morden	-3.71**	1.81	1.81	269 x EC.68415	2.69*	2.69	14.46**	269 x Genepool	-7.24**	-6.48**	4.23**
270 x Morden	-2.90**	0.60	0.60	270 x EC.68415	5.79**	7.87**	15.66**	270 x Genepool	-5.46**	-2.79	4.23**
272 x Morden	-0.30	1.81	1.81	272 x EC.68415	5.58**	9.24**	13.86**	272 x Genepool	1.38	5.77**	10.25**
275 x Morden	4.32**	9.04**	9.04**	275 x EC.68415	-0.54	0.50	9.65**	275 x Genepool	-0.81	1.11	10.25**
276 x Morden	-2.29*	2.42	2.42	276 x EC.68415	6.80**	7.68**	18.07**	276 x Genepool	4.86**	6.59**	16.88**
277 x Morden	-6.44**	0.60	0.60	277 x EC.68415	-4.79**	-3.24**	7.84**	277 x Genepool	-8.71**	7.98**	4.23**
278 x Morden	-1.75	1.21	1.21	278 x EC.68415	3.04**	5.67**	12.05**	278 x Genepool	-4.94**	-1.70	4.23**
284 x Morden	-5.98**	-0.60	-0.60	284 x EC.68415	4.86**	4.86**	16.88**	284 x Genepool	-4.57**	-3.79**	7.23**
286 x Morden	14.46**	14.46**	14.46**	286 x EC.68415	13.38**	19.88**	19.88**	286x Genepool	11.86**	19.28**	19.28**
288 x Morden	-1.99*	3.02	3.02	288 x EC.68415	-0.54	0.00	10.25**	288 x Genepool	3.51**	4.92**	15.67**
289 x Morden	-0.28	4.23**	4.23**	289 x EC.68415	-8.74**	-7.72**	0.60	289 x Genepool	-0.81	1.11	10.25**
290 x Morden	-4.87**	0.00	0.00	290 x EC.68415	-4.34**	-3.82**	6.03**	290 x Genepool	-0.81	0.50	10.84**
290Ax Morden	-3.15**	1.81	1.81	290Ax EC.68415	0.00	0.50	10.84**	290Ax Genepool	-3.49**	-2.18	7.84**
292 x Morden	0.81	12.05**	12.05**	292 x EC.68415	-3.62**	1.07	12.65**	292 x Genepool	-0.77	3.19*	16.88**
294 x Morden	9.89**	13.86**	13.86**	294 x EC.68415	-3.02**	-1.11	6.03**	294 x Genepool	3.82**	6.74**	14.46**
296 x Morden	0.58	3.61**	3.61**	295 x EC.68415	2.49**	5.11**	11.46**	296 x Genepool	1.09	4.53**	10.84**
298 x Morden	-1.16	3.61**	3.61**	298 x EC.68415	10.07**	10.98**	21.68**	298 x Genepool	2.16**	3.84**	13.86**

*Significant at 5 per cent.
**Significant at 1 per cent.

MP = Mid-parent.
HP = Higher parent.
BP = Better parent

Only one hybrid 284 x Morden flowered earlier than best parent and the extent of negative heterosis was -0.60 which however was not significant. Two hybrids did not show any heterosis. Remaining 63 hybrids flowered later than best parent and the extent of positive heterosis was from 0.60 to 21.68 per cent, but only in 51 hybrids it was significant.

Crosses between earliest male and female parents did not result in early flowering hybrids.

2.2. Plant height

Line 259 (161.2 cm) was the tallest among the female parents and EC.68415 (178.7 cm) was the tallest among males. The hybrid 276 x EC.68415 (184.2 cm) was the tallest among the hybrids.

Fifty out of 66 hybrids showed positive heterosis ranging from 0.59 to 39.27 per cent over mid-parent values (Table 5), of which only 16 hybrids showed significant positive heterosis. The remaining 16 hybrids showed negative heterosis over mid-parent values ranging from -0.06 to -20.66 per cent. Only one hybrid (289 x EC.68415) was significantly shorter than its mid-parental value.

Forty four hybrids out of 66 showed negative heterosis over higher parent ranging from -0.67 to -30.55 per cent. But

Table 5. Heterosis in respect of plant height

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	-6.58	-17.18*	-25.29**	256 x EC.68415	-7.88	-12.42	-12.42	256 x Genepool	-10.46	-11.22	-18.58*
260 x Morden	9.85	9.15	-23.89**	260 x EC.68415	7.23	-9.51	-9.51	260 x Genepool	5.16	-7.99	-15.61*
263 x Morden	8.59	7.65	-23.61**	263 x EC.68415	-0.06	-14.60	-14.60	263 x Genepool	11.29	-1.34	-9.51
263Ax Morden	13.70*	5.97	-14.55	263Ax EC.68415	12.33	-1.45	1.45	263Ax Genepool	6.67	0.24	-8.06
266 x Morden	3.01	1.80	-27.31**	266 x EC.68415	7.45	-7.95	-7.95	266 x Genepool	-8.85	-18.97*	-25.68**
269 x Morden	13.89*	12.64	-19.69*	269 x EC.68415	3.39	-11.47	-11.47	269 x Genepool	-5.15	-15.68*	-22.66**
270 x Morden	-7.33	-11.64	-32.06**	270 x EC.68415	1.07	-10.63	-10.63	270 x Genepool	-3.52	-11.35	-18.69*
272 x Morden	6.85	3.93	-27.53**	272 x EC.68415	17.48*	-2.57	-2.57	272 x Genepool	15.06*	-1.16	-9.34
275 x Morden	18.21**	4.78	-5.54	275 x EC.68415	-12.12	-16.45*	-16.45*	275 x Genepool	-7.95	-8.72	-16.28*
276 x Morden	16.32*	15.57*	-19.42*	276 x EC.68415	22.15**	3.08	3.08	276 x Genepool	9.76	-3.96	-11.92
277 x Morden	2.89	2.81	-28.26**	277 x EC.68415	1.12	-14.15	-14.15	277 x Genepool	6.58	-6.16	-13.93
278 x Morden	1.59	0.95	-28.71**	278 x EC.68415	12.93*	-3.59	-3.6[illegible]	278 x Genepool	1.86	-9.88	-17.35*
284 x Morden	9.77	-5.08	-5.08	284 x EC.68415	3.37	-7.39	-7.39	284 x Genepool	1.24	-5.67	-13.49
286 x Morden	39.27**	34.91**	-5.93	286 x EC.68415	19.50**	-1.23	-1.23	286 x Genepool	24.38**	6.47	-2.35
288 x Morden	9.49	1.72	-17.35*	288 x EC.68415	-2.47	-11.64	-11.64	288 x Genepool	7.89	1.71	-6.71
289 x Morden	-1.86	-5.30	-29.04**	289 x EC.68415	-20.66**	-30.55**	-30.55**	289 x Genepool	-0.87	-9.94	-17.40*
290 x Morden	0.59	-6.12	-24.45**	290 x EC.68415	4.16	-6.04	-6.04	290 x Genepool	12.87*	5.92	-2.85
290Ax Morden	6.91	-1.49	-18.58*	290A xEC.68415	-0.92	-9.51	-9.51	290Ax Genepool	4.49	-0.67	-8.89
292 x Morden	5.91	-1.85	-19.81*	292 x EC.68415	5.05	-4.59	-4.59	292 x Genepool	-0.71	-6.16	-13.93
294 x Morden	28.45**	26.16**	-8.78	294 x EC.68415	11.89	-3.64	-3.64	294 x Genepool	14.27*	2.13	- 6.32
296 x Morden	1.05	-5.14	-24.68**	296 x EC.68415	2.49	-8.06	-8.06	296 x Genepool	11.58	4.09	- 4.53
298 x Morden	3.64	0.22	-25.18**	298 x EC.68415	12.88*	-1.45	-1.45	298 x Genepool	20.12**	8.91	0.00

*Significant at 5 per cent.
**Significant at 1 per cent.

only in 5 hybrids namely 256 x Morden, 275 x EC.68415, 289 x EC.68415, 266 x Genepool and 269 x Genepool, it was significant. The remaining 22 hybrids showed positive heterosis ranging from 0.22 to 34.91 per cent of which the 3 hybrids viz., 276 x Morden, 286 x Morden and 294 x Morden were significantly taller than their parents.

Sixty three hybrids out of 66 showed negative heterosis ranging from -1.23 to -32.06 per cent over best parent of which in 28 hybrids it was significant. Two hybrids namely 263A x EC.68415 and 276 x EC.68415 showed positive heterosis which however was not significant and the hybrid 298 x Genepool did not show heterotic effect for height.

The female line 286 showed significant positive heterosis in combination with all the three testers over mid-parental value.

2.3. Stem girth

Line 275 (2.47 cm) and EC.68415 (2.40 cm) had the highest stem diameter among females and males respectively. The hybrids 263A x EC.68415 and 266 x EC.68415 recorded the highest stem girth (2.23 cm) among the hybrids.

All the hybrids except two 290A x EC.68415 and 290A x Genepool showed either significant positive or negative heterosis over mid-parental values. Nineteen hybrids showed significant positive heterosis ranging from 0.93 to 7.65 per cent. Forty five hybrids showed significant negative heterosis ranging from -1.03 to -20.58 per cent (Table 6).

As regards heterosis over higher parent, 57 hybrids showed significant negative heterosis ranging from -1.50 to -23.75 per cent. Six hybrids showed significant positive heterosis ranging from 1.45 to 4.93 per cent. Three hybrids viz., 294 x Morden, 292 x Genepool and 294 x Genepool did not show heterosis.

All the hybrids showed significant negative heterosis over best parent. The extent of negative heterosis was -9.72 to -34.01 per cent.

Out of 66 hybrids six hybrids (namely, 276 x Morden, 294 x EC.68415, 286 x Genepool, 288 x Genepool, 290 x Genepool and 296 x Genepool) showed significant positive heterosis over mid-parental value and higher parent.

2.4. Capitulum diameter

The line 275 had the highest capitulum diameter (17.3 cm) among females and EC.68415 had the highest capitulum diameter (18.4 cm) among pollen parents. The hybrid, 263 x EC.68415 recorded highest capitulum diameter (17.6 cm) among the hybrids.

Table 6. Heterosis in respect of stem girth

Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP
256 x Morden	-13.02**	-18.70**	-24.29**	256 x EC.68415	-19.15**	-20.83**	-23.08**	256 x Genepool	-12.84**	-17.39**	-23.08**
260 x Morden	-12.85**	-13.50**	-29.96**	260 x EC.68415	-12.84**	-20.83**	-23.08**	260 x Genepool	-9.85**	-11.59**	-25.91**
263 x Morden	-1.04**	-3.50**	-21.86**	263 x EC.68415	0.93**	-9.58**	-12.15**	263 x Genepool	-3.02**	-6.76**	-21.86**
263Ax Morden	1.05**	-3.50**	-21.86**	263Ax EC.68415	6.19**	-7.08**	-9.72**	263Ax Genepool	-6.15**	-11.59**	-25.91**
266 x Morden	-4.19**	-8.50**	-25.91**	266 x EC.68415	6.19**	-7.08**	-9.72**	266 x Genepool	-9.23**	-14.49**	-28.34**
269 x Morden	-7.81**	-8.50**	-25.91**	269 x EC.68415	-3.67**	-12.50**	-14.98**	269 x Genepool	-9.85**	-11.59**	-25.91**
270 x Morden	-12.85**	-13.50**	-29.86**	270 x EC.68415	-14.22**	-22.08**	-24.29**	270 x Genepool	-11.33**	-13.04**	-27.13**
272 x Morden	-7.08**	-11.66**	-20.24**	272 x EC.68415	-10.39**	-13.75**	-16.19**	272 x Genepool	2.33**	-1.35**	-10.93**
275 x Morden	-11.66**	-20.24**	-20.24**	275 x EC.68415	-20.58**	-21.86**	-21.86**	275 x Genepool	-14.98**	-21.86**	-21.86**
276 x Morden	3.90**	4.93**	-13.77**	276 x EC.68415	-4.05**	-11.25**	-13.77**	276 x Genepool	-3.90**	-4.83**	-20.24**
277 x Morden	-14.80**	-16.50**	-32.39**	277 x EC.68415	-7.41**	-16.67**	-19.03**	277 x Genepool	-3.50**	-6.76**	-21.86**
278 x Morden	-42.21**	-16.50**	-32.39**	278 x EC.68415	-2.40**	-15.42**	-17.81**	278 x Genepool	-7.81**	-14.49**	-28.34**
284 x Morden	-1.90**	-7.17**	-16.19**	284 x EC.68415	-10.39**	-13.75**	-16.19**	284 x Genepool	-6.98**	-10.31**	-19.03**
286 x Morden	7.65**	-1.50**	-20.24**	286 x EC.68415	1.97**	-13.75**	-16.19**	286 x Genepool	16.04**	4.83**	-12.15**
288 x Morden	-4.93**	-6.76**	-21.86**	288 x EC.68415	-11.66**	-17.92**	-20.24**	288 x Genepool	2.90**	2.90**	-13.77**
289 x Morden	-15.63**	-16.26**	-31.17**	289 x EC.68415	-15.77**	-22.03**	-24.29**	289 x Genepool	-20.49**	-21.26**	-34.01**
290 x Morden	-7.69**	-10.00**	-27.13**	290 x EC.68415	-10.23**	-19.53**	-21.86**	290 x Genepool	9.05**	4.83**	-12.15**
290Ax Morden	-1.53**	-3.50**	-21.86**	290A xEC.68415	0.00	-11.25**	-13.77**	290Ax Genepool	0.15	-1.93**	-17.81**
292 x Morden	-11.64**	-16.50**	-32.39**	292 x EC.68415	1.97**	-13.75**	-16.19**	292 x Genepool	7.81**	0.00	-16.19**
294 x Morden	3.63**	0.00	-19.03**	294 x EC.68415	1.97**	22.08**	-24.29**	294 x Genepool	5.08**	0.00	-16.19**
296 x Morden	-12.81**	-14.49**	-28.34**	296 x EC.68415	-12.21**	-23.75**	-25.91**	296 x Genepool	1.45**	1.45**	-14.98**
298 x Morden	3.14**	-1.50**	-20.24**	298 x EC.68415	-17.94**	-15.67**	-19.03**	298 x Genepool	4.10**	-1.93**	-17.81**

*Significant at 5 per cent.
**Significant at 1 per cent.

Of the 66 hybrids studied, 49 showed negative heterosis over mid-parental values ranging from -0.64 to -19.41 per cent; however in 46 hybrids it was significant. The remaining 17 hybrids showed positive heterosis from 0.61 to 10.69 per cent (Table 7) of which in 12 hybrids it was significant.

As regards, higher parent and best parent heterosis all the 66 hybrids showed highly significant negative heterosis, the extent being -2.91 to -24.42 per cent over higher parent and -4.35 to -29.35 per cent over best parent.

2.5. Plant yield

The line 275 recorded highest yield (45.60 g) among the females and EC.68415 (47.58 g) among the males. However, the high yielding hybrid (49.32 g) involved the parents 263 and EC.68415.

Twelve hybrids out of the 66 showed positive heterosis over the mid-parent value ranging from 0.44 to 43.58 per cent, however only in 7 hybrids it was significant. The hybrid 263 x EC.68415 recorded higher significant positive heterosis. Fifty three hybrids showed negative heterosis of which in 45 hybrids it was significant. The extent of heterosis ranged from -2.09 to -47.72 per cent (Table 8). One hybrid 263 x Genepool did not show any heterosis.

Table 7. Heterosis in respect of capitulum diameter

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	-11.34**	-14.53**	-20.11**	256 x EC.68415	-11.69**	-17.93**	-17.93**	256 x Genepool	-7.14**	-12.36**	-15.22**
260 x Morden	1.28	-8.14**	-14.13**	260 x EC.68415	-2.48**	-14.67**	-14.67**	260 x Genepool	-6.33**	-16.85**	-19.57**
263 x Morden	5.23**	-6.39**	-12.50**	263 x EC.68415	10.69**	-4.35**	-4.35**	263 x Genepool	-0.64	-12.92**	-15.76**
263Ax Morden	+9.88**	-15.12**	-20.65**	263Ax EC.68415	-7.14**	-15.21**	-15.21**	263Ax Genepool	-11.51**	-17.98**	-20.65**
266 x Morden	-2.59**	-12.79**	-18.48**	266 x EC.68415	3.75**	-9.78**	-9.78**	266 x Genepool	-10.19**	-20.79**	-23.37**
269 x Morden	-9.81**	-14.53**	-20.11**	269 x EC.68415	-2.96**	-10.87**	-10.87**	269 x Genepool	-6.63**	-12.92**	-15.76**
270 x Morden	-9.26**	-14.53**	-20.11**	270 x EC.68415	-10.71**	-18.48**	-18.48**	270 x Genepool	-9.09**	-15.73**	-18.48**
272 x Morden	-1.86*	-8.14**	-14.13**	272 x EC.68415	-1.79*	-10.87**	-10.87**	272 x Genepool	3.66**	-4.49**	-7.61**
275 x Morden	-7.51**	-7.51**	-13.04**	275 x EC.68415	-8.99**	-11.96**	-11.96**	275 x Genepool	-10.86**	-12.36**	-15.22**
276 x Morden	-1.82*	-5.81**	-11.96**	276 x EC.68415	-6.43**	-13.04**	-13.04**	276 x Genepool	-2.98**	-8.43**	-11.41**
277 x Morden	-3.87**	-13.37**	-19.02**	277 x EC.68415	-8.69**	-20.11**	-20.11**	277 x Genepool	1.26	-10.11**	-13.04**
278 x Morden	-11.69**	-20.93**	-26.09**	278 x EC.68415	0.62	-12.50**	-12.50**	278 x Genepool	-5.73**	-16.85**	-19.56**
284 x Morden	-5.85**	-6.39**	-12.50**	284 x EC.68415	-10.67**	-13.59**	-13.59**	284 x Genepool	-10.92**	-12.92**	-15.76**
286 x Morden	1.83*	-2.91**	-9.24**	286 x EC.68415	2.94**	-4.89**	-4.89**	286 x Genepool	2.39**	-3.93**	-7.06**
288 x Morden	-11.31**	-13.37**	-19.02**	288 x EC.68415	-4.60**	-9.78**	-9.78**	288 x Genepool	-4.09**	-7.86**	-10.87**
289 x Morden	-9.58**	-12.21**	-17.93**	289 x EC.68415	-12.72**	-17.93**	-17.93**	289 x Genepool	-19.41**	-23.03**	-25.54**
290 x Morden	2.51**	-5.23**	-11.41**	290 x EC.68415	-4.85**	-14.67**	-14.67**	290 x Genepool	-1.85*	-10.67**	-13.59**
290Ax Morden	-3.18**	-11.63**	-17.39**	290Ax EC.68415	0.61	-10.87**	-10.87**	290Ax Genepool	-4.37**	-14.04**	-16.85**
292 x Morden	-2.48**	-8.72**	-14.67**	292 x EC.68415	-1.19	-10.33**	-10.33**	292 x Genepool	2.38**	-5.62**	-8.69**
294 x Morden	-0.65	-11.04**	-16.85**	294 x EC.68415	0.62	-12.50**	-12.50**	294 x Genepool	-5.73**	-16.85**	-19.56**
296 x Morden	-16.67**	-24.42**	-29.35**	296 x EC.68415	-4.32**	-15.61**	-15.61**	296 x Genepool	3.14**	-7.86**	-10.87**
298 x Morden	8.55**	-4.07**	-10.33**	298 x EC.68415	6.33**	-8.69**	-8.69**	298 x Genepool	-7.74**	-19.66**	-22.28**

*Significant at 5 per cent.
**Significant at 1 per cent.

Table 8. Heterosis in respect of plant yield

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	-21.08**	-33.05**	-39.81**	256 x EC.68415	-8.97**	-25.98**	-25.98**	256 x Genepool	-33.10**	-44.13**	-47.81**
260 x Morden	-20.04**	-38.43**	-44.64**	260 x EC.68415	-3.42	-28.27**	-28.27**	260 x Genepool	-16.85**	-36.81**	-40.98**
263 x Morden	2.69	-23.30**	-31.04**	263 x EC.68415	43.58**	3.66	3.66	263 x Genepool	0.00	-26.19**	-31.06**
263Ax Morden	-21.26**	-33.52**	-40.23**	263Ax EC.68415	15.13**	-6.79*	-6.79*	263Ax Genepool	-17.83**	-31.68**	-36.19**
266 x Morden	-16.83**	-39.11**	-45.26**	266 x EC.68415	0.44	-28.81**	-28.81**	266 x Genepool	2.33	-25.97**	-30.85**
269 x Morden	-4.43	-28.00**	-35.27**	269 x EC.68415	-17.87**	-40.23**	-40.23**	269 x Genepool	-19.90**	-40.41**	-44.35**
270 x Morden	-26.32**	-39.92**	-45.98**	270 x EC.68415	-33.56**	-47.94**	-47.94**	270 x Genepool	-28.11**	-42.23**	-46.05**
272 x Morden	-2.27	-31.60**	-38.50**	272 x EC.68415	-2.69	-33.86**	-33.86**	272 x Genepool	-4.87	-34.13**	-38.48**
275 x Morden	-35.64**	-37.63**	-40.23**	275 x EC.68415	-28.25**	-29.74**	-29.74**	275 x Genepool	-32.94**	-33.79**	-36.55**
276 x Morden	6.14*	-5.00	-14.58**	276 x EC.68415	-21.97**	-33.70**	-33.27**	276 x Genepool	-2.09	-13.82**	-19.50**
277 x Morden	-37.31**	-49.88**	-54.94**	277 x EC.68415	-25.93**	-43.02**	-43.02**	277 x Genepool	-6.19*	-26.05**	-30.94**
278 x Morden	-31.59**	-45.23**	-50.76**	278 x EC.68415	-2.70	-25.06**	-25.06**	278 x Genepool	5.16*	-16.99**	-22.47**
284 x Morden	-20.26**	-25.66**	-33.16**	284 x EC.68415	-19.25**	-28.24**	-28.24**	284 x Genepool	-33.06**	-38.06**	-42.73**
286 x Morden	-13.62**	-25.15**	-32.70**	286 x EC.68415	-11.40**	-26.50**	-26.50**	286 x Genepool	-5.17*	-19.13**	-24.46**
288 x Morden	-16.86**	-24.26**	-31.90**	288 x EC.68415	-20.96**	-31.27**	-31.27**	288 x Genepool	-18.84**	-27.31**	-32.11**
289 x Morden	-18.74**	-26.29**	- 33.72**	289 x EC.68415	-21.46**	-31.99**	-31.99**	289 x Genepool	-47.72**	-53.34**	-56.45**
290 x Morden	5.48*	-14.09**	- 22.76**	290 x EC.68415	-12.46**	-31.48**	-31.48**	290 x Genepool	-5.29**	-23.99**	-29.00**
290Ax Morden	-21.27**	-36.56**	-42.96**	290Ax EC.68415	2.96	-20.34**	-20.34**	290Ax Genepool	-4.08	-23.94**	-28.96**
292 x Morden	-34.37**	-44.09**	-49.73**	292 x EC.68415	-7.74**	-24.67**	-24.67**	292 x Genepool	-10.14**	-24.62**	-29.59**
294 x Morden	-13.56**	-24.29**	-31.92**	294 x EC.68415	-18.71**	-31.88**	-31.88**	294 x Genepool	-30.60**	-40.19**	-44.14**
296 x Morden	-12.67**	-35.72**	-42.20**	296 x EC.68415	-11.30**	-36.82**	-36.82**	296 x Genepool	11.88**	-18.63**	-24.00**
298 x Morden	1.88	-21.57**	-29.49**	298 x EC.68415	7.50**	-20.17**	-20.17**	298 x Genepool	-13.86**	-34.56**	-38.88**

*Significant at 5 per cent.
**Significant at 1 per cent.

Only one hybrid 263 x EC.68415 showed positive heterosis which however was not significant over higher parent. Sixty four hybrids showed negative heterosis ranging from -5.00 to -49.88 per cent over higher parent.

Sixty five out of 66 hybrids showed significant negative heterosis over best parent ranging from -6.79 to -54.94 per cent. One hybrid 263 x EC.68415 had shown positive heterosis but the value was not significant.

The line 263 performed better showing positive heterosis in combination with Morden and significant positive heterosis in combination with EC.68415 over mid-parent value. It also showed positive heterosis over higher and better parent in combination with EC.68415 (Table 8).

2.6. <u>Volume weight</u>

The line 275 (79.86 g) and Genepool (74.53 g) had highest volume weight recorded among females and males respectively. The hybrid 290 x EC.68415 had shown highest volume weight (85.47 g) among the hybrids.

Forty out of 66 hybrids showed positive heterosis over mid-parental value ranging from 0.16 to 18.54 per cent of which in 22 it was significant. The remaining 26 hybrids recorded negative heterosis ranging from -0.81 to -12.42 per cent; and in twelve of them it was significant (Table 9).

Twenty four hybrids showed positive heterosis over higher parent, and in 7 of them it was significant. The extent of heterosis ranged from 0.81 to 15.81 per cent. The remaining 42 hybrids showed negative heterosis ranging from -0.71 to -16.44 per cent, but in 30 of them only it was significant.

Four hybrids showed positive heterosis over best parent ranging from 0.18 to 7.02 per cent of which one hybrid (290 x EC.68415) was significant. Sixty two remaining hybrids showed negative heterosis ranging from -0.16 to -18.57 per cent and in 52 of them it was significant.

Line 296 performed better with all the three testers by giving positive heterosis over mid and higher parental values. Line 260 in combination with EC.68415 and Genepool showed significant positive heterosis over mid-parental value and positive heterosis over higher parent.

2.7. Test weight

The line 289 had the highest test weight (4.97 g) among the females and EC.68415 had the highest test weight (6.00 g)

Table 9. Heterosis in respect of volume weight

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	3.62	0.82	-3.21	256 x EC.68415	9.49**	7.43**	3.14	256 x Genepool	-5.25*	-6.57**	-10.31**
260 x Morden	-2.26	-5.10*	-13.81**	260 x EC.68415	5.60**	1.67	-6.05*	260 x Genepool	8.00**	4.12	-2.83
263 x Morden	7.51**	1.47	-7.84**	263 x EC.68415	-5.89**	-11.88**	-18.57**	263 x Genepool	1.31	-5.58*	- 11.88**
263Ax Morden	-6.37**	-8.21**	-16.64**	263Ax EC.68415	6.97**	3.97	-3.92	263Ax Genepool	-1.35	-4.56*	-10.93**
266 x Morden	-2.79	-8.68**	-17.07**	266 x EC.68415	-0.81	-7.59**	-14.60**	266 x Genepool	-1.06	-8.22**	-14.35**
269 x Morden	6.32**	3.23	-6.25*	269 x EC.68415	-1.86	-5.51*	-12.68**	269 x Genepool	3.44	-0.89	-7.50**
270 x Morden	2.72	-1.97	-10.97**	270 x EC.68415	-5.90**	-10.93**	-17.69**	270 x Genepool	-3.11	-8.63**	-14.73**
272 x Morden	6.86**	1.85	-7.50**	272 x EC.68415	1.02	-4.51*	-11.76**	272 x Genepool	7.13**	0.81	-5.92*
275 x Morden	-12.42**	-16.44**	-16.44**	275 x EC.68415	-7.16**	-10.68**	-10.68**	275 x Genepool	-1.28	-4.58*	-4.58*
276 x Morden	5.06*	2.67	-6.75**	276 x EC.68415	-1.73	-4.78*	-12.01**	276 x Genepool	-4.38*	-7.78**	-13.94**
277 x Morden	-5.97**	-9.94**	-10.68**	277 x EC.68415	8.23**	3.57	2.72	277 x Genepool	1.35	-1.64	-2.45
278 x Morden	1.38	-5.05*	-13.76**	278 x EC.68415	0.93	-6.10*	-13.22**	278 x Genepool	2.71	-4.87*	-11.22**
284 x Morden	5.59**	1.57	-0.16	284 x EC.68415	-6.59**	-9.39**	-10.68**	284 x Genepool	0.16	2.38	-4.04
286 x Morden	-5.42*	-8.86**	-17.23**	286 x EC.68415	-8.15**	-12.70**	-19.32**	286 x Genepool	-4.40*	-9.07**	-15.14**
288 x Morden	9.27**	1.93	-7.43**	288 x EC.68415	6.73**	-1.22	-8.72**	288 x Genepool	1.66	-6.35**	-12.60**
289 x Morden	8.76**	8.55**	-1.41	289 x EC.68415	2.45	1.49	-6.21*	289 x Genepool	-2.60	-3.97	-10.38**
290 x Morden	8.03**	6.44**	-3.33	290 x EC.68415	18.54**	15.81**	7.02**	290 x Genepool	1.02	-1.78	-8.34**
290Ax Morden	0.35	-3.33	-5.58*	290Ax EC.68415	-0.59	-3.13	-5.67*	290Ax Genepool	-1.27	-3.33	-5.87*
292 x Morden	3.18	-2.52	-12.26**	292 x EC.68415	2.01	-5.24*	-12.43**	292 x Genepool	9.13**	0.90	-5.91*
294 x Morden	13.98**	10.30**	0.18	294 x EC.68415	5.04*	0.81	- 6.84**	294 x Genepool	3.95	-0.71	-7.34**
296 x Morden	1.97	1.10	-8.18**	296 x EC.68415	8.20**	6.37**	-1.70	296 x Genepool	7.85**	5.50*	-1.54
298 x Morden	-2.04	-6.62**	-15.19**	198 x EC.68415	-3.08	-8.36**	-15.19**	298 x Genepool	4.08*	-2.05	-8.59**

*Significant at 5 per cent.
**Significant at 1 per cent.

among the pollen parents. The hybrid 263 x EC.68415 had the highest test weight (6.17 g) among the hybrids.

Twelve hybrids showed positive heterosis ranging from 0.22 to 28.27 per cent over mid-parent and in 8 of them it was significant and the hybrid 263 x EC.68415 recorded highest positive heterosis. Fifty two hybrids showed significant negative heterosis ranging from -0.57 to -26.14 per cent. Two out of 66 hybrids viz., 276 x Morden and 290A x Genepool did not show heterosis (Table 10).

One hybrid - 263 x EC.68415 - exhibited significant positive heterosis over higher parent and also over best parent. Remaining 65 hybrids showed significant negative heterosis ranging from -6.39 to -35.00 per cent over higher parent and from -10.00 to -38.33 per cent over best parent.

The line 296 showed significant positive heterosis over mid-parent value in combination with all the three testers. The line 263 also showed significant positive heterosis over mid-parent value, higher parent and best parent in combination with EC.68415 and over mid-parental value with Genepool.

2.8. Hull content

In sunflower low hull content is preferred as oil content is inversely related to hull content. The line 275

Table 10. Heterosis in respect of test weight

Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP	Crosses	Percentage over MP	Percentage over HP	Percentage over BP
256 x Morden	-15.67**	-30.20**	-34.50**	256 x EC.68415	-8.66**	-26.17**	-26.17**	256 x Genepool	-7.87**	-24.04**	-27.83**
260 x Morden	-8.07**	-23.09**	-27.83**	260 x EC.68415	-5.51**	-22.83**	-22.83**	260 x Genepool	-3.16**	-19.30**	-23.33**
263 x Morden	-9.03**	-28.42**	-32.83**	263 x EC.68415	28.27**	2.83**	2.83**	263 x Genepool	3.81**	-18.77**	-22.83**
263Ax Morden	-4.11**	-12.97**	-18.33**	263Ax EC.68415	-1.89**	-13.33**	-13.33**	263Ax Genepool	-6.21**	-15.26**	-19.50**
266 x Morden	-12.36**	-29.48**	-33.83**	266 x EC.68415	-10.19**	-29.40**	-29.50**	266 x Genepool	-1.97**	-21.58**	-25.50**
269 x Morden	-1.08**	-18.29**	-23.33 **	269 x EC.68415	-4.76**	-23.33**	-23.33**	269 x Genepool	-16.03**	-31.05**	-34.50**
270 x Morden	-22.03**	-28.95**	-33.33**	270 x EC.68415	-14.72**	-29.50**	-29.50**	270 x Genepool	-9.15**	-23.33**	-27.17**
272 x Morden	0.44	-18.83**	-23.83**	272 x EC.68415	-0.63*	-21.67**	-21.67**	272 x Genepool	-6.11**	-24.56**	-28.33**
275 x Morden	-19.89**	-24.87**	-29.50**	275 x EC.68415	-15.20**	-22.83**	-22.83**	275 x Genepool	-9.04**	-15.26**	-19.50**
276 x Morden	0.00	-9.41**	-15.00**	276 x EC.68415	-26.14**	-35.00**	-35.00**	276 x Genepool	-2.53**	-12.28**	-16.67**
277 x Morden	0.22	-20.60**	-25.50**	277 x EC.68415	0.43	-22.17**	-22.17**	277 x Genepool	-6.00**	-25.79**	-29.50**
278 x Morden	-24.49**	-34.28**	-38.33**	278 x EC.68415	-13.39**	-26.67**	-26.67**	278 x Genepool	-4.67**	-17.54**	-21.67**
284 x Morden	-3.61**	-14.74**	-20.00**	284 x EC.68415	-3.10**	-16.67**	-16.67**	284 x Genepool	-11.58**	-22.28**	-26.17**
286 x Morden	-12.06**	-24.87**	-29.50**	286 x EC.68415	-6.00**	-21.67**	-21.67**	286 x Genepool	-11.96**	-25.09**	-28.83**
288 x Morden	-12.78**	-23.62**	-28.33**	288 x EC.68415	-18.40**	-30.50**	-30.50**	288 x Genepool	-8.67**	-20.53**	-24.50**
289 x Morden	-0.57*	-6.39**	-12.17**	289 x EC.68415	-12.96**	-20.50**	-20.50**	289 x Genepool	-15.01**	-20.53**	-24.50**
290 x Morden	-5.82**	-19.54**	-24.50**	290 x EC.68415	0.60*	-16.17**	-16.17**	290 x Genepool	-9.20**	-22.81**	-26.67**
290Ax Morden	-10.00**	-28.07**	-25.00**	290Ax EC.68415	4.25**	-10.00**	-10.00**	290Ax Genepool	0.00	-11.75**	-16.17**
292 x Morden	-18.80**	-32.50**	-36.67**	292 x EC.68415	-5.35**	-23.33**	-23.33**	292 x Genepool	0.42	-17.02**	-21.17**
294 x Morden	-6.88**	-23.09**	-27.83**	294 x EC.68415	6.21**	-14.50**	-14.50**	294 x Genepool	-11.75**	-27.54**	-31.17**
296 x Morden	3.86**	-18.83**	-23.83**	296 x EC.68415	2.62**	-21.67**	-21.67**	296 x Genepool	8.35**	-15.79**	-20.00**
298 x Morden	-4.95**	-14.74**	-20.00**	298 x EC.68415	-4.40**	-16.67**	-16.67**	298 x Genepool	-21.26**	-29.82**	-33.33**

*Significant at 5 per cent.
**Significant at 1 per cent.

(21.22 per cent) and EC.68415 (23.43 per cent) had low hull content among females and males respectively. The hybrid 290 x Genepool (21.95 per cent) recorded lowest hull content among hybrids.

Thirty one out of 66 hybrids showed negative heterosis ranging from -0.58 to -19.22 per cent over mid-parental value, 26 of them had significant negative values. Remaining 35 hybrids exhibited positive heterosis, ranging from 0.47 to 26.78 per cent, and in 26 hybrids it was significant (Table 11).

Fourteen hybrids showed lesser hull content than the higher parent. Extent of negative heterosis was from -0.64 to -14.95 per cent and in 10 hybrids it was significant. None of them lines showed negative heterosis with EC.68415. Fifty one out of 66 hybrids exhibited positive heterosis ranging from 0.27 to 37.04 per cent, of which only in 5 hybrids it was not significant. One hybrid 256 x Morden did not show any heterosis positive or negative for this character over higher parent.

All the sixty six hybrids under study had more hull content than their best parent. They showed significant positive heterosis ranging from 2.73 to 38.97 per cent. The lines 294 and 298 did show significant negative heterosis over mid-parental value with all the three testers. The lines 294

Table 11. Heterosis in respect of hull content

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	-0.58	0.00	28.13**	256 x EC.68415	11.74**	20.74**	33.32**	256 x Genepool	-1.56	-0.64	24.46**
260 x Morden	1.34	20.49**	34.11**	260 x EC.68415	2.46*	2.86*	13.57**	260 x Genepool	-3.47**	2.37*	13.95**
263 x Morden	-6.22**	0.27	30.06**	263 x EC.68415	-1.42	15.24**	27.24**	263 x Genepool	-5.05**	3.70**	29.40**
263Ax Morden	6.03**	10.10**	32.51**	263Ax EC.68415	2.98**	7.59**	18.80**	263Ax Genepool	4.07**	5.99**	27.56**
266 x Morden	-2.84**	3.31**	33.93**	266 x EC.68415	2.02*	18.48**	30.82**	266 x Genepool	-8.28**	-0.91	24.17**
269 x Morden	-2.91**	4.16**	17.86**	269 x EC.68415	0.88	2.13	12.77**	269 x Genepool	-2.02*	2.99*	16.54**
270 x Morden	0.60	3.02*	33.55**	270 x EC.68415	10.17**	22.87**	35.67**	270 x Genepool	-1.73	2.60*	28.03**
272 x Morden	7.02**	19.38**	25.68**	272 x EC.68415	8.35**	10.97**	16.82**	272 x Genepool	9.18**	19.29**	25.58**
275 x Morden	19.38**	37.04**	37.04**	275 x EC.68415	6.99**	12.53**	12.53**	275 x Genepool	1.09	13.62**	13.62**
276 x Morden	1.98*	11.69**	21.58**	276 x EC.68415	26.78**	27.66**	38.97**	276 x Genepool	-2.02*	5.15**	14.46**
277 x Morden	14.50**	27.53**	34.68**	277 x EC.68415	12.91**	15.48**	21.96**	277 x Genepool	-2.54*	6.29**	12.25**
278 x Morden	-4.73**	0.63	30.11**	278 x EC.68415	2.49*	17.84**	30.11**	278 x Genepool	-15.42**	-9.06**	13.47**
284 x Morden	-4.85**	8.20**	10.03**	284 x EC.68415	0.89	5.19**	6.97**	284 x Genepool	9.74**	22.19**	24.27**
286 x Morden	-6.43**	-1.71	27.42**	286 x EC.68415	0.82	15.58**	27.61**	286 x Genepool	-15.64**	-9.59**	12.81**
288 x Morden	0.47	1.13	31.10**	288 x EC.68415	0.89	10.45**	21.96**	288 x Genepool	-5.74**	-3.25**	20.73**
289 x Morden	-3.59**	1.69	18.80**	289 x EC.68415	6.34**	9.43**	20.83**	289 x Genepool	-11.39**	-8.39**	7.02**
290 x Morden	-8.21**	-5.19**	15.31**	290 x EC.68415	0.49	5.59**	16.58**	290 x Genepool	-16.03**	-14.95**	3.44**
290Ax Morden	3.57**	10.59**	19.04**	290Ax EC.68415	2.12*	3.41**	11.31**	290Ax Genepool	3.77**	12.04**	20.59**
292 x Morden	2.41**	6.16**	28.23**	292 x EC.68415	4.73**	9.64**	21.06**	292 x Genepool	-8.41**	-6.90**	12.44**
294 x Morden	-13.95**	-4.98**	23.18**	294 x EC.68415	-14.89**	2.94*	13.66**	294 x Genepool	-19.22**	-8.87**	13.71**
296 x Morden	-0.78	7.46**	19.46**	296 x EC.68415	6.38**	6.74**	17.86**	296 x Genepool	5.27**	11.69**	24.17**
298 x Morden	-5.74**	-1.96	17.67**	298 x EC.68415	-8.03**	4.65**	5.27**	298 x Genepool	-16.06**	-15.41**	2.73*

*Significant at 5 per cent.
**Significant at 1 per cent.

and 286 showed significant negative heterosis over mid-parental and higher parental values in combination with Morden and Genepool.

2.9. Oil content

The line 278 recorded highest oil content (47.60 per cent) among females and genepool recorded highest oil content (44.20 per cent) among the pollen parents. The hybrid 260 x EC.68415 exhibited highest oil content (47.10 per cent) among the hybrids.

Forty nine out of 66 hybrids exhibited positive heterosis over mid-parental values; however in 38 hybrids only it was significant. Extent of heterosis was from 0.01 to 22.81 per cent. The hybrid 272 x EC.68415 recorded highest positive heterosis. Seventeen hybrids showed negative heterosis ranging from -0.03 to -11.25 per cent. Of them, twelve hybrids showed significant negative heterosis (Table 12).

Twenty six hybrids showed positive heterosis over higher parent ranging from 1.06 to 18.84 per cent and in 21 hybrids it was significant. The hybrid 260 x EC.68415 recorded highest positive heterosis. Thirty seven of the remaining forty hybrids showed negative heterosis ranging

Table 12. Heterosis in respect of oil content

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	1.21	-1.64	-12.26**	256 x EC.68415	4.31**	3.74**	-12.68**	256 x Genepool	-3.86**	-8.37**	-14.91**
260 x Morden	0.08	-3.83**	-14.22**	260 x EC.68415	18.40**	18.84**	-1.05	260 x Genepool	10.62**	5.27**	-2.24
263 x Morden	9.34**	2.21	-8.88**	263 x EC.68415	7.26**	3.60**	-13.73**	263 x Genepool	-0.03	-8.52**	-15.06**
263Ax Morden	-5.12**	-5.79**	-15.96**	263Ax EC.68415	11.02**	8.05**	-4.97**	263Ax Genepool	-0.09	-3.55**	-10.44**
266 x Morden	1.41	-8.54**	-18.42**	266 x EC.68415	9.62**	2.01	-15.06**	266 x Genepool	9.55**	-2.94*	-9.87**
269 x Morden	3.60**	0.00	-10.02**	269 x EC.68415	11.59**	10.76**	-6.38**	269 x Genepool	3.45**	-1.19	-8.25**
270 x Morden	0.02	-7.44**	-17.43**	270 x EC.68415	5.66**	0.00	-16.11**	270 x Genepool	1.62	-7.85**	-14.43**
272 x Morden	7.72**	-5.08**	-15.33**	272 x EC.68415	22.81**	11.53**	-7.14**	272 x Genepool	11.36**	-3.55**	-10.44**
275 x Morden	-3.84**	-7.96**	-10.23**	275 x EC.68415	4.88**	-2.79*	-5.18**	275 x Genepool	-11.25**	-3.51**	-5.88**
276 x Morden	0.02	-1.58	-8.82**	276 x EC.68415	6.54**	1.13	-6.30**	276 x Genepool	1.92	1.81	-5.46**
277 x Morden	-4.42**	-4.47**	-14.78**	277 x EC.68415	9.01**	5.42**	-6.02**	277 x Genepool	7.82**	5.65**	-1.89
278 x Morden	-10.00**	-18.98**	-27.73**	278 x EC.68415	12.19**	4.21**	-13.23**	278 x Genepool	4.42**	-7.62**	-14.22**
284 x Morden	-2.73*	-7.98**	-7.98**	284 x EC.68415	13.64**	4.11**	4.11**	284 x Genepool	1.96	-1.68	-1.68
286 x Morden	-4.67**	-5.01**	-15.27**	286 x EC.68415	-5.03**	-7.89**	-18.42**	286 x Genepool	-2.82*	-5.06**	-11.84**
288 x Morden	-0.07	-4.85**	-15.12**	288 x EC.68415	7.76**	6.81**	-11.07**	288 x Genepool	-0.07	-6.65**	-13.31**
289x Morden	8.69**	5.74**	-5.67**	289 x EC.68415	6.61**	5.90**	-10.65**	289 x Genepool	5.90**	1.06	-6.15**
290 x Morden	10.51**	4.71**	-6.59**	290 x EC.68415	21.18**	18.67**	-1.19	290 x Genepool	6.32**	-1.13	-8.19**
290A xMorden	-1.18	-1.41	-12.05**	290Ax EC.68415	-2.88*	-5.91**	-16.47**	290Ax Genepool	-2.31*	-4.45**	-11.28**
292 x Morden	0.04	-3.83**	-14.22**	292 x EC.68415	5.66**	5.54**	-12.96**	292 x Genepool	6.02**	-0.04	-7.56**
294 x Morden	3.50**	-1.86	-12.45**	294 x EC.68415	16.78**	14.45**	-4.70**	294 x Genepool	1.70	-5.36**	-12.12**
296 x Morden	2.86*	-1.01	-11.70**	296 x EC.68415	13.91**	13.37**	-5.60**	296 x Genepool	5.67**	-0.02	-7.35**
298 x Morden	0.01	0.00	-10.65**	298 x EC.68415	6.23**	2.68*	-8.40**	298 x Genepool	5.83**	3.75**	-3.65**

*Significant at 5 per cent.
**Significant at 1 per cent.

from -0.02 to -8.54 per cent, and in 27 it was significant. Three hybrids did not show heterosis.

Sixty five out of 66 hybrids showed negative heterosis over best parent ranging from -1.05 to -27.73 per cent and 63 of them exhibited significant values. One hybrid - 284 x EC.68415 - recorded significant positive heterosis.

The line 272 showed significant positive heterosis over mid-parental value in combination with all the three testers. The line 277 exhibited significant positive heterosis over mid-parental value and higher parent in combination with EC.68415 and Genepool. Line 284 with EC.68415 recorded significant positive heterosis over mid-parent, higher parent and best parent values. Line 289 with all the three testers showed significant positive heterosis over mid and higher parental values.

2.10. Oil yield per plant

The line 275 (19.08 g) and EC.68415 (18.92 g) recorded highest oil yield per plant among females and males respectively, and the hybrid 263 x EC.68415 recorded highest oil yield per plant (18.28 g) among the hybrids.

Sixteen out of 66 hybrids exhibited significant positive heterosis over mid-parental values, ranging from 2.66 to 40.80 per cent. The hybrid 263 x EC.68415 recorded highest positive heterosis. Forty nine hybrids showed negative heterosis, ranging from -0.07 to -44.90 per cent, of them in 46 it was significant. One hybrid 276 x Genepool did not show heterosis (Table 13).

The hybrid 276 x Morden recorded significant positive heterosis over higher parent. Remaining 65 hybrids exhibited negative heterosis ranging from -2.70 to -53.09 per cent, of them except one hybrid (290 x Morden) others showed significant negative values.

All the hybrids exhibited significant negative heterosis over best parent ranging from -4.19 to -62.10 per cent. The lines 263, 272 and 298 in combination with Morden and EC.68415 showed highly significant positive heterosis over mid-parental values.

3. Combining ability variance

The variances were partitioned into variances due to general combining ability (GCA) and specific combining ability (SCA). GCA and SCA variances for ten characters under study are detailed in Table 14.

It could be inferred from the table that non-additive gene action is more prominent for seven out of ten characters

Table 13. Heterosis in respect of oil yield per plant

Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP	Crosses	Percentage over MP	HP	BP
256 x Morden	-16.92**	-28.94**	-43.65**	256 x EC.68415	-10.51**	-29.80**	-30.39**	256 x Genepool	-36.31**	-48.78**	-52.56**
260 x Morden	-17.33**	-36.02**	-49.26**	260 x EC.68415	6.61**	-23.30**	-23.95**	260 x Genepool	-10.24**	-34.06**	-38.94**
263 x Morden	15.50**	-15.33**	-32.86**	263 x EC.68415	40.83**	-3.38**	-4.19**	263 x Genepool	-3.07*	-32.20**	-37.21**
263Ax Morden	-21.83**	-32.31**	-46.33**	263Ax EC.68415	21.41**	-3.80*	-4.61**	263Ax Genepool	-19.06**	-34.18**	-39.04**
266 x Morden	-13.65**	-39.39**	-51.93**	266 x EC.68415	-0.07	-34.35**	-34.90**	266 x Genepool	8.07**	-27.27**	-32.65**
269 x Morden	3.39**	-21.48**	-37.73**	269 x EC.68415	-15.08**	-39.90**	-40.40**	269 x Genepool	-18.33**	-41.02**	-45.38**
270 x Morden	-23.48**	-39.72**	-52.20**	270 x EC.68415	-35.23**	-52.69**	-53.09**	270 x Genepool	-28.35**	-46.51**	-50.47**
272 x Morden	5.77**	-29.80**	-44.33**	272 x EC.68415	4.85**	-33.82**	-34.38**	272 x Genepool	-0.08	-36.55**	-41.24**
275 x Morden	-35.73**	-42.40**	-42.40**	275 x EC.68415	-28.47**	-28.77**	-28.77**	275 x Genepool	-34.02**	-36.47**	-36.47**
276 x Morden	11.22**	4.82**	-16.87**	276 x EC.68415	-20.91**	-32.45**	-33.01**	276 x Genepool	0.00	-12.11**	-18.60**
277 x Morden	-30.59**	-48.11**	-58.85**	277 x EC.68415	-17.48**	-42.38**	-42.87**	277 x Genepool	9.14**	-22.29**	-28.03**
278 x Morden	-37.40**	-52.11**	-62.10**	278 x EC.68415	-1.63	-30.07**	-30.66**	278 x Genepool	5.38**	-23.54**	-29.19**
284 x Morden	-18.47**	-18.47**	-33.85**	284 x EC.68415	-12.25**	-19.39**	-20.07**	284 x Genepool	-31.52**	-35.08**	-39.88**
286 x Morden	-14.65**	-23.79**	-39.57**	286 x EC.68415	-20.37**	-35.14**	-35.69**	286 x Genepool	-8.11**	-23.14**	-28.82**
288x Morden	-14.00**	-22.07**	-38.20**	288 x EC.68415	-20.11**	-34.09**	-34.64**	288 x Genepool	-18.89**	-31.23**	-36.32**
289 x Morden	-8.08**	-15.86**	-33.28**	289 x EC.68415	-21.21**	-34.46**	-35.01**	289 x Genepool	-44.90**	-52.85**	-56.34**
290 x Morden	18.32**	-2.70	-22.85**	290 x EC.68415	-3.41**	-26.84**	-27.46**	290 x Genepool	-3.20*	-24.90**	-30.45**
290Ax Morden	-18.30**	-32.45*	-44.43**	290Ax EC.68415	-6.03**	-28.43**	-29.03**	290Ax Genepool	-6.38**	-26.99**	-32.38**
292 x Morden	-31.51**	-41.96**	-53.98**	292 x EC.68415	-9.44**	-29.59**	-30.18**	292 x Genepool	-5.81**	-24.90**	-30.45**
294 x Morden	2.66*	-10.77**	-29.24**	294 x EC.68415	-12.09**	-30.07**	-30.66**	294 x Genepool	-30.09**	-42.95**	-47.16**
296 x Morden	-7.36**	-31.85**	-45.96**	296 x EC.68415	-6.68**	-35.78**	-36.32**	296 x Genepool	14.35**	-19.75**	-25.68**
298 x Morden	7.43**	-15.00**	-32.59**	298 x EC.68415	8.43**	-20.50**	-21.17**	298 x Genepool	3.29**	-32.03**	-37.05**

*Significant at 5 per cent.
**Significant at 1 per cent.

Table 14. Variances due to general and specific combining ability

Character	Variance due to gca	Variance due to sca	gca : sca
No. of days taken to 50% flowering	5.039	4.294	1:0.852
Plant height	133.172	66.533	1:0.499
Stem girth	0.0049	0.0056	1:1.143
Capitulum diameter	0.143	0.008	1:0.056
Plant yield	4.357	14.185	1:3.256
Volume weight	0.706	8.578	1:12.150
Test weight	0.0204	0.1152	1:5.647
Hull content	0.746	1.130	1:1.515
Oil content	1.352	1.672	1:1.237
Oil yield per plant	0.979	2.445	1:2.497

under study namely, stem girth, plant yield, volume weight, test weight, hull content, oil content and oil yield per plant as the variances due to SCA were higher in these characters. But the remaining three characters - Number of days taken to 50 per cent flowering, plant height and capitulum diameter - have higher variances due to GCA compared to SCA suggesting the operation of additive gene action. The ratio between GCA and SCA variances was least (1:0.056) for the character volume weight and highest (1:12.150) for volume weight among the characters studied.

4. Combining ability effects

The general combining ability effects for lines and testers pertaining to ten characters are presented in Table 15.

The lines 277, 289, 266, 290, 278, 260, 269, 270 and 290A showed significant negative effects while the lines 286, 292, 298, 276 and 294 showed significant positive effects for number of days taken to 50 per cent flowering. The lines 286, 294, 263A, 298 and 276 showed high gca effects for plant height. The lines 289, 270, 260, 277, 256 and 269 exhibited significant gca effects for dwarfness. The lines 272, 276 and 286 showed high gca effects for stem girth while the lines 289, 270, 260 and 278 had significant negative gca effects for

Table 15. General combining ability effects for female and male parents

Parents	No.of days taken to 50% flowering	Plant height	Stem girth	Capitulum diameter	Plant yield	Volume weight	Test weight	Hull content	Oil content	Oil yield per plant
256	-0.63	-8.54**	-0.06	-0.52	-1.94	4.27**	-0.32*	1.54**	-1.45*	-1.14*
260	-1.41**	-4.22	-0.12*	-0.18	-1.98	0.99	-0.03	-0.17	2.09**	-0.22
263	0.48	-3.42	0.06	0.79*	6.80**	-3.16**	0.40**	1.59**	-1.09	2.19**
263A	0.70	12.34**	0.05	0.68	2.88*	-1.35	0.43**	1.04*	-0.11	1.18*
266	-1.85**	-11.34**	0.00	-0.40	-0.56	-5.22**	-0.33*	1.75**	-2.00**	-0.68
269	-1.18*	-7.12*	-0.02	-0.09	-2.93*	0.01	-0.17	-1.20*	0.95	-0.94
270	-1.07*	-11.58**	-0.14**	-0.73*	-6.12**	-4.52**	-0.35**	2.34**	-2.74**	-2.99**
272	-0.07	1.47	0.13*	0.77*	-1.50	0.32	-0.03	0.28	-0.35	-0.71
275	0.48	2.18	0.00	0.29	-0.81	-1.41	0.01	-0.06	1.49*	0.06
276	2.03**	8.13*	0.13*	0.54	5.39**	-1.67	0.11	0.77	1.60**	2.55**
277	-2.52**	-8.93**	-0.08	-0.43	-4.36**	4.26**	-0.09	0.34	1.26*	-1.34*
278	-1.63**	-4.66	-0.12*	-0.78*	0.49	-3.14**	-0.28*	0.68	-3.88**	-0.84
284	-0.52	-2.21	0.09	-0.20	-0.43	5.00**	0.19	-1.61**	3.99**	0.94
286	5.03**	19.31**	0.12*	1.45**	2.81*	-6.73**	-0.15	0.26	-2.35**	0.28
288	0.48	3.72	0.06	0.35	0.96	-0.62	-0.22	0.68	-1.39*	-0.03
289	-2.07**	-20.88**	-0.21**	-0.98*	-3.30**	2.24*	0.30*	-1.23*	1.30*	-1.02*
290	-1.74**	5.09	0.02	0.33	2.87*	5.79**	0.10	-2.03**	2.33**	1.77**
290A	-1.07*	2.92	0.08	-0.01	1.43	2.25*	0.43**	-0.93*	-1.44*	0.04
292	2.81**	2.09	-0.01	0.73*	-0.42	-1.09	-0.17	-0.17	-0.64	-0.37
294	1.48**	13.82**	0.03	-0.22	-1.04	3.30**	-0.02	-0.96*	0.22	0.09
296	-0.07	2.78	-0.05	-0.66	-0.26	3.99**	0.14	-0.18	0.95	0.04
298	2.37**	9.07**	0.05	0.23	2.03	-3.37**	0.01	-2.72**	1.26*	1.13*
Morden	-2.67**	-13.57**	-0.08**	-0.31*	-1.91**	-0.28	-0.14**	0.96**	-1.31**	-1.02**
EC.68415	1.93**	10.07**	0.07**	0.44**	2.61**	0.21	0.19**	-0.14	0.69**	1.17**
Genepool	0.74**	3.50**	0.01	-0.13	-0.69	0.07	-0.05	-0.82**	0.62**	-0.15
C.D.										
Females at 5%	0.94	6.03	0.10	0.73	2.32	1.82	0.24	0.89	1.12	1.01
at 1%	1.33	8.53	0.14	1.03	3.28	2.57	0.34	1.27	1.58	1.43
Males at 5%	0.35	2.23	0.04	0.27	0.85	0.67	0.09	0.33	0.41	0.37
at 1%	0.49	3.15	0.05	0.38	1.21	0.95	0.13	0.47	0.58	0.53

this character. Lines 286, 263, 272 and 292 had high gca effects and the lines 289, 278, 270 had significant negative gca effects for capitulum diameter. The lines 263, 276, 263A, 290 and 286 had significant gca effects for the character plant yield, whereas the lines 270, 277, 289 and 269 had significant negative effects. The lines 290, 284, 277, 256, 294, 290A had high gca effects, while the lines 286, 266, 270, 298, 278 and 263 had significant negative gca effects for volume weight. Lines 290A, 263A, 263, 289 exhibited high gca effects for test weight, whereas the lines 280, 266, 256, 289 and 278 showed significant negative gca effects for this character. The lines which have significant negative gca effects for hull content were 298, 290, 284, 289, 269, 294 and 290A, whereas the lines which had significant positive effects for this character were 270, 266, 263, 256 and 263A. The lines 284, 290, 260, 276, 275, 289 and 298 had high gca effects for oil content while the lines 278, 270, 286, 266, 256, 290A and 286 had significant negative gca effects for this character. With respect to oil yield per plant the lines 276, 263, 290, 263A and 298 exhibited high gca effects whereas the lines 270, 256, 277 and 289 had significant negative gca effects.

Among the three males Morden showed significant negative gca effects for all the characters studied except for hull content in which it showed high positive gca effects. EC.68415 exhibited high significant positive effects for all the characters except hull content and volume weight. It showed non-significant positive gca effect and non-significant negative gca effect for volume weight and hull content respectively. Genepool had high gca effects for number of days taken to 50 per cent flowering, plant height and oil content and it had significant negative gca effect for hull content. It had non-significant positive gca effects for the characters stem girth and volume weight, non-significant negative gca effects for the characters capitulum diameter, plant height, test weight and oil yield per plant.

The specific combining ability effects (sca) pertaining to ten characters studied are presented in Table 16.

Lines 294, 289, 275 and 292 with Morden and 284, 270, 298, 260, 269 with EC.68415 and 288, 289, 290, 256 and 276 with Genepool had high sca effects for number of days taken to 50 per cent flowering. Lines 276, 298, 284 with Morden and 294, 289, 292, 275 with EC.68415 and 260, 270, 269 with Genepool had significant negative sca effects for this character. Six lines with Morden, seven with EC.68415 and six with Genepool also had positive sca effects and the rest had negative effects.

Table 16. Specific combining ability effects of the hybrids

Crosses	No.of days taken to 50% flowering	Plant height	Stem girth	Capitulum diameter	Plant yield	Volume weight	Test weight	Hull content	Oil content	Oil yield per plant
256 x Morden	-1.21	1.88	0.06	-0.09	0.99	0.48	-0.16	-1.06	1.79	0.74
260 x Morden	-1.10	0.06	-0.01	0.67	-1.27	-5.20**	-0.05	1.92*	-2.68*	-1.24
263 x Morden	0.33	-0.23	-0.00	-0.01	-3.59	4.22*	-0.78**	-0.71	0.40	-0.53
263Ax Morden	0.45	0.19	0.01	-0.03	-4.03*	-4.62**	0.06	0.36	-1.30	-2.09*
266 x Morden	-0.33	1.08	-0.03	0.09	-2.98	-1.12	-0.11	-0.05	-0.57	-1.29
269 x Morden	0.00	10.46*	-0.01	-0.52	4.14*	2.33	0.36	-0.50	0.45	1.67
270 x Morden	-0.77	-7.18	0.01	0.11	2.23	3.07	-0.05	-0.71	0.82	0.96
272 x Morden	-1.11	-12.12*	-0.02	-0.28	1.16	0.99	0.19	-0.33	-0.76	0.18
275 x Morden	2.33**	26.46**	0.10	0.39	-0.33	-4.40*	-0.19	2.43**	-0.18	-0.22
276 x Morden	-2.88**	-4.29	0.13	0.34	5.65*	3.59*	0.57*	-1.68*	0.37	2.15*
277 x Morden	0.67	-3.02	-0.11	0.01	-3.78	-5.47**	0.15	1.53	-2.12*	-1.95*
278 x Morden	0.11	-8.10	-0.07	-0.93	-6.65**	-0.53	-0.42*	0.21	-3.13**	-3.07**
284 x Morden	-1.99*	-3.54	0.10	0.58	2.65	2.18	0.19	-1.75*	-1.60	0.52
286 x Morden	0.78	8.63	-0.01	-0.06	-0.38	0.28	-0.02	0.06	1.26	0.09
288 x Morden	-0.99	3.82	0.00	-0.76	1.84	2.00	0.10	0.42	0.37	0.67
289 x Morden	2.23*	7.53	0.04	0.77	5.23*	3.95*	0.55*	-0.27	2.18*	2.60**
290 x Morden	-0.44	-10.24	-0.08	0.66	4.29*	-1.13	0.01	-0.21	0.70	1.79*
290Ax Morden	-0.11	1.92	-0.02	-0.11	-3.88	0.60	-0.33	-0.52	1.88	-0.97
292 x Morden	1.67*	1.04	-0.18*	-0.34	-5.25*	-1.38	-0.43*	0.66	0.05	-1.99*
294 x Morden	4.00**	9.02	0.10	0.20	3.84	4.15*	-0.06	0.38	0.02	2.25*
296 x Morden	-0.11	-8.33	-0.05	-1.65*	-1.82	-3.20*	0.02	-1.18	-0.34	-0.88
298 x Morden	-2.55**	-15.52**	0.05	0.96	1.93	-1.44	0.34	0.97	-0.35	0.57

Table 16 (Contd)

Crosses	No.of days taken to 50% flowering	Plant height	Stem girth	Capitulum diameter	Plant yield	Volume weight	Test weight	Hull content	Oil content	Oil yield per plant
256 x EC.58415	-0.82	1.24	-0.06	-0.46	3.04	5.06**	0.01	1.13	-0.40	1.08
260 x EC.68415	2.62**	2.12	0.01	-0.19	2.00	0.99	-0.08	-1.34	1.58	1.39
263 x EC.68415	0.73	-7.78	0.09	0.73	8.39**	-4.84**	1.02**	-0.21	-1.26	2.74**
263Ax EC.68415	-0.82	5.15	0.16	0.21	7.36**	5.04**	0.03	-1.45	1.91	3.66**
266 x EC.68415	1.40	12.04*	0.21*	0.93	0.31	0.38	-0.18	0.39	-0.98	-0.23
269 x EC.68415	2.39**	1.52	0.11	0.42	-2.74	-3.30*	0.03	-0.48	0.18	-1.02
270 x EC.68415	2.95**	7.47	0.00	-0.34	-3.21	-2.79	-0.16	0.83	-0.74	-1.39
272 x EC.68415	0.95	8.83	0.07	-0.44	-1.14	-2.89	-0.01	-1.11	1.13	-0.10
275 x EC.58415	-1.93*	-16.58**	-0.08	-0.17	0.12	-0.30	-0.12	-1.67*	0.21	0.17
276 x EC.68415	1.17	12.26*	-0.02	-0.61	-7.75**	-1.09	-0.95**	3.10**	-0.42	-3.11**
277 x EC.68415	0.07	-1.47	0.06	-0.34	-2.54	4.73**	0.02	-0.07	0.04	-1.09
278 x EC.68415	1.51	12.95*	0.14	0.81	1.06	-0.59	-0.05	1.31	1.76	0.73
284 x EC.68415	3.07**	3.91	-0.04	-0.38	0.46	-0.91	0.06	-1.31	2.14*	0.96
286 x EC.68415	-0.82	-6.61	-0.06	-0.02	-1.95	-1.87	0.11	1.20	-2.23*	-1.36
288 x EC.68415	-1.60	-9.62	-0.11	0.17	-2.38	0.48	-0.35	-0.42	0.30	-0.84
289 x EC.68415	-4.37**	-18.81**	0.06	0.01	1.54	-0.37	-0.27	1.26	-2.19*	0.07
290 x EC.68415	-1.71*	-0.99	-0.10	-0.70	-4.39*	6.63**	0.18	1.15	1.27	-1.27
290Ax EC.58415	0.28	-5.02	0.02	0.33	2.32	0.04	0.23	-1.06	-2.21*	0.14
292 x EC.68415	-2.60**	4.59	0.06	-0.30	2.14	-2.01	0.03	0.24	-1.34	0.35
294 x EC.68415	-4.93**	-5.42	-0.17*	0.24	-0.55	-1.94	0.40	-0.53	1.71	-0.21
296 x EC.68415	-0.37	-2.28	-0.14	0.08	-3.79	1.46	-0.17	-0.42	0.55	-1.23
298 x EC.68415	2.84**	3.23	-0.17	0.49	1.82	-2.03	0.21	-0.55	-1.09	0.56

Table 16 (Contd)

Crosses	No. of days taken to 50% flowering	Plant height	Stem girth	Capitulum diameter	Plant yield	Volume weight	Test weight	Hull content	Oil content	Oil yield per plant
256 x Genepool	2.04*	-3.13	0.00	0.62	-4.04*	-5.54**	0.14	-0.07	-1.40	-1.82*
260 x Genepool	-2.51**	-2.21	0.00	-0.51	-0.74	3.70*	0.12	-0.58	1.08	-0.14
263 x Genepool	-1.07	7.88	-0.09	-0.79	-4.81*	0.63	-0.27	0.92	-1.82	-2.22*
263Ax Genepool	0.37	-5.28	-0.18*	-0.21	-3.33	-0.42	-0.10	1.08	-0.61	-1.57
266 x Genepool	-1.07	-13.09*	-0.18*	-0.99	2.66	0.71	0.29	-0.34	1.55	1.52
269 x Genepool	-2.06*	-13.91*	-0.10	0.09	-1.40	0.97	-0.40	0.99	-0.64	-0.65
270 x Genepool	-2.18*	-0.36	-0.01	0.23	0.98	-0.28	0.21	-0.11	0.11	0.42
272 x Genepool	0.15	3.29	0.11	0.73	-0.03	1.89	-0.17	1.43	-0.37	-0.38
275 x Genepool	-0.40	-9.81	-0.02	-0.19	0.20	4.70**	0.31	-0.76	-0.84	0.03
276 x Genepool	1.71*	-7.97	-0.12	0.26	2.10	-2.50	0.38	-1.42	0.04	0.95
277 x Genepool	-0.73	5.49	0.05	0.93	6.42**	0.73	-0.18	-1.45	2.07*	3.05**
278 x Genepool	-1.62	-4.88	-0.06	0.08	5.59*	1.13	0.48*	-1.54	1.36	2.33*
284 x Genepool	-1.07	-0.43	-0.05	-0.20	-3.11	-1.27	-0.26	3.04**	-0.54	-1.49
286 x Genepool	0.04	-2.05	0.09	0.15	2.33	1.59	-0.08	-1.26	0.95	1.27
288 x Genepool	2.59**	5.74	0.10	0.55	0.53	-2.48	0.24	0.00	-0.69	0.16
289 x Genepool	2.15*	11.25*	-0.11	-0.81	-6.78**	-3.57*	-0.27	-0.99	0.01	-2.66**
290 x Genepool	2.15*	11.27*	0.19*	0.07	0.09	-5.49**	-0.21	-0.95	-1.99*	-0.52
290Ax Genepool	-0.13	2.64	-0.01	-0.19	1.56	0.01	0.09	1.58*	0.31	0.83
292 x Genepool	0.93	-5.54	0.12	0.57	3.11	3.39*	0.39	-0.90	1.28	1.62
294 x Genepool	0.92	-3.66	0.08	-0.48	-3.18	-2.20	-0.35	0.15	-1.74	-2.03*
296 x Genepool	0.43	10.58*	0.19*	1.56*	5.62*	1.73	0.16	1.59*	-0.21	2.11*
298 x Genepool	-0.29	12.19*	0.02	-1.42*	-3.75	3.47*	-0.55*	-0.47	1.23	-1.14
CD at 5%	1.63	10.45	0.17	1.26	4.02	3.15	0.41	1.55	1.94	1.75
CD at 1%	2.30	14.77	0.24	1.79	5.68	4.45	0.58	2.19	2.75	2.47

*Significant at 5 per cent.
**Significant at 1 per cent.

Lines 275, 269 with Morden, 278, 276, 266 with EC.68415 and 298, 296, 290, 289 with Genepool had high sca effects whereas lines 298, 272 with Morden; 275, 289 with EC.68415 and 266, 269 with Genepool had significant negative sca effects for plant height. Ten lines with Morden, eight with EC.68415 and five with Genepool had positive sca effects for the same character.

Only three hybrids i.e., 266 x EC.68415 and the lines 290, 296 with Genepool had high sca effects and 292 with Morden; 289 with EC.68415; 263A and 266 with Genepool had significant negative sca effects for stem girth. Eleven lines with Morden, eleven with EC.68415 and eight with Genepool also showed positive sca effects and the rest had negative sca effects for stem girth.

Only one hybrid - 296 x Genepool - had high sca effect and 296 with Morden and 298 with Genepool had significant negative sca effect for capitulum diameter. Eleven lines with Morden, eleven with EC.68415 and twelve with Genepool had significant positive sca effects and the rest had negative effects for capitulum diameter.

Lines 276, 289, 269 with Morden; 263, 263A with EC.68415 and 276, 296, 278 with Genepool showed high sca effects for plant yield whereas 278, 292, 263A with Morden; 276, 290 with EC.68415 and 289, 263, 256 with Genepool had significant negative sca effects. Seven lines with Morden, ten with EC.68415 and nine with Genepool had positive sca effects and rest of the hybrids had negative effects.

Morden with 263, 294, 289, 276 and EC.68415 with 290, 256, 263A, 277 and Genepool with 275, 260, 298, 292 showed high sca effects for volume weight, whereas lines 277, 260, 263A, 265, 296 with Morden; 263, 269 with EC.68415 and 256, 290, 289 with Genepool had significant negative sca effects. Eight lines with Morden, five with EC.68415 and nine with Genepool also had positive sca effects, remaining hybrids had negative effects.

Lines 276, 289 with Morden; 263 x EC.68415 and 278 x Genepool showed significant positive sca effects and the lines 263, 292, 278 with Morden, 278 x EC.68415 and 298 x Genepool had significant negative sca effects for test weight. Nine lines with Morden, eleven with EC.68415 and ten with Genepool also had positive sca effects.

Lines 284, 276 with Morden; hybrid 275 x EC.68415 have got high significant negative sca effect and the lines 275, 260 with Morden; the hybrid 276 x EC.68415 and lines 284, 296, 290A with Genepool had significant positive sca effects for the character hull content. Ten lines with Morden, twelve with EC.68415 and thirteen with Genepool also showed negative sca effects and rest had positive effects.

The hybrids 289 x Morden, 284 x EC.68415 and 277 x Genepool had high sca effects for oil content and the lines 278, 260, 277 with Morden; 286, 290A, 289 with EC.68415 and the hybrid 290 x Genepool had significant negative sca effects. Eleven lines with Morden, eleven with EC.68415 and ten with Genepool had positive sca effects for the oil content.

Four lines 289, 294, 276, 290 with Morden; two lines 263A, 263 with EC.68415 and three lines 277, 278, 296 with Genepool had high sca effects for oil yield per plant and 278, 263A, 292, 277 with Morden; 276 with EC.68415 and 289, 263, 294, 256 with Genepool had significant negative sca effects. Eight lines with Morden, nine with EC.68415 and eight with Genepool showed positive sca effects and remaining hybrids exhibited negative sca effects.

DISCUSSION

V. DISCUSSION

Breeders are mainly interested in the improvement of the ultimate yield and its components which are polygenically inherited and they do not behave as simple Mendelian traits. The component analysis is helpful in predicting which of the crosses are promising on the basis of the extent of additive genetic variance. The concept of general and specific combining ability (Sprague and Tatum, 1942), which are due to additive and non-additive gene action respectively, helps the breeder in assessing many lines of cross pollinated crop plants in a short period for commercial exploitation of heterosis.

The ultimate choice of the line to be used is determined by two factors: (i) Per se performance of the lines (ii) its behaviour in hybrid combination. Some idea on the usefulness of the parents may be obtained from their individual performance particularly in respect of yield components (Gilbert, 1958).

Genetic structure and divergence between the parents involved governs the nature of gene action. It is therefore necessary to assess the genetic potentialities of the parents in hybrid combination through systematic studies in relation to general and specific combining abilities. Line x tester analysis or inbred x variety or top cross, method has been extensively used in estimating the combining ability of lines in various crops like maize, bajra, sorghum, castor and sunflower.

In sunflower, the exploitation of heterosis and development of hybrids was made easy with the discovery of genetic and cytoplasmic male-sterility. The maximum utilization of heterosis in a crop is possible when variances due to both additive and non-additive gene action are fully exploited as they play a significant role in determining the magnitude of the expression of yield and its components. In the present investigation line x tester analysis was under taken for estimating the combining ability and magnitude of heterosis in twenty two inbred lines of sunflower. The results obtained are discussed in the following pages.

A. Magnitude of Heterosis

One of the objectives of the present study was to estimate the extent of heterosis for various characters. Three methods viz., deviation from mid, higher and best parent were employed to measure the magnitude of heterosis.

For days taken to 50 per cent flowering, all the hybrids showed positive heterosis over best parent. Thirty eight out of sixty six hybrids showed negative heterosis over mid-parent value suggesting the non-additive gene action for earliness in these crosses. Fourteen hybrids exhibited negative heterosis over higher parent, hence over dominance for earliness operated in these crosses. However 26 and 8 hybrids showed significant negative heterosis over mid and higher parental values respectively. Kovacik (1959, 1960), Meagu and Catrina (1963), Vulpe (1967, 1977), Vranceanu (1973), Semienchuk et al. (1974), Meagu (1970), Skoric (1977) and Voskoboinik (1978) reported that hybrids have flowered earlier. Seetharam et al. (1977) reported significant positive heterosis; Setty and Basudeo Singh (1977) observed heterosis upto -1.18 per cent in the best cross. Kurnik and Zelles (1962) and Kovacik and Skaloud (1978) reported delayed flowering in the hybrids.

For plant height, only 2 hybrids (263A x EC.68415 and 276 x EC.68415) showed non-significant positive heterosis over best parent. Forty hybrids had positive heterosis over mid-parental value indicating the non-additive gene action in those crosses, but the heterosis was significant only in 16 hybrids. Twenty hybrids showed positive heterosis over higher parental value upto 34.91 per cent suggesting the over dominance gene action for plant height in these crosses. Several authors have reported marked heterosis for plant height (Kurnik and Zelles, 1962; Schuster, 1964; Putt, 1966; Neagu, 1970; Velkov, 1970; Kloczowskii, 1971; Stoyanova et al., 1971; Kovacik and Skaloud, 1972 and 1978; Pogroletskii, 1973; Seetharam et al., 1977). On the contrary Vulpe (1967, 1977) and Skoric (1977) observed reduction in plant height in hybrids.

Negative heterosis over best parent was observed by all the 66 hybrids for the character stem girth. However, 20 hybrids out of 66 showed positive heterosis over mid-parental value suggesting the non-additive gene action for this character. Six hybrids showed positive heterosis over higher parent indicating over-dominance for higher stem girth in these crosses. Vulpe (1967) reported thicker stem in the hybrids. Seetharam et al. (1977) reported non-significant heterosis for this character.

All the 66 hybrids showed significant negative heterosis over higher and best parent values for capitulum diameter. Seventeen hybrids showed positive heterosis over mid-parental value upto 10.69 per cent and of these in 12 hybrids it was significant. So, non-additive gene action was found to be operating in these crosses for head diameter. Line 286 showed significant positive heterosis over the mid-parental value in combination with all the testers. Significant positive heterosis has also been observed by Schuster (1964) upto 60 per cent and upto 17 per cent by Setty and Basudeo Singh (1977) and various degrees by Pogorletskii (1973), Kovacik and Skaloud (1972, 1978), Vulpe (1977) and Seetharam et al. (1977).

For seed yield, only one hybrid 263 x EC.68415 showed non-significant positive heterosis over higher and best parent values. Positive heterosis over mid-parental values was observed in 12 hybrids and a maximum of 43.58 per cent was recorded in the cross 263 x EC.68415. This is suggestive of non-additive gene action for this character atleast in these crosses. The crosses which showed higher magnitude of heterosis for seed yield, in general also showed higher heterosis in important yield components like stem girth, volume weight, test weight, capitulum diameter. Marked heterosis for the character seed yield has also been reported by many authors (Habura, 1958; Kovacik, 1959 and 1960; Kurnik and Zelles, 1962; Popov and Lazarov, 1963; Neagu and Catrina, 1963; Schuster, 1964; Putt, 1966; Vulpe, 1967; Vranceanu, 1967 and 1973; Grebenjuk, 1967; Gundaev, 1968 and 1968a; Vranceanu and Stoenescu, 1969; Neagu, 1970; Vicentini, 1971; Leclercq, 1971; Klecsowskii, 1972 and 1975; Vol'F and Dumacheva, 1972; Kovacik and Skaloud, 1972 and 1978; Shuravina, 1972; Turchi, 1974; Fick and Zimmer, 1974; Voskoboinik and Soldatov, 1975; Paccucci and Alba, 1977;

Klimov and Ermoshin, 1977; Setty and Basudeo Singh, 1977; Seetharam *et al.*, 1977; Gorbachenko, 1977 and 1979; Voskoboinik, 1978; Vratario and Krizmanic, 1978; Singh *et al.*, 1978; Dedio, 1979; Frank, 1979; Rozhkova, 1978).

For volume weight, 4 hybrids showed positive heterosis over best parent and in the cross 290 x EC.68415 it was significant. Forty hybrids exhibited positive heterosis over mid-parental value suggesting non-additive gene action for this character in these crosses. Twenty four hybrids showed positive heterosis upto 15.81 per cent over higher parents revealing over domin nce in these crosses for volume weight. Line 296 performed well with all the three testers by showing positive heterosis over mid and higher parental values. Vulpe (1967) observed heterosis for hectolitre weight.

For test weight, only one hybrid - 263 x EC.68415 - showed significant positive heterosis over higher and best parent. Twelve hybrids showed positive heterosis over mid-parental values upto 28.27 per cent. This suggested again the operation of non-additive gene action in these crosses. Kurnik and Zelles (1962) observed heterosis upto 10.8 per cent for 100 seed weight. Vulpe (1967), Pogorletskii (1973), Seetharam *et al.* (1977), Vulpe (1977), Singh *et al.* (1978) have also reported significant positive heterosis for test weight.

Hull content is an important character that determines the oil content in the seed. All the 66 hybrids under study had more hull content than best parent. Thirty one hybrids showed negative heterosis upto -19.22 per cent over mid-parental values suggesting non-additive gene action in these crosses. But the negative heterosis was significant in 14 hybrids. In 14 hybrids negative heterosis for hull content was observed over higher parent upto -14.95 per cent indicating the operation of over dominance gene action in these crosses. Lines 294 and 298 showed significant negative heterosis over mid-parental values with all the three testers. Schuster (1964), Pogorletskii (1972), Setty and Basudeo Singh (1977) and Scerbak (1966) observed generally lower husk content in the hybrids, while Shuravina (1972) reported that the hybrids had higher hull contents.

Heterosis for oil content has been reported by several authors (Habura, 1958; Popov and Lazarov, 1963; Neagu and Catrina, 1963; Schuster, 1964; Vranceanu, 1967 and 1973; Vulpe, 1967; Shuravina, 1969 and 1972; Vranceanu and Stoenescu, 1969; Vol'F, 1969; Turchi, 1974; Pogorletskii, 1973; Kloczowskii, 1971 and 1972; Stoyanova et al., 1971 and 1975; Seetharam et al., 1977; Fick and Zimmer, 1974; Stoyanova and Ivanova, 1975; Bunnit et al., 1978; Skeric, 1977; Vratario and Krizmanic, 1978;

Frank, 1979; Rosoriteleva and Beletskii, 1979). In the present study only one hybrid (284 x EC.68415) recorded significant positive heterosis (4.11 per cent) over best parent. Forty nine out of 66 hybrids showed positive heterosis upto 22.81 per cent over mid-parental values indicating the predominance of non-additive gene action in the control of this character. Besides 26 hybrids exhibited positive heterosis over higher parental values upto 18.84 per cent. Hence overdominance gene action also cannot be ruled out. The lines 272 and 289 performed well with all the three testers. Kovacik and Skaloud (1978) and Turchi (1974) did not observe heterosis for oil content in the hybrids.

For oil yield per plant none of the 66 hybrids showed heterosis over best parent. Only one hybrid (276 x Morden) showed significant positive heterosis (4.82 per cent) over higher parent. Sixteen out of 66 hybrids showed significant positive heterosis over mid-parental values upto 40.80 per cent suggesting that non-additive gene action is operating in these crosses for oil yield. The lines 263, 272, 298 in combination with Morden and EC.68415 showed significant heterosis over mid-parental values. Heterosis for oil yield was reported by Vulpe (1967), Gundeav (1968, 1968a), Pogorletskii (1974), Semienchuk _et al._ (1974) and Gorbachenko (1979).

B. *Per se* performance and combining ability

Among the females, for the character days taken to 50 per cent flowering, the line 286 which was earliest in flowering and the line 292 which flowered later among the female lines tested showed high gca effects, while the line 277 which was intermediate showed significant negative effects. With respect to plant height, the line 256 (tallest) has significant negative gca effect compared to the line 275 (next tallest) which had slight positive effect, whereas the lines 260 and 276 (dwarfs) showed negative and significant positive effects respectively. The line 272, dwarfest among all female lines showed slight positive effect.

The line 275 which had thicker stem among the lines had very low gca effect. Line 256 (next best) showed slight negative effect, while the line 286 though its *per se* performance was low had higher gca effect.

As regards capitulum diameter the line 275 had higher mean diameter but it had slight positive gca effect. Line 298 having least mean diameter also had low positive effect. But the line 263 had slightly low mean diameter with high gca effect. Lines 286, 272, 263 and 292 though have average diameter have high gca effects.

Though the line 275 was the top yielder with highest yield per plant among all the lines, had negative gca effect. But the line 284 (next best) has got high positive effect. Line 272 (poor yielder) had negative effect. Lines 263, 276, 290, 263A and 286 have got high gca effects with average *per se* performance.

With respect to volume weight, line 275 possessed higher mean volume weight but showed negative effect while 277 and 284 (next best lines) showed higher gca effects. The lines 256, 290 and 296 also showed higher gca effects eventhough they had average volume weight.

As regards test weight, the line 289 performed well both in *per se* performance and gca effect. Lines 263A and 290A have average test weight but showed high effect. The line 296 with least test weight showed low effect.

The line 294 has got highest hull content but showed slight negative effect. Lines 266 and 270, though had slightly higher hull content also showed higher gca effects. The line 275 had lowest hull content and also negative effect.

The line 284 which had highest oil content also had high gca effect for this character. The line 272 with low oil content showed negative effect.

The line 275 was good in per se performance but the line 276 was good combiner for oil yield per plant. The line 272 had low per se performance and also had negative effect.

Among males EC.68415 was a good performer in 7 out of 10 characters studied. Morden was good in per se performance in respect of days taken to flowering whereas Genepool was good in per se performance for volume weight and oil content. EC.68415 had high gca effects for all the characters excepting volume weight and hull content. Morden had high gca effect for hull content but showed significant negative effects for days to 50 per cent flowering, plant height, stem girth, capitulum diameter, plant yield, test weight, oil content and oil yield per plant. Genepool showed high effects for plant height, days to 50 per cent flowering, oil content but showed significant negative effect for hull content.

Only a few hybrids showed significant sca effects for the characters studied. The hybrids 284 x Morden, 276 x Morden, 289 x EC.68415 and 260 x Genepool were better in performance for early flowering and also found to be the good specific combinations. The best combinations for tallness were the crosses of 275 and 269 with Morden, 278, 276, 266 with EC.68415 and 298, 296, 290 and 289 with Genepool, while for dwarfness the hybrids 298 x Morden, 275 x EC.68415, 289 x EC.68415, 266 x Genepool and 269 x Genepool showed significant effects. There was great variation for plant height among crosses. The hybrids 263A x EC.68415, 266 x EC.68415, 290 x Genepool and 296 x Genepool have performed well with respect to stem girth and also showed high sca effects. Only one hybrid -296 x Genepool - showed significant sca effect for capitulum diameter with fairly high mean diameter. For plant yield the combinations of 263 and 263A with EC.68415 showed high sca effects with high mean performance. Also the hybrids viz., 277, 278, 296 with Genepool and 276, 289, 290, 269 with Morden had good sca effects.

The combinations of 290, 256, 263A and 277 with EC.68415 have got high mean volume weight and also had good sca effects. The hybrids 275 x Genepool, and 263, 294, 289, 276 in combination with Morden and 260, 298 with Genepool also had high sca effect with average mean performance for volume weight. For test weight, 263 x EC.68415 had highest test weight among the hybrids and also highest sca effect. The hybrids 276 x Morden and 278 x Genepool also had good sca effect for test weight. With regard to hull content, 284 x Morden, 276 x Morden and 275 x EC.68415 had high negative sca effects and also low hull content. The hybrids 289 x Morden, 284 x EC.68415 and 277 x Genepool have got high mean performance for oil content and also high sca effects for this character. The hybrids 263A x EC.68415 and 263 x EC.68415 have given high oil yield per plant and also had high sca effect for this character. In addition to these hybrids, 277 x Genepool and 289, 294, 276 in combination with Morden and 278, 296 with Genepool have given moderate oil yield per plant with high sca effects.

In the present study the three testers used were well established varieties with broad genetic base. These varieties have been under continuous intensive selection to maintain their performance for both yield and oil productivity at a high level. Infact in these populations, the genetic basis of their high average performance has been due to exploitation of heterosis using the additive genetic component. The extent of heterosis observed in the top cross hybrids in the present study particularly for yield was not of very high order. One of the reasons for this is that the genetic background of the pollen involved in the pollination is not uniform in view of the highly heterogeneous nature of the tester parent. Naturally each plant in the top cross hybrid is genotypically and phenotypically different which is not the case in the single cross hybrid. This heterogeneity naturally brings down the extent the heterosis expressed for various characters.

Further in the present study the *per se* performance of lines was not related to their gca effects or their performance in combination with testers. So both *per se* performance and gca effects of the lines should be taken into consideration while selecting the lines for future use. Similar observations have been made by Pathak and Prakash Kumar (1975) in cotton.

Line 277 was a good combiner for early flowering while line 286 was a good combiner for late flowering, capitulum diameter and tallness, and the line 289 for dwarfness. Lines 276 and 272 were good combiners for thick stem and 263 was good combiner for plant yield and 290 for volume weight. Lines 263A and 290A were found to be good combiners for test weight and the lines 298, 284 and 276 were good combiners for low hull content, high oil content and high oil yield per plant respectively.

The lines 275, 284, 276, 289, 263A and 256 have showed higher *per se* performance for all the characters studied. Besides the lines particularly 284, 276, 289 and 263A also had good gca effects for important yield contributing characters like plant yield, test weight, head diameter, volume weight, oil content and oil yield. So these lines could be utilised further in breeding in the development of hybrids and/or synthetics.

C. Gene action

The estimates of variances due to GCA (general combining ability) and SCA (specific combining ability) revealed that the both additive and non-additive gene action play an important role in the control of characters studied.

Nature of gene action was preminently non-additive for seven out of ten characters studied namely, stem girth, plant yield, volume weight, test weight, hull content, oil content and oil yield per plant. Whereas in the remaining three characters viz., number of days taken to 50 per cent flowering, plant height and capitulum diameter the additive gene action was found to be important.

The ratio between variance due to GCA and SCA varied from character to character. The difference was minimum in the character capitulum diameter and maximum in volume weight.

Different results have been reported in the literature on the nature of gene action in the control of various characters in sunflower. Setty and Basudeo Singh (1977) observed non-additive gene action is more predominant for days to flowering, capitulum diameter, seed filling, seed yield and hull content, while additive gene action for 75 per cent maturity and plant height. Kovacik and Skaloud (1972) reported non-additive gene action was prominent for days to flowering, plant height, stem girth, capitulum diameter, volume weight and test weight whereas additive gene action for plant yield, hull content and oil content. Putt (1966) reported predominant role of additive gene action for days to maturity bushel weight and oil content, while Manjunath (1978) reported non-additive gene action for days to flowering, stem girth and 100 seed weight, but additive gene action for plant height, head diameter and plant yield.

Sudhakar (1978) reported predominant role of non-additive gene action for seedling height, plant height, days to flowering, stem girth, head diameter, days to 75 per cent maturity, number of filled seeds, volume weight and test weight, whereas additive gene action for number of leaves, plant yield, hull content and oil content.

SUMMARY

VI. SUMMARY

The present study was envisaged to assess the breeding value of 22 inbred lines of sunflower for their utility in the development of hybrids and synthetics. The inbreds used in study were viz., 256, 260, 263, 263A, 266, 269, 270, 272, 275, 276, 277, 278, 284, 286, 288, 289, 290, 290A, 292, 294, 296 and 298. They were crossed with three open pollinated varieties viz., Morden, EC.68415 and Genepool which were used as testers. The resulting 66 inbred x variety hybrids were studied for the amount of heterosis for 10 characters namely, days taken to 50 per cent flowering, plant height, stem girth, capitulum diameter, plant yield, volume weight, test weight, hull content, oil content and oil yield per plant and estimation of general combining ability of females and males besides the study nature of gene action in the control of these characters. The important findings were:

1. Among 22 inbred lines, 275, 284, 276, 289, 263A and 256 have showed higher *per se* performance for all the characters studied, besides they also had good gca effects for many yield contributing characters. So these lines could be utilized for the development of synthetics or hybrids.

2. Considerable heterosis was observed over mid-parental values for all the characters studied in different top crosses. Nevertheless heterosis over higher and best parents was observed only in a few crosses for most of the characters excepting capitulum diameter and plant yield.

3. For plant yield, the extent of heterosis observed over mid-parental values ranged from 0.44 to 43.58 per cent, for oil content from 0.01 to 22.81 per cent and for oil yield per plant from 2.66 to 40.80 per cent in different top crosses.

4. Hybrids having higher magnitude of desirable heterosis also had considerable mean performance with respect to other characters excepting plant height and hull content.

5. Heterosis in seed yield was expressed through heterosis in yield components like stem girth, capitulum diameter, volume weight and test weight.

6. Non-additive gene action was more important for seven out of ten characters studied viz., stem girth, plant yield, volume weight, test weight, hull content, oil content and oil yield per plant where as additive gene action was important for days to 50 per cent flowering, plant height and capitulum diameter.

7. Mean performance of the crosses had not corresponded with the *per se* performance of the parents but well related with the gca effects of their parents. So the crosses involving the parents with good gca effects yielded superior hybrids. Thus the performance of the cross could be predicted on the basis of gca effects of parents involved.

REFERENCES

VII. REFERENCES

*Alekseev, A.P., Voskoboinik, L.K. and Gorbachenko, F.I., 1979, (Combining ability of short forms of sunflower). Selestsiya i.semenovodstvo., No.4:7-9.

Anonymous, 1980, FAO monthly bulletin of statistics, 3(12):16.

*Anashcenko, A.V. and Roshkova, V.T., 1974, (A study of combining ability for seed yield in Sunflower). Trudy Po. Prikladnoi Botanike, Genetike i.Selektsii., 53:221-227.

*Anashcenko, A.V. and Roshkova, V.T., 1975, (The results of a study of heterosis in Sunflower). Trudy Po Prikladnoi Botanike, Genetike i.Selektsii., 55:134-142.

*Bunnit, B., Stoenescu, F.M. and Filipescu, H., 1978, (Heterosis of oil content and quality in Sunflower seeds). Probleme de Genetica Teoretica si Aplicata, 10(5):511-525.

*Burlov, V.V. and Buntovskii, R.P., 1978, (The general combining ability of inbred sunflower lines in diallel and poly cross). Nauchn-tekhn.byul.Vses Selekts genet.in-ta, 1(31):22-28.

*Dedio, W., 1979, (Performance of sunflower hybrids). In Technical and scientific papers, presented at Manitoba Agronomists annual conference, Dec.12 & 13, 1978, Winnipeg, Canada, 44-46(En).

*Ermakov, A.I. and Popova, E.V., 1974, (Changes in the content of fatty acids in the oil of sunflower seeds during hybridisation). Trudy Po Prikladnoi Botanike, Genetike i Selektsii, 53(3):255-261.

*Fick, G.N. and Zimmer, D.E., 1974, (Parental lines for production of confectionary sunflower hybrids). N.Dak.Fm.Res., 31(5):15-16.

*Fick, G.N. and Zimmer, D.E., 1974a, (RHA-271, RHA-273 and RHA-274 sunflower parental lines for producting downy mildew resistant hybrids). N.Dak.Fm.Res., 32(2):7-9.

*Frank, J., 1979, (Experiments on sunflower hybrids produced on the basis of genic and cytoplasmic male sterility). Novenytermeles, 28(1):1-5.

Gilbert, N.E., 1958, Diallel crosses in plant breeding. Heredity, 12:447-492.

*Gorbachenko, F.I., 1977, (Some results of studies on the problem of using heterosis in low growing forms of Sunflower). Genet. i Selektsiya Rast. Taz. dokl., 127(Ru).

*Gorbachenko, F.I., 1979, (Manifestation of heterosis after crossing short and tall forms of sunflower). Vestnik Sel' skokhozyaistvennoi Nauki, 8:35-40.

*Grebenjuk, G.K., 1967, (The results of a study of ways of using inbred lines of sunflower in breeding for heterosis). Bull. Akad. Sti. Res. Moldov., Ser. Biol. Selskohoz Nauk., 11:51-59.

*Gundeav, A.I., 1968, (Prospects for breeding sunflower for heterosis) from Referativny i. Zhurnal., 1.55.183(Ru).

*Gundeav, A.I., 1968a, (Obtaining interline hybrids of sunflower using male sterility) from Referativny i. Zhurnal., (1969) 10.55.166(Ru).

*Habura, C.H., 1958, (Heterosis in yield characters in Sunflower). Zuchter., 28:285-287.

Harinarayana, G., Kamalm, P. and Ganga Prasad Rao, N., 1976, A partially self compatible sunflower. Current Science, 45(16):598-599.

Hull, F.H., 1947, Cryptic homozygous lines. J. Amer. Soc. Agron., 39:438-439.

Kempthorne, O., 1957, An introduction to Genetic Statistics. The Iowa State University Press.

*Klimov, M.M., 1972, (The combining ability of sunflower varieties). Selektsiya i Semenovodstvo maslich. Kulture, Krasnodar 71-75(Ru).

*Klimov, M.M. and Ermoshin, S.A., 1977, (Inter-varietal hybridisation of sunflower). Selektsiya i semenovodstvo, 6:61-62.

*Kloczowskii, Z., 1967, (Investigations on methods of obtaining heterosis in the estimation of combining ability of certain varieties and lines of oil sunflower in reciprocal crosses). Aklimatyz Nasiennictwo.Hodowla Roslin, 11:235-237.

*Kloczowskii, Z., 1971, (A comparision of the F_1 and F_2 of interline sunflower hybrids grown for oil). Aklimatyz Nasiennictwo.Hodowla Roslin, 15(1):71-86.

*Kloczowskii, Z., 1972, (Prospects for breeding synthetic oil - sunflower varieties based on inbred lines). Biuletyn Instytutu Hodowli i Aklimatyzacja Roslin, No.5/6:227-230.

*Kloczowskii, Z., 1975, (A study of some characters in oil sunflower and their significance in the breeding of that crop in Poland). Hodowla Roslin.Aklimatyzacja i Nasiennictwo., 19(2):89-131.

*Kloczowskii, Z. and Kolodziejczak, A., 1967, (Variances of the more important character of the first generation of various types of hybrids of oil sunflower). Aklimatyz Nasiennictwo Hodowla Roslin., 6:95-99.

*Kostyuchenko, V.J., 1976, (Comparative evaluation of methods of determining the combining ability of inbred lines). Lenina., 6:10-11.

*Kovacik, A., 1959, (A study of the effect of inter-varietal hybridisation on yield, husk and oil content of sunflower seed in F_1 and F_2). Pol'nohospodarstvo., 6:823-842.

*Kovacik, A., 1960, (The influence of inter-varietal hybridisation on morphological characters of F_1 and F_2 sunflower Hybrids). Sborn.Cal.Akad.Zemed.Ved:Rada rostlinna Vyroba, 33:447-466.

*Kovacik, A. and Skaloud, V., 1972, (Combining ability and prediction of heterosis in sunflower, (Helianthus annuus L.). Scientia Agriculturae Bohemoslovaca., 4:263-273.

*Kovacik,A. and Skaloud,V., 1978, (A study of the combining ability of sunflower lines and of heterosis effects on crossing them). From Pl.Br.Abst., 48(2):No.1040.

*Kurnik,E. and Zelles,J., 1962, (Physiological heterosis in hybrid progenies of members of sunflower clones III. The characterization of hybrid vigour on the basis of developmental physiology). Iregsz.Bull., 2:63-70.

*Leclercq,P., 1966, (An utilizable male sterile for the production of hybrid sunflowers). Ann.Amelior.Plants, 76:135-139.

*Leclercq,P., 1971, (Production of sunflower hybrids utilizing male sterility). Sementi.elette., 17:3-9.

*Lyalunshkin,V.I. and Sharova,P.G., 1975, (Breeding sunflower at Moldavian Experimental Station). From Referativnyi Zhurnal., 12.55.302.

Manjunath,A., 1978, Genetics of seed yield, oil content and other quantitative characters in sunflower. Mysore J. Agric.Sci., 12(4):667-668.

Miller,P.A. and Lee,J.A., 1964, Heterosis and combining ability in varietal and top crosses of upland cotton, Gossypium hirsutum L. Crop Sci., 4:646-649.

Murthy,B.R., Tiwari,T.L. and Harinarayana,G., 1967, Line x tester analysis of combining ability and heterosis for yield factors in Pennisetum typhoides (Bum) S & H. Indian J. Genet., 27:238-245.

*Neagu,M., 1970, (Performance of some F_1 hybrids between mutant sunflower lines). Lucrani Stiintifice Institutal Agronomic Timisoara, Agronomie, 13:549-547.

*Neagu,M. and Catrina,E., 1963, (The performance of some sunflower hybrids in the F_1). Stud.Care.Biol.Sti.agric.Timisoara, 10:67-79.

*Pacucci,G. and Alba,E., 1977, (Evaluating hybrids and commercial varieties of sunflower as a main crop and as a catch crop). Annali della Facolta di Agraria, Universita di Bari, 29:363-376.

Pathak,R.S. and Prakash Kumar, 1975, Combining ability studies in upland cotton. Z.pflazen., 75:297-310.

*Pogorletskii,B.K., 1972, (Identification of male sterility factors in sunflower). Genetika, 8(3):30-33.

*Pogorletskii,B.K., 1973, (Yield in single interline hybrids of sunflower). Sb.nanoh.ti.vses.selekts:genet.in i., 10:122-126.

*Popov,A. and Lazarov,M., 1963, (Possibilities of utilising heterosis in sunflower). News Inst.Pl.Indust.Sofiia., 16:500.

Putt,E.D., 1966, Heterosis, combining ability and predicted synthetics from a diallel cross in sunflower, Helianthus annuus L. Cand.J.Pl.Sci., 46:59-67.

*Rozhkova,V.T., 1978, (The sunflower collection as initial material in breeding for heterosis). Byul.NTJ Po maslich.kulturam (VNIIMK), 2:8-12.

*Rozhkova,V.T., 1978a, (Study of combining ability in a collection of sunflower varieties). Byulleten' Vsesoyuznogo Ordena Lenina i Ordena Druzhby Naradov Instituta Rastenievodstva Imeni N.I. Vavilova, 78:47-49.

*Rozoriteleva,E.K. and Beletskii,D., 1979, (Genome-plastom interaction in sunflower-II. A mutant plastom in different genetic backgrounds and its effect on heterosis). Genetika, 15(8):1420-1426.

Russel,W.A., 1953, A study of inter-relationships of seed yield, oil content and other agronomic characters with sunflower inbred lines and their top crosses. Canad.J.agric.Sci., 33:291-314.

*Scerbak,S.N., 1966, (Characteristics observed in the inter-varietal hybridisation of sunflower). Zap.Voronez. Selskohoz.Inst., 32:163-183.

*Schulze,J., 1960, (Testing the combining ability of inbred lines of sunflower, (Helianthus annuus L.) by means of top cross method). Z.Pflanzenz., 44:135-156.

*Schuster, W., 1964, (Inbreeding and Heterosis in sunflower *Helianthus annuus* L.). *Wilhelm.Schmitz.Verlag. Giessen.*, pp.135.

Seetharam, A. and Kusuma Kumari, P., 1975, Induction of male sterility by GA_3 in sunflower. *Indian J.Genet.*, **35**:136-138.

Seetharam, A., Kusuma Kumari, P., Patil, N.M. and Sindagi, S.S., 1977, Performance of hybrids of sunflowers produced by means of cytoplasmic male sterility. *SABRAO Journal*, **9**(1):51-55.

Seetharam, A., 1980, Hybrid sunflowers. *Indian Farming*, **24**(12:15.

Seetharam, A., 1981, Sunflower cultivation. *Indian Farming*, **25**(1):

*Semienchuk, J., Semienchuk, P., Nider, F. and Krull, C., 1974, (Deklab.G.104 - an Argentine hybrid sunflower). *Revista Agronomica del.Noreoste Argentino*, **11**:99-107.

Setty, K.L.T. and Basudeo Singh, 1977, Line x tester analysis of combining ability in sunflower. *Pantnagar J.Res.*, **2**(1):25-26.

Shankare Gowda, B.T., 1970, Heterosis and line x tester analysis of combining ability in selected lines of *Sorghum vulgare* Pers. M.Sc(Agri) Thesis No.74, U.A.S., Bangalore (unpublished).

Sharma, D., Tandon, J.P. and Batra, J.N., 1967, Effect of tester on combining ability estimates of maize germplasm complexes. *Euphytica.*, **16**:370-376.

*Shuravina, L.G., 1969, (Biological characteristics of intervarietal and variety x line hybrids of sunflower in the 1st generation in the course of ripening). *Sborn. Trud.Aspirant.Mold.nauc.sotrud.Vses.nauc-issled Inst. Rastan*, **10**:366-371.

*Shuravina, L.G., 1970, (Activity of enzyme addolase in relation to the dynamics of carbohydrates and oil in seeds of F_1 sunflower hybrids). Sbornik Trudov Aspirantov i Molodykh Nauchnykh Sotrudnikov, 17:261-265.

*Shuravina, L.G., 1972, (The influence of inter-varietal and variety x line crossing on the chemical composition of first generation sunflower seeds). Genetika i Selektsii., 48(1):168-176.

Sindagi, S.S., 1972, Combining ability of some Ricinus communis L., lines. Genetica polonica, 13(1):75-82.

Sindagi, S.S., Kulkarni, R.S. and Seetharam, A., 1979, Line x tester Analysis of the combining ability in sunflowers (Helianthus annuus). Sunflower News Letter, 3(2):11-12.

Singh, H., Yadav, T.P. and Yadav, A.K., 1978, Heterosis in inter-varietal crosses of sunflower (Helianthus annuus L.). Crop Improvement, 5(1):84-85.

Skoric, D., 1977, Production of economic values of new NS sunflower hybrids. Sunflower Newsletter, 1(2):5-8.

Sprague, G.F. and Tatum, L.A., 1942, General vs specific combining ability in single crosses of corn. J.Amer.Soc.Agron., 34:923-932.

*Stoyanova, I., Ivanova, P. and Georgiev, I., 1971, (Inheritance of some characters in the F_1). Genetika i selektsiya., 4(1):3-14.

*Stoyanova, I. and Ivanova, P.I., 1975, (The inheritance of oil and protein content in sunflower in the F_1). Rastenievdni Nauki, 12(9):30-35.

*Stoyanova, I., Velkov, V. and Ivanova, P., 1975, (Features and problems of heterosis in sunflower). Byul.nauch-tekhn. inform.po maslich.Kulturam, 2:7-11.

Sudhakar, D., 1978, Heterosis and combining ability studies in sunflower (Helianthus annuus L.). M.Sc(Agri) Thesis No.615, U.A.S., Bangalore (Unpublished).

Sudhakar, D. and Seetharam, A., 1980, Studies on the performance of top cross hybrids in sunflower. Sunflower Newsletter, 4(3):7-8.

*Turchi, F., 1974, (Growing sunflowers for oil in Kenya). Rivista. di Agricoltura Subtropicale e tropicale., 68:285-292.

*Velkov, V.N., 1970, (Inheritance of stem height in sunflower). Genetika i.Selekciia., 3:393-401.

*Vicentini, G., 1971, (The latest results in Romanian sunflower breeding). Sementi.elette., 17:27-33.

*Vol'F, V.G., 1969, (Heterosis in the sunflower and the use of cytoplasmic sterility) From Referativny i.Zhurnal Abst., 2:55-173.

*Vol'F, V.G. and Dumacheva, L.P., 1972, (Heterosis in sunflower). Selektsiya i Semenovodstvo.Resp.Meshved.temat.nauch., Sb., 20:64-70.

*Voskoboinik, L.K. and Soldatov, K.I., 1975, (Results of studies on breeding for heterosis in sunflower). Byul. nauch-tekhn.inform.po.maslich. Kulturam, 1:3-6.

*Voskoboinik, L.K., 1977, (Breeding sunflower for heterosis in Bulgaria). Byul.NTI Po maslich. Kulturam, 1:14-17.

*Voskoboinik, L.K., 1978, (Results and prospects of heterosis breeding in sunflower). Selektsiya i semenovodstvo, 6:14-17.

*Vranceanu, V., 1967, (Studies of methods of obtaining heterosis in sunflower). An.Inst.Cerca.Cereal.Pl.tech.Fundulea: Ser.C., 33:301-310.

*Vranceanu, V., 1973, (Achievements and prospects in sunflower breeding). Bulletin de l' Academie des Sciences Agricoles et.Forestieres., 3:17-30.

*Vranceanu, V. and Stoenescu, F., 1969, (Sunflower single hybrids a production prospect for near future). Probl.Agric. Bucuresti., 21(10):21-22.

*Vranceanu,V., Stoenescu,F., Rusanovschi,V., Iliescici,S., Naeguti,I. and Sielovan,V., 1973, (Study of sunflower hybrids in different areas of cultivation). An.Inst. Cerce.cereal.Pentru.Cereale.Si.Plante Tehnice.C., 39:241-251.

*Vranceanu,V., 1975, (Theoritical and practical problems in the use of heterosis in sunflower). Byul.nauch-tekhn. inform.Po masliich. Kulturam, 1:7-11.

*Varnceanu,V. and Strenescu,F.M., 1976, (Mildew resistance a new characteristics of sunflower hybrids). An Inst.Cerce. Cereal.Pl.Techn., 28(3):18-23.

*Vranceanu,V. and Stoenescu,F.M., 1979, (Expression of heterosis in single, three-way and double sunflower hybrids). Analale Inst.de Cerc.Pentru Careale si Pl.Techn. Fundulea, 44:29-36.

*Vrataric,M. and Krismanic,M., 1978, Zbornik Radova Poljoprivrednog Inst.Osijek, 8(1):113-126.

*Vulpe,V.V., 1967, (Study of some sunflower hybrids produced through male sterility and fertility restoration). An.Inst.Cerce.Cereal.Pl.techn.Fundulea.Ser.C., 34:391-399.

*Vulpe,V.V., 1977, (Experimental results on breeding sunflower hybrids). An.Inst.de Cercetari Pentru Cereale si Pl. Tehnice., 42:53-60.

*Zakharskii,V.T., 1978, (The selection of parental pairs in breeding sunflower for heterosis for yield). Nauch.tr. Voronezh.S-kh in-t., 100:88-92.

*Original not seen.